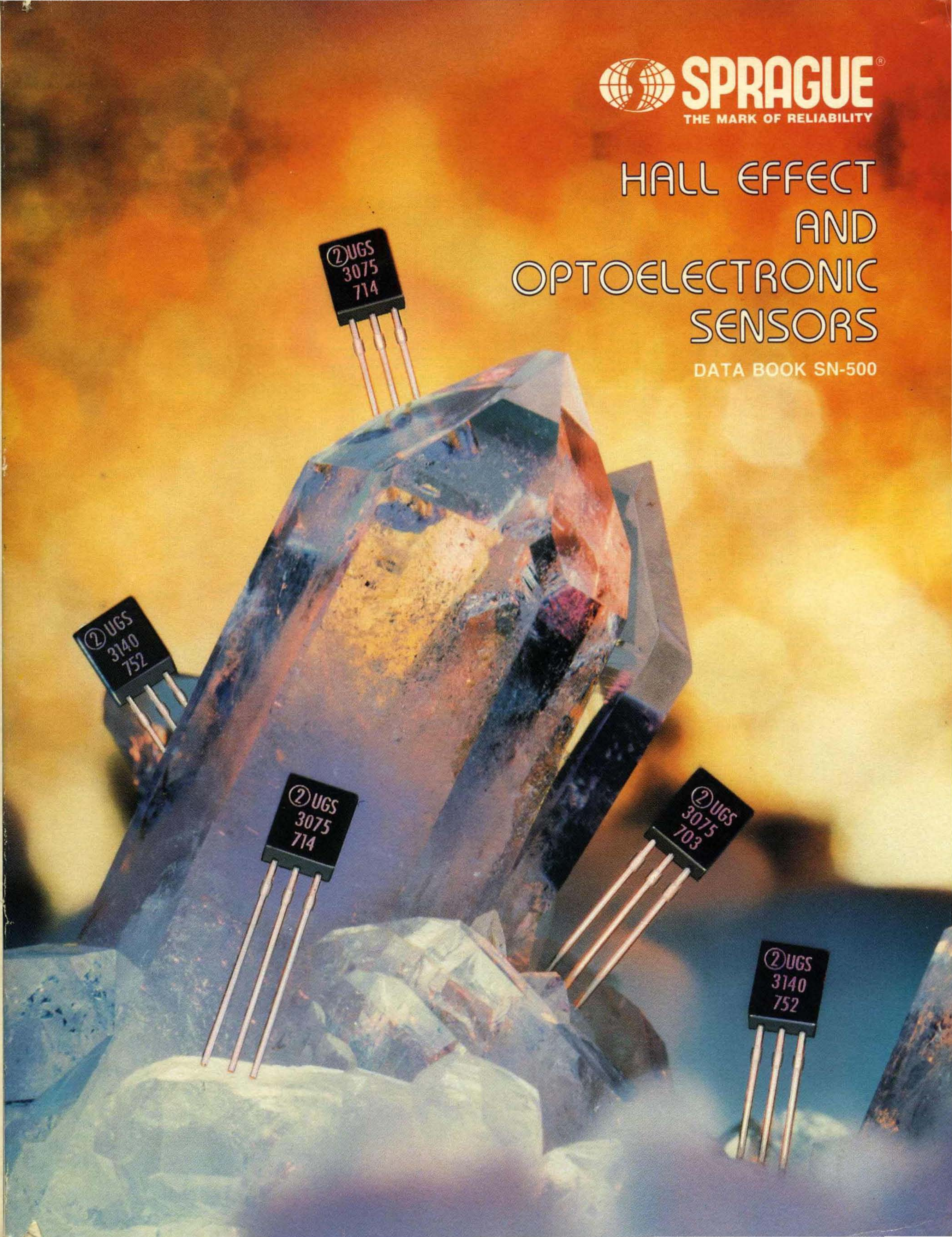
SPRAGUE®

THE MARK OF RELIABILITY

HALL EFFECT AND OPTOELECTRONIC SENSORS

DATA BOOK SN-500



SPRAGUE® HALL EFFECT AND OPTOELECTRONIC SENSORS SN-500

SPRAGUE®
THE MARK OF RELIABILITY

HALL EFFECT AND OPTOELECTRONIC SENSORS

HALL EFFECT SENSORS
- Switches
- Latches
- Linears
- Unipolar
- Bipolar
- Dual Output
- PowerHall™
- Geartooth

OPTOELECTRONIC SENSORS
- Encoder Switches
- High Speed Switches
- Twilight Sensing Switches
- Precision Linears

SPRAGUE ELECTRIC COMPANY

SEMICONDUCTOR GROUP
70 Pembroke Road, Concord, N.H. 03301
603/224-1961

Contents

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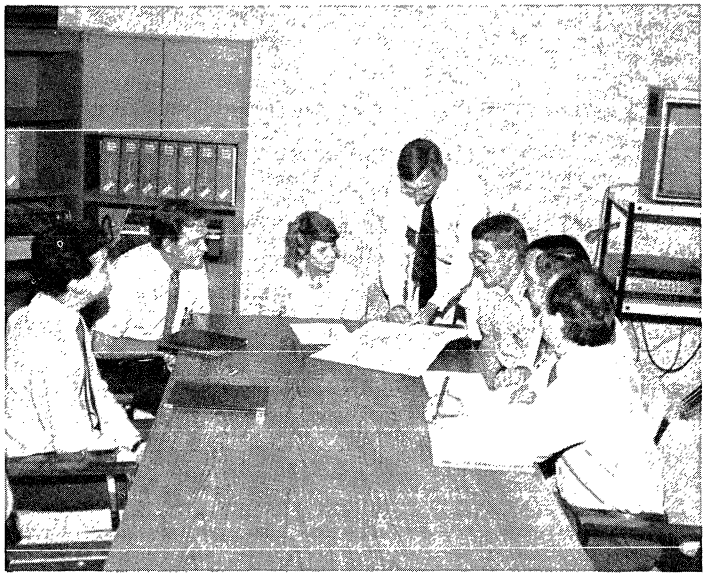
Contents

The following data books, covering the other products of Sprague's Semiconductor Group, may be obtained by writing to Technical Literature Service, Sprague Electric Company, Post Office Box 9102, 41 Hampden Road, Mansfield, MA 02048-9102.

WR-504 Integrated Circuits
CN-250 Transistors and Diodes

SECTION 1—GENERAL INFORMATION

1



SPRAGUE ELECTRIC COMPANY

The Sensor Division of the Sprague Semiconductor Group manufactures Hall Effect and optoelectronic sensor components for the automotive, computer, appliance, and telecommunication industries. We are the premier manufacturer of silicon-based sensors, having developed the technology nearly twenty years ago. We are committed to excellence in all we do. Our objective is to be the worldwide leader in circuit design, process and packaging technology, and customer service. As our customer, you benefit from the in-depth knowledge and experience of our design and applications staff; state-of-the-art manufacturing and test facilities; advanced quality standards and programs; European and Japanese customer service centers and worldwide sales coverage.

Sprague is committed to sensors. We are recognized as a worldwide leader as a result of our continuing commitment. That commitment begins with our Division Headquarters Customer Service Center in Concord, New Hampshire. Here, our staff stands ready to help you with your requirements. Whether you are a hobbyist, performing research, or have ongoing requirements, your needs will be thoroughly addressed by our Marketing and Customer Service groups.

Tell us about your requirements and tell us how we can help.

Sprague
Sensing the Future

SENSOR DIVISION HISTORY

Sprague Electric Company entered the Hall sensor business at its inception in 1967 through a joint venture agreement with a major keyboard manufacturer. Sprague agreed to manufacture Hall Effect integrated circuits in its Worcester, Massachusetts, integrated circuit facility. During the term of this agreement from 1967 through 1970, Sprague shipped millions of dice for keyboard applications. When the agreement was terminated, Sprague decided to remain in the Hall IC sensor business and to supply these circuits to OEM accounts.

Sprague, after the termination of the agreement, decided to design circuits capable of more than keyboard switch applications. A linear circuit was then developed to complement the digital switch offerings. During the early years of Sprague's entrance into the market, a great deal of effort was spent in developing a market for these practical, reliable, and versatile sensors. The initial efforts were moderately successful and the Sprague Semiconductor Group dedicated resources in establishing a sensor business.

In 1974, the decision was made to move the sensor business to the Concord, New Hampshire, facility so that the available assembly and test capacity could be utilized. At this time, a design function was staffed and circuit development began in Concord under the direction of the design manager who still leads this group and is one of the foremost Hall IC circuit designers in the world.

The major problems associated with Hall IC sensor circuits were insensitivity and performance over a broad temperature range. In 1977, a circuit was developed which exhibited satisfactory performance at temperatures of −40°C to +125°C, which made them suitable for automotive and other harsh environmental applications. This circuit was successfully used in many applications in the U.S., Europe, and Japan, and marked the start of a growth curve in the Sprague sensor business. This circuit was followed in 1979 by a new circuit which extended the temperature range to 150°C and offered better performance so that it was widely accepted for automotive applications in Europe and brushless motors in Japan. The sensor business was truly international in scope and its horizons were expanding.

By 1980, the packaging of these circuits had improved and the American automotive industry began to evaluate their use in automotive requirements and other sensing applications. The growth potential for Hall sensors began to accelerate rapidly. As the sensor business began to grow, the manufacturing capacity had to be increased rapidly. Staff and additional assembly equipment were added in Concord, New Hampshire, and in a Sprague-owned facility in Manila, Republic of the Philippines.

The period from 1981 to the present has shown a dramatic growth in the sensor business. During 1982, Sprague introduced the first bipolar latching Hall IC (UGN-3075) which is used extensively in the brushless motor market throughout the world. In 1983, Sprague also introduced a temperature-stable linear device (UGN-3503) with an operating temperature range of −40°C to +150°C. In 1986, a new, adjustable, temperature-compensated digital switch (3100 series) was introduced and is now widely accepted. Additionally, two new dual-output circuits are now available and our product offerings continue to grow. In 1985, an optoelectronic product line was introduced and we are now designing and selling these circuits.

Today, Sprague has gained the stature of a major supplier of sensor products for many diverse applications. The circuit design function and applications engineering have been expanded. Manufacturing space devoted to sensors now occupies a significant portion of the 120,000 square foot facility in Concord, New Hampshire. In addition, manufacturing capacity is utilized in our Manila facility and at a contract assembly location in Korea. Our assembly and test processes utilize state-of-the-art equipment. Statistical process control is being implemented in all production processes. IC wafer facilities in Worcester, Massachusetts, and Willow Grove, Pennsylvania, support our wafer requirements and give us access to Bipolar, BiMOS, and CMOS technologies.

Sprague is proud of its reputation as a leader in Hall Effect sensor technology and as a supplier of reliable sensors. We are solidly committed to maintaining, enhancing, and expanding our reputation and participation in the sensor market. We firmly believe in meeting our customers' needs and in finding new ways to utilize sensor technology. Our motto says it well. "We Sense the Future."

SENSOR PART NUMBERING SYSTEM

UG N 3140 U

PACKAGE DESIGNATION.

C	=	UNENCAPSULATED CHIPS
D	=	METAL CAN, 3-LEAD, (TO-52)
DA	=	METAL CAN, 3-LEAD, (TO-52), INDUSTRY PIN OUT (OBSOLETE)
H	=	CERAMIC, 3-LEAD (OBSOLETE)
HH	=	CERAMIC, 3-LEAD
K	=	4-LEAD S.I.P.
L	=	SOT-89 (OBSOLETE—REPLACED BY LT)
LI	=	SOIC-8, 8-LEAD VERSION
LL	=	SOT-89, LONG LEAD VERSION
LT	=	SOT-89
T	=	MODIFIED TO-92 (0.080" THICK)
TA	=	MODIFIED TO-92 (0.080" THICK), INDUSTRY PIN OUT (OBSOLETE)
U	=	MODIFIED TO-92 (0.060" THICK)
UA	=	SHORT "U" PACKAGE
W	=	WAFER
Y	=	TO-92 TRANSISTOR (OBSOLETE)

DEVICE TYPE (FOUR-DIGITS).

OPERATING TEMPERATURE RANGE.

N = −20°C to +85°C
S = −40°C to +125°C

FAMILY.

UG = HALL EFFECT
UL = OPTOELECTRONIC

PRODUCT INDEX in Alphanumerical Order

PRODUCT INDEX in Alphanumerical Order (Continued)

1

CROSS-REFERENCE in Alphanumerical Order

The suggested Sprague replacement devices are based primarily on magnetic sensitivity and operational descriptions. Significant differences may exist in dynamic operating range, package and electrical specification. Other Sprague devices may be applicable. If you need additional information, consult the nearest Sensor Division Customer Service Center.

Competitive Part Number	Manufacturer	Description	Suggested Sprague Replacement
103SR	Microswitch	Linear	UGN-3501
103SR13A-1	Microswitch	Unipolar Digital Switch	UGS-3019
103SR17A-1	Microswitch	Bipolar Digital Switch	UGS-3030
103SR5A-1	Microswitch	Unipolar Digital Switch	UGN-3013
513SS16	Microswitch	Unipolar Digital Switch	UGS-3020
517SS16	Microswitch	Bipolar Digital Switch	UGS-3131
55SS16	Microswitch	Unipolar Digital Switch	UGN-3013
613SS2	Microswitch	Unipolar Digital Switch	UGN-3019
617SS2	Microswitch	Bipolar Digital Switch	UGS-3030
65SS2	Microswitch	Unipolar Digital Switch	UGN-3013
6SS	Microswitch	Differential Output Hall Element	UGN-3501
8SS1	Microswitch	Bipolar Digital Switch	UGS-3030
8SS1E1	Microswitch	Bipolar Digital Switch	UGN-3030
8SS3	Microswitch	Unipolar Digital Switch	UGS-3019
8SS3E1	Microswitch	Unipolar Digital Switch	UGN-3013
8SS5	Microswitch	Bipolar Digital Switch	UGS-3030
8SS5E1	Microswitch	Bipolar Digital Switch	UGN-3030
8SS7	Microswitch	Unipolar Digital Switch	UGN-3019
8SS7E1	Microswitch	Unipolar Digital Switch	UGN-3019
91SS12-2	Microswitch	Ratiometric Linear	UGN-3503
92SS12-2	Microswitch	Linear	UGN-3501
BH-200	Bell	Differential Output Hall Element	UGN-3604/05
BH-700	Bell	Differential Output Hall Element	UGN-3604/05
BHA-900	Bell	Differential Output Hall Element	UGN-3604/05
BHT-900	Bell	Differential Output Hall Element	UGN-3604/05
DN6835	Matsushita, National	Linear	UGN-3501
DN6836	Matsushita, National	Linear	UGN-3501
DN6837	Matsushita, National	Unipolar Digital Switch	UGN-3019
DN6838	Matsushita, National	Bipolar Digital Switch	UGN-3030
DN6839	Matsushita, National	Unipolar Digital Switch	UGN-3019
DN834	Matsushita, National	Dual Output Unipolar Digital Switch	UGN-3201
DN835	Matsushita, National	Dual Output Linear	
DN837	Matsushita, National	Dual Ouptut Unipolar Digital Switch	UGN-3201
DN838	Matsushita, National	Dual Output Unipolar Digital Switch	UGN-3203
DN839	Matsushita, National	Dual Output Unipolar Digital Switch	UGN-3201
EW-500	Asahi	Bipolar Digital Latch	UGN-3075
EW-550	Asahi	Unipolar Digital Switch	UGN-3040
FH-301	Bell	Differential Output Hall Element	UGN-3604/05

Competitive Part Number	Manufacturer	Description	Suggested Sprague Replacement
H300A	Asahi	Differential Output Hall Element	UGN-3604/05
HW101A	Asahi	Differential Output Hall Element	UGN-3604/05
HW200A	Asahi	Differential Output Hall Element	UGN-3604/05
HW300A	Asahi	Differential Output Hall Element	UGN-3604/05
HW300B	Asahi	Differential Output Hall Element	UGN-3604/05
KSY10	Siemens	Differential Output Hall Element	UGN-3604/05
OH360	TRW	Unipolar Digital Switch	UGN-3020
OHN3013U	TRW	Unipolar Digital Switch	UGN-3013U UGN-3113U
OHN3019U	TRW	Unipolar Digital Switch	UGN-3019U UGN-3119U
OHN3020U	TRW	Unipolar Digital Switch	UGN-3020U UGN-3120U
OHN3030U	TRW	Unipolar Digital Switch	UGN-3030U UGN-3130U
OHN3040U	TRW	Unipolar Digital Switch	UGN-3040U UGN-3140U
OHS3019U	TRW	Unipolar Digital Switch	UGS-3019U UGS-3119U
OHS3020U	TRW	Unipolar Digital Switch	UGS-3020U UGS-3120U
OHS3030U	TRW	Bipolar Digital Switch	UGS-3030U UGS-3130U
OHS3040U	TRW	Unipolar Digital Switch	UGS-3040U UGS-3140U
SAS-241	Siemens	Dual Output Unipolar Digital Switch	UGN-3201
SAS-250	Siemens	Dual Output Unipolar Digital Switch	UGN-3201
SAS-251	Siemens	Dual Output Unipolar Digital Switch	UGN-3201
SAS-251-S4	Siemens	Dual Output Bipolar Digital Switch	UGN-3275
SAS-251-S5	Siemens	Dual Output Bipolar Digital Switch	UGN-3275
SAS-261	Siemens	Unipolar Digital Switch	UGN-3019
SS31EA	Microswitch	Bipolar Digital Switch	UGS-3131
SS41	Microswitch	Bipolar Digital Switch	UGS-3131
SS46	Microswitch	Bipolar Digital Switch	UGN-3030
SS81CA	Microswitch	Bipolar Digital Switch	UGS-3131
SS81EA	Microswitch	Bipolar Digital Switch	UGN-3131
THS102	Toshiba	Differential Output Hall Element	UGN-3604/05
TL170	Texas Instruments	Bipolar Digital Switch	UGN-3030
TL172C	Texas Instruments	Unipolar Digital Switch	UGN-3019
TL173C	Texas Instruments	Linear	UGN-3503
TL173I	Texas Instruments	Linear	UGN-3503
TL175C	Texas Instruments	Bipolar Digital Latch	UGN-3076

CUSTOMER SERVICE CENTER

Consisting of personnel from Production Control, Marketing and Applications, the Sensor Division Customer Service Center is your optimum source for Sensor information. We believe our customers are the most important asset we have, and our friendly Customer Service personnel are here to serve you.

From U.S. and Canada:	Sprague Electric Company Sensor Division 70 Pembroke Road Concord, NH 03301 Tel: (603) 224-1961 (603) 224-2755 Tlx: 910-250-3643 Fax: 603-224-2466

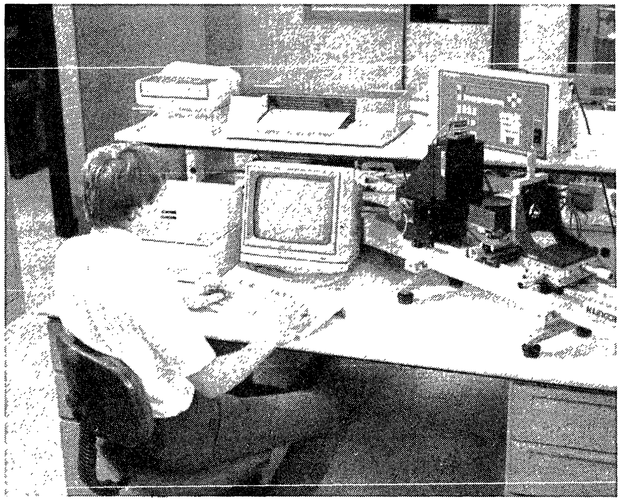
For technical information, applications assistance and samples: Extensions 349 and 389

For special pricing and selected parts: Extension 275

For delivery information, standard pricing and order updates: Extension 332

From Europe and Mideast:	Sprague World Trade Corp. 18 Avenue Louis Casai 1209 Geneva Switzerland Tel: 011-41-22-98-40-21 Tlx: 845-23469 Fax: 011-41-22-98-40-75
From Asia:	Sprague Asia Ltd. G.P.O. Box 4289 Hong Kong, BCC Tel: 011-852-0-28-31-88 Tlx: 43395 Fax: 011-852-0-22-00-42 011-852-0-26-96-03

APPLICATIONS AND ENGINEERING SERVICES



Our highly qualified Sensor Applications technical staff and engineering lab personnel are professionally equipped to assist you in the development of Hall Effect and Optoelectronic transducer-based sensor solutions. Our experience and technical expertise enable us to offer a wide spectrum of engineering services including:

Product Information: General data or specific technical needs can be met quickly and efficiently.

Engineering Samples: Prototype quantities of our devices are entered and shipped through the Sample Request System.

Calibrated Linear Devices: Valuable as application development tools, these devices are individually calibrated in the lab.

Application Evaluation: Recommendations with respect to optimizing sensor systems performance.

Other Services: Magnet characterization, bench prototypes, and failure analysis are examples of our capabilities in extended engineering support.

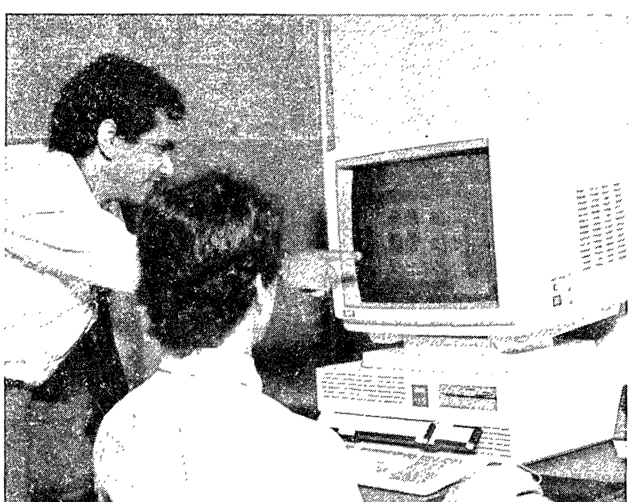
SPRAGUE SENSOR TECHNOLOGY

Sprague Hall Effect switches are a proven sensing technology and have set the industry standard for sensitivity, performance and reliability since the 1970's.

The Series 3000 Sprague Hall Effect switches are based on a single integrated circuit design designated the 3023 IC wafer type. These devices have proven perfomance in many automotive, industrial and computer-related applications in the past decade. The Series 3000 Sprague Hall Effect latches are based on a single integrated circuit design designated the 3025 IC wafer type. These devices are also proven performers for electronic commutation of brushless dc motors and rotary position encoders.

The latest innovations in Sprague Hall Effect technology are incorporated in the new 3100 series of switches and latches. These parts are based on a single integrated circuit design designated the 3050 IC wafer type. This innovative chip design incorporates a high quality, low offset differential amplifier stage and a temperature-compensated Schmitt trigger whose switching threshold varies to compensate for thermal drift of the Hall element. The 3050 IC wafer type includes a quad element layout configuration to minimize operating parameter changes due to mechanical stress effects from encapsulation operations. An adjustable resistor is an integral part of the 3050's innovative design and enables fine tuning of switching characteristics during manufacturing. This combination of design innovations enable Sprague's Sensor Division to offer a series of Hall Effect devices that have improved performance and yet remain equivalent in price to our current series of Hall Effect devices.

We recently introduced a line of optoelectronic sensors to our standard product line. These devices, the Series 3300 sensors, consist of the ULN-3311 and ULN-3312 linear optoelectronic sensors and the ULN-3330, 3360, 3363 and 3390 optoelectronic switches. The ULN-3311 and 3312 are suitable for precision sensing of light levels in measurement and control systems. The ULN-3330, 3360 and 3363 are optoelectronic switches manufactured from the same basic circuit with various output stages. The standard part is the ULN-3330. The ULN-3360 has an internal 5.4 K ohm pull-up resistor that allows direct interface to TTL logic. The ULN-3363 has an



inverter implemented before the output transistor. These optoelectronic switches are typically used for encoders, control system and light level sensors. The ULN-3390 optoelectonic switch is referred to as the "Twilight Sensor." Its intended application is in street lighting controls and dawn/dusk sensing applications.

SPRAGUE OFFERS VERSATILITY IN PACKAGING

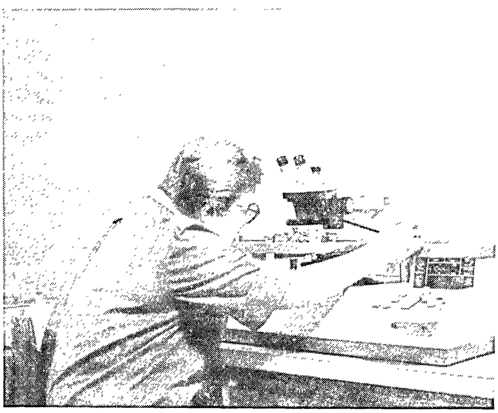
The Sprague sensor product line is continually evolving to fulfill the demand for better, more versatile packaging of IC sensors. The standard packages for Hall and opto sensors are the Sprague designation "U" and "T" style epoxy packages. Sprague Hall sensors are also supplied in two styles of surface-mountable parts, an SOT-89 package and an SOIC-8. The SOT-89 type comes in two package designations, "LT" for short-leaded and "LL" for long-leaded. The SOIC-8 comes as package designation "LI." A new, smaller, 4-lead SIP package designated as the "K" package has been implemented to replace the older 4-pin SIP. It will be used for Hall elements and dual output switches and latches. Hermetic HYREL® packaging for Sprague sensor products includes a ceramic "U" type package designated "HH" for Hall sensors and a top-looking metal can designated the "D" package for opto sensors. Sprague sensors can also be supplied as discrete wafers or tray-packed ICs for use in hybrid assemblies. Packaged sensor assemblies built around high-quality Sprague products are available from selected manufacturers. A Sprague customer service representative can recommend a suitable source for packaged sensor assemblies.

NEW GROWTH THROUGH PRODUCT DEVELOPMENT

As a division of Sprague's Semiconductor Group, we are constantly investigating new sensing technologies and incorporating the latest integrated circuit manufacturing techniques. The Sensor Division has several new products currently in engineering development. A Sprague Hall Effect-based gear-tooth sensor is currently being developed for the automotive market. Target specifications include temperature stability, zero-speed sensing ability and microprocessor-compatible output. A Smart Sensor, which is one of the first solid state sensors of this type, is also under development. This device employs the latest in bipolar and MOS fabrication techniques on a single silicon die. The target specifications for this device include factory programmable addresses, temperature stability and SAE-compatible addressing protocol. A power output Hall switch is also under development. Preliminary specifications call for an open-collector transistor output capable of sinking up to 300 mA of current. A power Hall device would allow direct control of triacs, relays and motor coils.

The family of sensors available from Sprague continues to grow as a direct result of customer demand, design innovations, and the desire to provide the best possible solutions to real world sensing challenges.

FUNCTIONS OF QAR



The functions of the QAR Department include new product design review, process and product quality control and direction and maintenance of high-reliability programs. QAR is also responsible for issuing and controlling specification and drawing changes, operation of environmental test facilities, and auditing and maintenance of calibration and serviceability of measuring equipment.

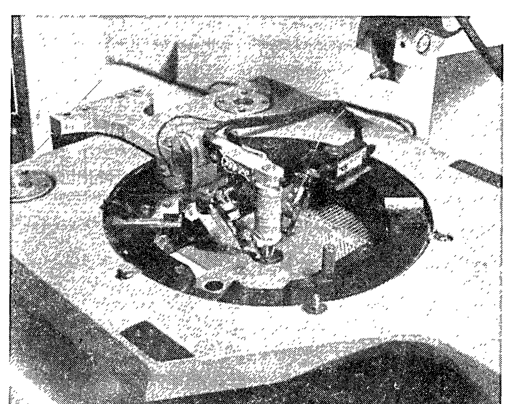
The QAR manager reports to the general manager of the Sensor Division. The QAR manager directs all local quality and reliability operations. He/she has section managers reporting to him/her who are responsible for the quality and reliability of all outgoing product: acceptance or rejection of incoming material; acceptance or rejection of in-process parts; specifications and other documentation controlling quality; reliability studies; calibration; and the quality evaluation of design materials, processes and procedures.

Quality Assurance and Reliability has two major objectives: first to assure the reliability and quality of all products, and second to provide reliability and quality services to Sprague customers, production engineering, and marketing departments within the division. QAR responsibilities include the following:

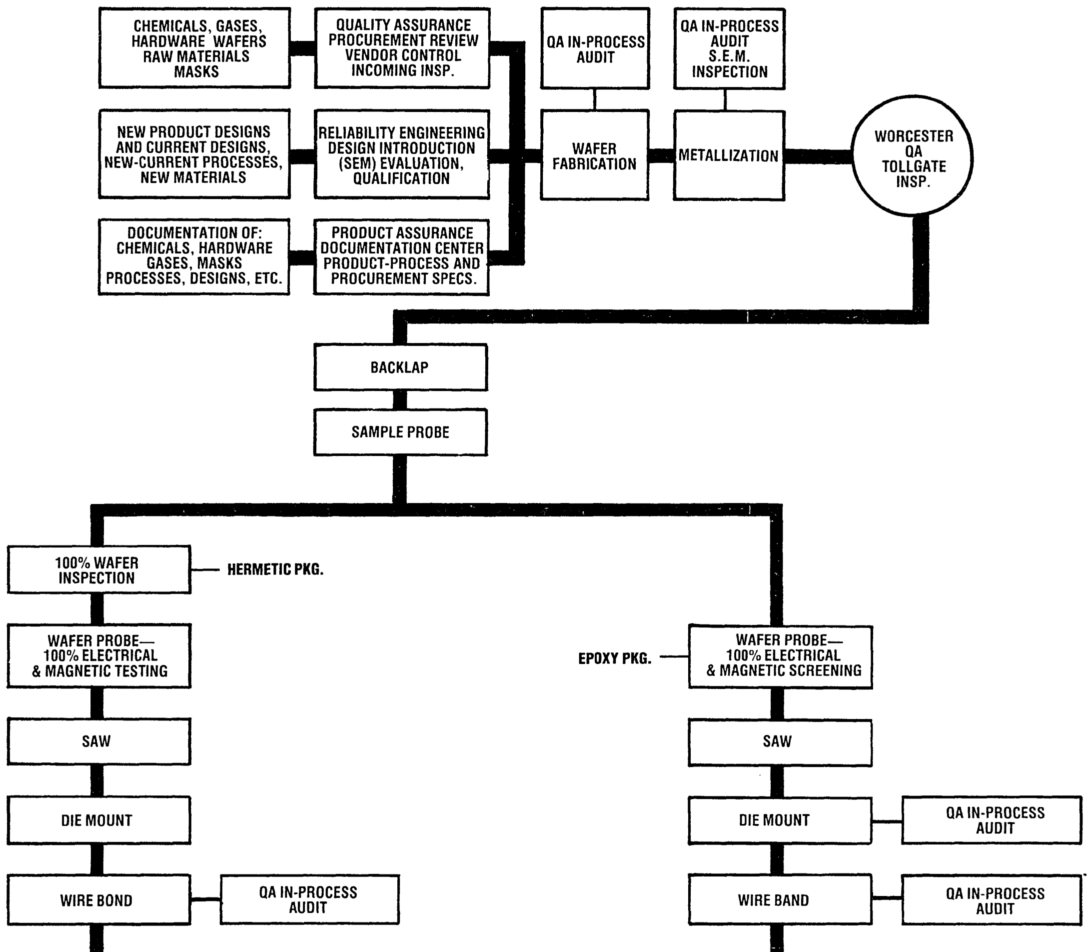
A. Quality Administration.
   1. Customer and Government Inspection Liaison
   2. Customer Specification Review
   3. Customer HYREL® Proposal Writing Assistance

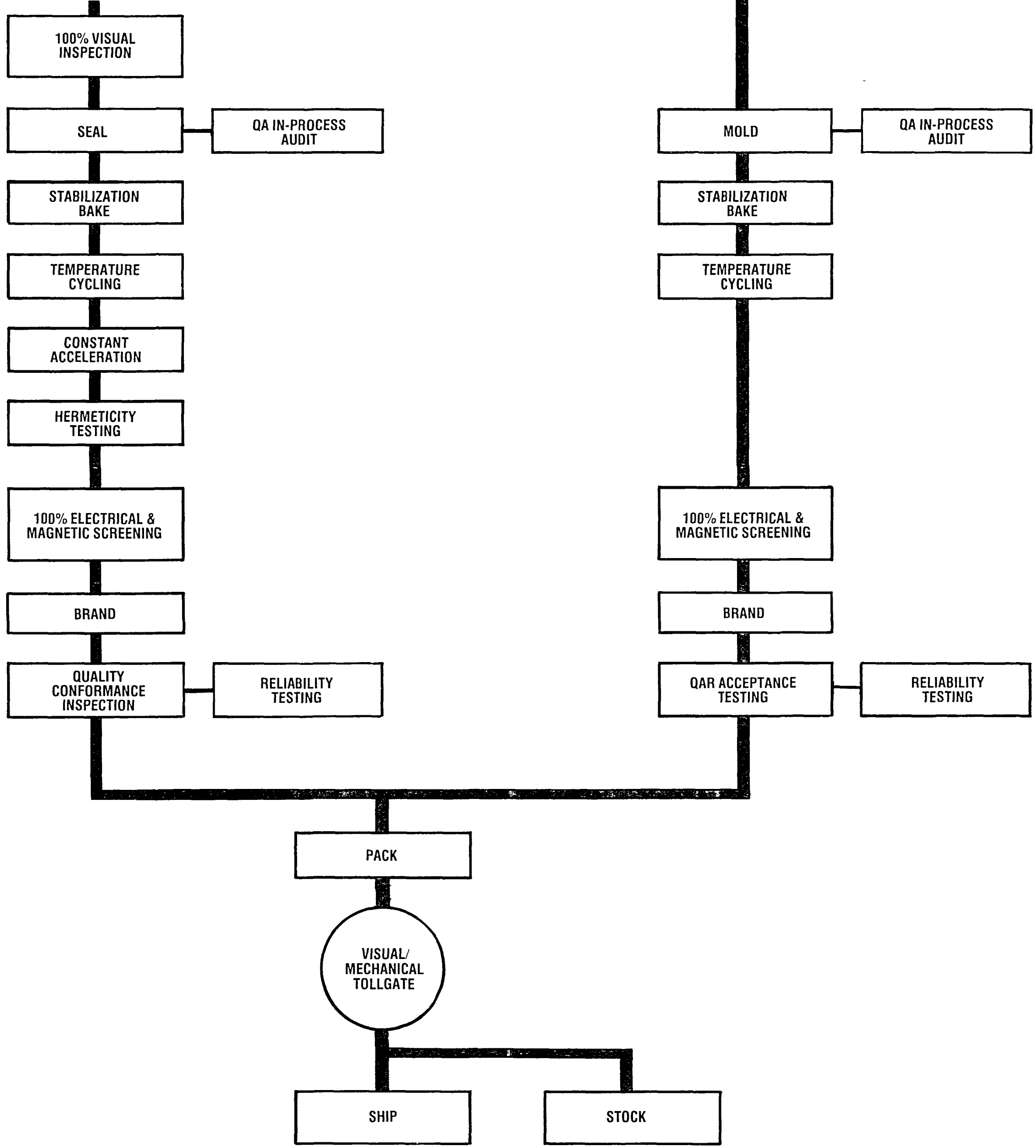
B. Quality Assurance.
   1. Outgoing Quality Control (Conformity to Customer and Sprague Requirements)
   2. HYREL—Life Environmental Testing
   3. Inspection of Material
   4. Process and Material Quality Control.

C. Reliability.
   1. Customer Return Testing
   2. Reliability Programs Testing
   3. Qualification Programs Testing
   4. New Product Evaluation
   5. Competitive Evaluation
   6. Life and Environmental Test Failure Analysis
   7. Customer Return Failure Analysis
   8. Step-Stress and Accelerated Testing
   9. Customer Product Specification Writing
   10. Data Accumulation, Processing and Evaluation
   11. Reliability Report Writing
   12. Reliability Product Engineering



QUALITY ASSURANCE FLOW CHART





100% VISUAL INSPECTION
SEAL
QA IN-PROCESS AUDIT
STABILIZATION BAKE
TEMPERATURE CYCLING
CONSTANT ACCELERATION
HERMETICITY TESTING
100% ELECTRICAL & MAGNETIC SCREENING
BRAND
QUALITY CONFORMANCE INSPECTION
RELIABILITY TESTING
MOLD
QA IN-PROCESS AUDIT
STABILIZATION BAKE
TEMPERATURE CYCLING
100% ELECTRICAL & MAGNETIC SCREENING
BRAND
QAR ACCEPTANCE TESTING
RELIABILITY TESTING
PACK
VISUAL/ MECHANICAL TOLLGATE
SHIP
STOCK

QUALITY AND RELIABILITY

Quality and reliability are terms that are often used interchangeably. Quality implies reliability, but a product's merit should always be defined by both. Quality is the extent to which a device conforms to specifications when it is shipped to the user. Reliability is the measure of a product's ability to meet specifications over time.

At the Sensor Division, quality and reliability are designed-in and maintained with very stringent process controls. Statistical Process Control (SPC), a statistical technique used to determine the quality status of product during the manufacturing process, is utilized for critical operations.

Sprague epoxy-encapsulated sensor ICs are used in very demanding applications and harsh environmental requirements such as automotive engine control where temperatures range from −40°C to as high as 170°C for short periods of time. A sensor failure would result in an inoperative engine. Epoxy-encapsulated sensor ICs are also used in many other extremely high-reliability requirements such as computers, where a sensor failure could result in faulty data and/or complete shutdown.

Extensive preconditioning processes are utilized to ensure that all components are properly cured; electrical parameters are completely stabilized, and any devices susceptible to possible infant mortality failure are culled out. The 4-hour cure at 175°C followed by a 24-hour bake at 150°C is designed to:

1. Assure that the encapsulating compounds are fully cured.
2. Stabilize electrical drift.
3. Accelerate degradation of possible surface chemical contaminates.

The temperature cycle conditioning consists of alternating the temperature between −65°C and 150°C for a minimum of eight cycles. Transfer time between temperature extremes is less than five minutes and soak time is thirty minutes at each temperature. This temperature cycle culls out possible assembly and package related failures.

All Sprague sensor ICs are 100 percent screened for all electrical and magnetic parameters at 25°C. All Hall Effect sensors are then 100 percent screened at the elevated temperature. Low temperature screen is also available for those applications where very tight functional parametric limits are required. Double testing is available for military applications.

In addition, burn-in and/or additional temperature cycling is available for those applications that require it. If you are interested in these extra services, please contact our Customer Service Center in Concord, New Hampshire.

All Sprague sensors are shipped in anti-static bags to protect them from possible static discharge, and double-boxed for added protection during shipment. Special shipment packing can be easily arranged by contacting our Customer Service Center in Concord, New Hampshire.

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MIL-STD-883 CLASS B HIGH-RELIABILITY SCREENING

All full-temperature hermetic devices are produced on a production line that is Class B certified and are processed to the production screen inspections and tests in accordance with the latest requirements of MIL-STD-883.

100% Production and High Reliability Screen Tests MIL-STD-883, Method 5004, Class B

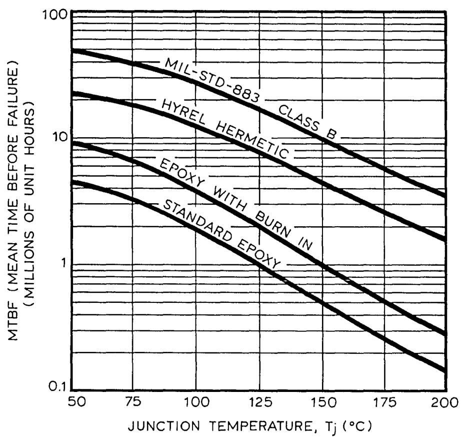
Screen	MIL-STD-883 Test Method	Conditions
Internal Visual	2010, Cond. B.	—
Stabilization Bake	1008, Cond. C	150°C, 24 Hours
Temperature Cycle	1010, Cond. C	—
Constant Acceleration	2001, Cond. E	30,000 Gs, Y1 Plane
Interim Electrical	5005, Gp A, Subgp. 1	25°C per Specification
Burn-In	1015, Cond. A	125°C, 160 Hrs or 150°C, 80 Hrs
Static Electrical	5005, Gp A, Subgp. 1	25°C per Specification
	5005, Gp A, Subgp. 2 & 3	−55°C & +125°C per Specification
Dynamic & Functional Electrical	5005, Gp A, Sub 4, 7 & 9	25°C per Specification
Fine Seal	1014, Cond. A1	5×10^{-8} atm $\times$ cm^3/s Max.
Gross Seal	1014, Cond. C	—
Marking	—	Sprague logo, part number and date code lot identification.
External Visual	2009	—

Quality Conformance Inspection MIL-STD-883, Method 5005, Class B

Test	MIL-STD-883 Test Method	Description
Group A, Subgp. 1-4, 7 & 9	5005, Table I	Each Inspection Lot
Group B	5005, Table II	Each Inspection Lot
Group C	5005, Table III	End Points, Gp. A, Subgp. 1, as required
Group D	5005, Table IV	End Points, Gp. A, Subgp. 1, as required

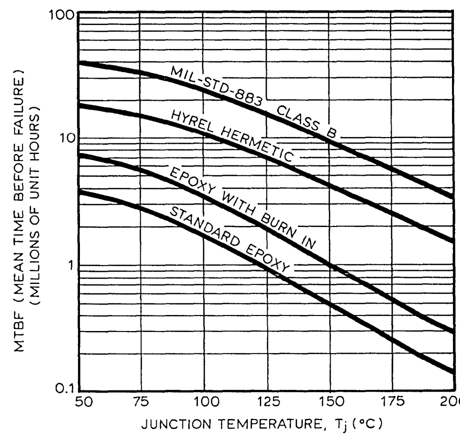
UGS-3119
RELIABILITY PER MIL-HDBK-217

Environment Ground Mobile



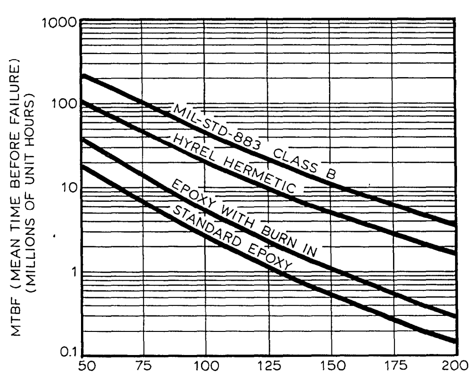
Dwg No A-14,440

Environment Missile Flight



Dwg No. A-14,441

Environment Ground Benign



Dwg No A-14,442

NOTES

NOTES

SECTION 2—HALL EFFECT SWITCHES

UNIPOLAR AND BIPOLAR SWITCHES

The open-collector output of a Sprague *unipolar* Hall Effect switch turns ON when the sensor is exposed to magnetic flux density equal to or greater than its operate threshold (south magnetic pole). The output turns OFF as the magnetic field is removed and field strength falls below the release threshold of the sensor.

Unipolar switches are available as single and dual output devices. Outputs of dual output switches in this section are both ON or both OFF, depending on magnetic flux density presented to the sensor.

Operation of a *bipolar* Hall Effect switch is similar to that of a unipolar switch, but requires application of magnetic fields of alternating polarity (south/north . . .) for guaranteed switch operation (ON/OFF . . .). A rotating multipole ring magnet is the most common source of such alternating polarity.

Two series of Hall Effect switches are now produced and marketed by the Sensor Division of Sprague Electric Company. The 3000 Series was introduced in 1978, the 3100 Series in 1986. Series 3100 switches feature factory-adjustable magnetic characteristics, mechanical stress compensation, and temperature compensation that allows operation at temperatures above +150°C.

SELECTION GUIDE

(In Order of Operate Threshold)

Max. Operate	Min. Release	Min. Hysteresis	Output	Max. I_{SINK}	Device Type	Page
95G	−95G	20G	Open-Collector	25 mA	UGN-3131T/U	2-30
150G	−150G	20G	Open-Collector	25 mA	UGN/S-3130T/U	2-27
200G	50G	20G	Open-Collector	25 mA	UGN/S-3040T/U	2-15
200G	50G	20G	Open-Collector	25 mA	UGN/S-3140T/U	2-33
250G	−250G	20G	Open-Collector	25 mA	UGN/S-3030T/U	2-12
350G	50G	20G	Open-Collector	25 mA	UGN/S-3020T/U	2-9
350G	50G	20G	Open-Collector	25 mA	UGN/S-3120T/U	2-24
350G	50G	20G	Dual Open-Collector	25 mA	UGN-3220K	2-38
450G	25G	30G	Open-Collector	25 mA	UGN-3013T/U	2-3
450G	30G	20G	Open-Collector	25 mA	UGN-3113T/U	2-18
500G	125G	50G	Open-Collector	25 mA	UGN/S-3019T/U	2-6
500G	125G	50G	Open-Collector	25 mA	UGN/S-3119T/U	2-21
750G	100G	50G	Dual Open-Collector	25 mA	UGN-3201K	2-36

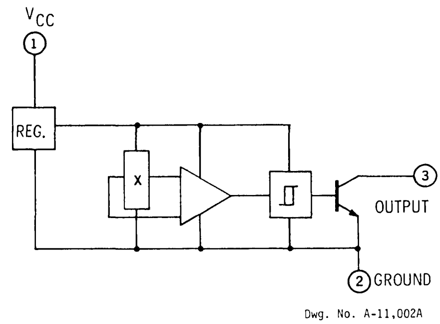
NOTE: Magnetic characteristics are guaranteed minimum/maximum values at +25°C.
Output current ratings are absolute maximum values.

UGN-3013T AND UGN-3013U LOW-COST HALL EFFECT DIGITAL SWITCHES

2

FEATURES

- 4.5 V to 24 V Operation
- Magnetically Driven Output
- High Reliability—No Moving Parts
- Small Size
- Output Compatible with All Digital Logic Families
- Constant Output Amplitude



FUNCTIONAL BLOCK DIAGRAM

LOW-COST Type UGN-3013 Hall Effect integrated circuits excel in applications not requiring extreme magnetic sensitivity, broadly spaced hysteresis boundaries, or premium operating temperature ranges. In all other respects, the economical, magnetically activated switches meet the high standards for fast, rugged, and reliable performance set by other Sprague Hall Effect devices.

Each Hall Effect circuit includes a voltage regulator, Hall voltage generator, signal amplifier, Schmitt trigger, and open-collector output on a single silicon chip. The on-board regulator permits operation over a wide range of supply-voltages.

The switches' open-collector outputs can sink up to 20 mA at a conservatively rated repetition rate of 100 kHz. They can be used directly with bipolar or MOS logic circuits. Selected devices, with outputs capable of sinking 50 mA, are available on special order.

Types UGN-3013T and UGN-3013U are rated for operation over the temperature range of −20°C to +85°C. The Hall Effect switches are offered in two three-pin plastic packages—a 60-mil (1.54 mm) magnetically optimized "U" package, and one 80 mils (2.03 mm) thick specified by the suffix "T"

ABSOLUTE MAXIMUM RATINGS

Supply Voltage, V_{CC}	25 V
Magnetic Flux Density, B	Unlimited
Output OFF Voltage	25 V
Output ON Current, I_{SINK}	25 mA
Operating Temperature Range, T_A	
UGN-3013T	−20°C to +85°C
UGN-3013U	−20°C to +85°C
Storage Temperature Range, T_S	−65°C to +150°C

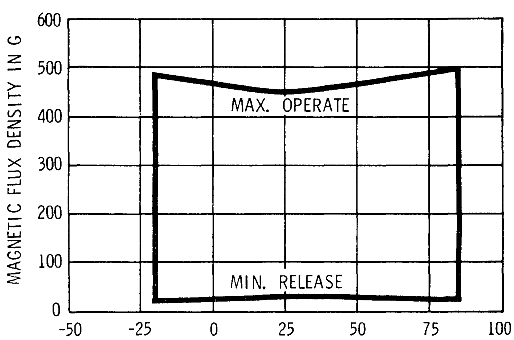
These Hall Effect sensors are also supplied in SOT 89 (TO-243AA) packages for surface-mount application. The regular SOT 89 package is specified by substituting an "LT" for the last character of the part number. The long leaded SOT 89 package is specified by substituting an "LL" for the last character of the part number and the Low profile "U" package is available by substituting "UA" for the last character of the part number (e.g., UGN-3XXXLT, UGN-3XXXLL, UGN-3XXXUA).

ELECTRICAL CHARACTERISTICS at T_A = +25°C, V_{CC} = 4.5 V to 24 V (unless otherwise noted)

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Operate Point*	B_{OP}		—	300	450	G
Release Point*	B_{RP}		25	225	—	G
Hysteresis*	B_H		30	75	—	G
Output Saturation Voltage	$V_{CE(SAT)}$	$B \geq 450$ G, $I_{SINK} = 20$ mA	—	85	400	mV
Output Leakage Current	I_{OFF}	$B \leq 25$ G, $V_{OUT} = 24$ V	—	0.05	10	μA
Supply Current	I_{CC}	$B \leq 25$ G, $V_{CC} = 4.5$ V, Output Open	—	2.3	5.0	mA
		$B \leq 25$ G, $V_{CC} = 24$ V, Output Open	—	3.0	5.0	mA
Output Rise Time	t_r	$V_{CC} = 12$ V, $R_L = 820\Omega$, $C_L = 20$ pF	—	150	—	ns
Output Fall Time	t_f	$V_{CC} = 12$ V, $R_L = 820\Omega$, $C_L = 20$ pF	—	400	—	ns

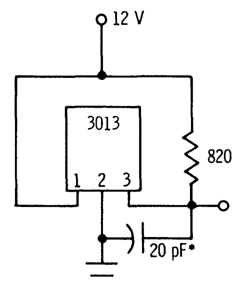
*Magnetic flux density is measured at most sensitive area of device located at 0.036" ± 0.002" (0.91 mm ± 0.05 mm) below the branded face of the 'T' package and 0.016" ± 0.002" (0.41 mm ± 0.05 mm) below the branded face of the 'U' package.

GUARANTEED OPERATE AND RELEASE POINTS AS FUNCTIONS OF TEMPERATURE



Dwg. No. A-12,579

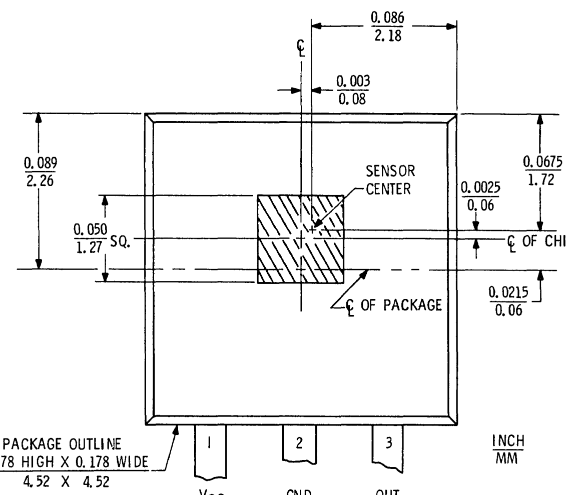
TEST CIRCUIT



Dwg. No. A-12,604

*Includes probe and test fixture capacitance.

SENSOR-CENTER LOCATION



Dwg No. A-12,399A

OPERATION

The most common modes of operation are head-on and slide-by. As shown in the drawing at right, the magnet's polar axis is the centerline of the Hall Effect package. Change of operating states in the head-on mode is accomplished by decreasing or increasing the distance between the magnet and Hall cell.

The output transistor is OFF when the flux density of the magnetic field perpendicular to the surface of the chip is below threshold (the operate point). When flux density reaches the operate point, the output transistor switches ON and is capable of sinking 25 mA of current.

Note that the device is turned ON by presenting the south pole of the magnet to the branded face of the package, which is opposite the side with the ejector pin indentation. With the branded side facing you and the pins pointing down, pinouts are, from left to right: (1) V_{CC}, (2) GND, (3) V_{OUT}.

The output transistor is switched OFF when flux density of the magnetic field falls below the release point, which is less than the operate point. Hysteresis, as illustrated in the Transfer Characteristics graph, prevents ambiguity and oscillation.

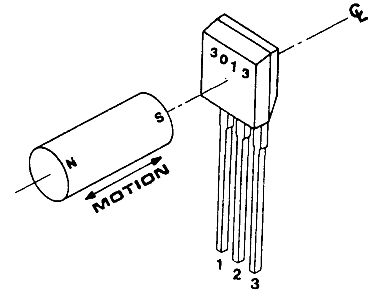
TOTAL EFFECTIVE AIR GAP

Type 3013 Hall Effect switches are offered in two packages, "T" and "U". The "U" package is about 0.020″ (0.05 mm) thinner than the "T" package. The difference is found in the distance from the surface of the Hall cell to the branded face of the package: The active area depth. The "T" pack's active area depth is 0.036″ (0.9 mm); the "U" pack's is 0.016″ (0.4 mm).

Total effective air gap is the sum of active area depth and the distance between the package's surface and the magnet's surface. The graph of Flux Density as a Function of Effective Air Gap illustrates the considerable increase in flux density at the sensor provided by the thinner package. The actual gain depends on the characteristic slope of flux density for a particular magnet.

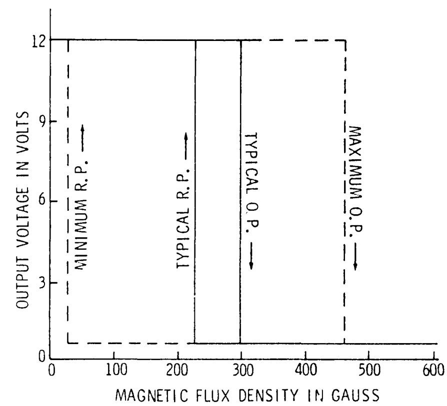
A wide variety of magnets is commercially available. Each type of magnet exhibits unique magnetic field characteristics. The magnets used to construct the Flux Density graph were measured for the head-on mode of operation, but the graph's information is valid for peak flux density in the slide-by mode of switch activation.

HEAD-ON MODE



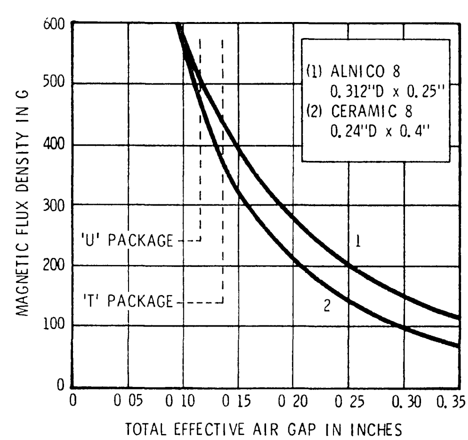
Dwg. No. A-12,603

TRANSFER CHARACTERISTICS AT T_A = +25°C



MAGNETIC FLUX DENSITY AS A FUNCTION OF TOTAL EFFECTIVE AIR GAP

Air Gap = 0.1″

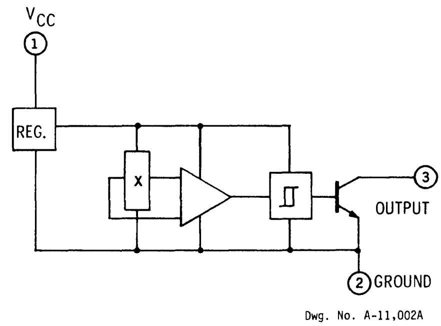


2

UGN-3019T/U AND UGS-3019T/U
LOW-COST HALL EFFECT DIGITAL SWITCHES

FEATURES

- 4.5 V to 24 V Operation
- Magnetically Driven Output
- High Reliability—No Moving Parts
- Small Size
- Output Compatible with All Digital Logic Families
- Constant Output Amplitude



FUNCTIONAL BLOCK DIAGRAM

ECONOMICAL TYPE 3019 Hall Effect integrated circuits provide fast, clean,and sure switching under demanding environmental conditions. The magnetically activated electronic devices are available with two operating temperature ranges and in two three-pin plastic packages.

Each Hall Effect circuit includes a voltage regulator, Hall voltage generator, signal amplifier, Schmitt trigger, and open-collector output on a single silicon chip. The on-board regulator permits operation over the supply-voltage range of 4.5 to 24 V.

The switches' open-collector outputs can sink up to 20 mA at a conservatively rated repetition rate of 100 kHz. They can be used directly with bipolar or MOS logic circuits. Selected devices, with outputs capable of sinking 50 mA, are available on special order.

Types UGN-3019T and UGN-3019U are rated for operation over the temperature range of −20°C to +85°C. Types UGS-3019T and UGS-3019U have an operating range of −40°C to +125°C.

The Hall Effect switches are offered in two three-pin plastic packages—a 60-mil (1.54 mm) magnetically optimized "U" package, and one 80 mils (2.03 mm) thick specified by the suffix "T."

ABSOLUTE MAXIMUM RATINGS

Supply Voltage, V_{CC}	25 V
Magnetic Flux Density, B	Unlimited
Output OFF Voltage	25 V
Output ON Current, I_{SINK}	25 mA
Operating Temperature Range, T_A	
UGN-3019T	−20°C to +85°C
UGN-3019U	−20°C to +85°C
UGS-3019T	−40°C to +125°C*
UGS-3019U	−40°C to +125°C*
Storage Temperature Range, T_S	−65°C to +150°F

*Selected devices are available with a T_A range of −55°C to +150°C.

These Hall Effect sensors are also supplied in SOT 89 (TO-243AA) packages for surface-mount application. The regular SOT 89 package is specified by substituting an "LT" for the last character of the part number. The long leaded SOT 89 package is specified by substituting an "LL" for the last character of the part number and the Low profile "U" package is available by substituting "UA" for the last character of the part number (e.g., UGN-3XXXLT, UGN-3XXXLL, UGN-3XXXUA).

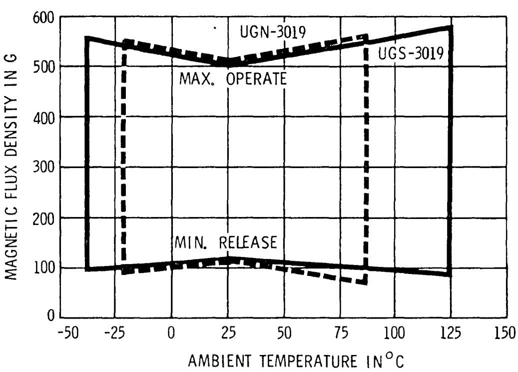
ELECTRICAL CHARACTERISTICS at T_A = +25°C, V_{CC} = 4.5 V to 24 V (unless otherwise noted)

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Operate Point*	B_{OP}		—	420	500	G
Release Point*	B_{RP}		125	300	—	G
Hysteresis*	B_H		50	120	—	G
Output Saturation Voltage	$V_{CE(SAT)}$	$B \geq 500$ G, I_{SINK} = 20 mA	—	85	400	mV
Output Leakage Current	I_{OFF}	$B \leq 125$ G, V_{OUT} = 24 V	—	0.05	10	µA
Supply Current	I_{CC}	$B \leq 125$ G, V_{CC} = 4.5 V, Output Open	—	2.3	5.0	mA
		$B \leq 125$ G, V_{CC} = 24 V, Output Open	—	3.0	5.0	mA
Output Rise Time	t_r	V_{CC} = 12 V, R_L = 820Ω, C_L = 20 pF	—	150	—	ns
Output Fall Time	t_f	V_{CC} = 12 V, R_L = 820Ω, C_L = 20 pF	—	400	—	ns

*Magnetic flux density is measured at most sensitive area of device located at 0.036" ± 0.002" (0.91 mm ± 0.05 mm) below the branded face of the 'T' package and 0.016" ± 0.002" (0.41 mm ± 0.05 mm) below the branded face of the 'U' package.

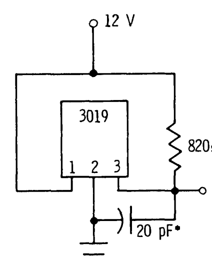
2

GUARANTEED OPERATE AND RELEASE POINTS AS FUNCTIONS OF TEMPERATURE



Dwg. No. A-12,563

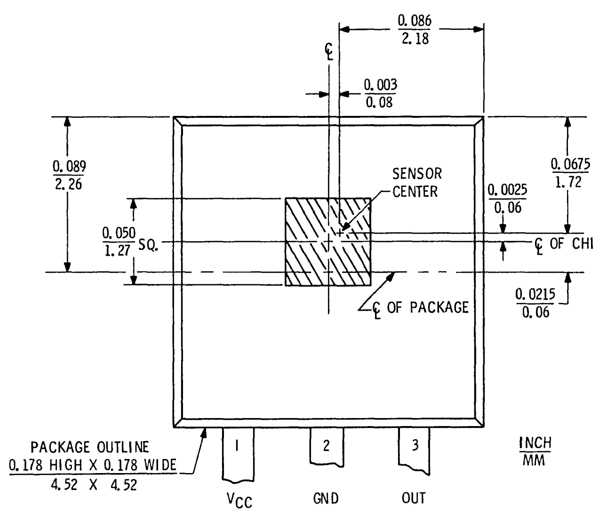
TEST CIRCUIT



DWG. NO. A-12,562

*Includes probe and test fixture capacitance.

SENSOR-CENTER LOCATION



Dwg. No. A-12,399A

OPERATION

The most common modes of operation are head-on and slide-by. As shown in the drawing at right, the magnet's polar axis is the centerline of the Hall Effect package. Change of operating states in the head-on mode is accomplished by decreasing or increasing the distance between the magnet and Hall cell.

The output transistor is OFF when the flux density of the magnetic field perpendicular to the surface of the chip is below threshold (the operate point). When flux density reaches the operate point, the output transistor switches ON and is capable of sinking 25 mA of current.

Note that the device is turned ON by presenting the south pole of the magnet to the branded face of the package, which is opposite the side with the ejector pin indentation. With the branded side facing you and the pins pointing down, pinouts are, from left to right: (1) V_{CC}, (2) GND, (3) V_{OUT}.

The output transistor is switched OFF when flux density of the magnetic field falls below the release point, which is less than the operate point. Hysteresis, as illustrated in the Transfer Characteristics graph, prevents ambiguity and oscillation.

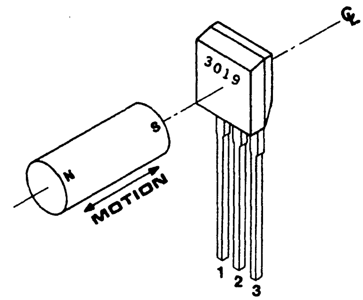
TOTAL EFFECTIVE AIR GAP

Type 3019 Hall Effect switches are offered in two packages, "T" and "U". The "U" package is about 0.020" (0.05 mm) thinner than the "T" package. The difference is found in the distance from the surface of the Hall cell to the branded face of the package: The active area depth. The "T" pack's active area depth is 0.036" (0.9 mm); the "U" pack's is 0.016" (0.4 mm).

Total effective air gap is the sum of active area depth and the distance between the package's surface and the magnet's surface. The graph of Flux Density as a Function of Effective Air Gap illustrates the considerable increase in flux density at the sensor provided by the thinner package. The actual gain depends on the characteristic slope of flux density for a particular magnet.

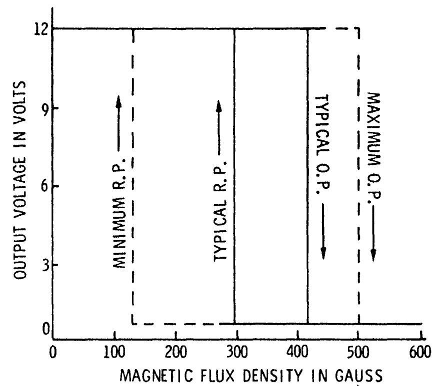
A wide variety of magnets is commercially available. Each type of magnet exhibits unique magnetic field characteristics. The magnets used to construct the Flux Density graph were measured for the head-on mode of operation, but the graph's information is valid for peak flux density in the slide-by mode of switch activation.

HEAD-ON MODE



DWG. NO. A-12,564

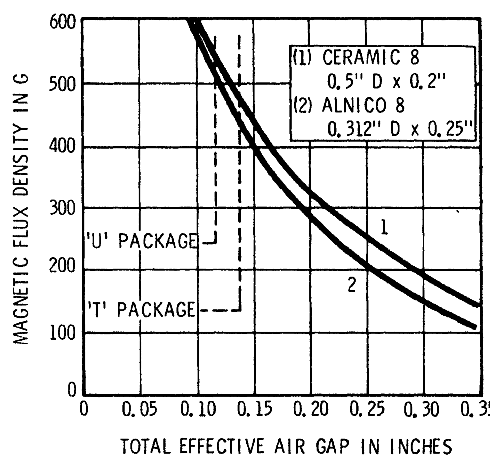
TRANSFER CHARACTERISTICS AT T_A = +25°C



Dwg. No. A-9015D

MAGNETIC FLUX DENSITY AS A FUNCTION OF TOTAL EFFECTIVE AIR GAP

Air Gap = 0.1"



DWG. NO. A-12,565

UGN-3020T/U AND UGS-3020T/U HALL EFFECT DIGITAL SWITCHES

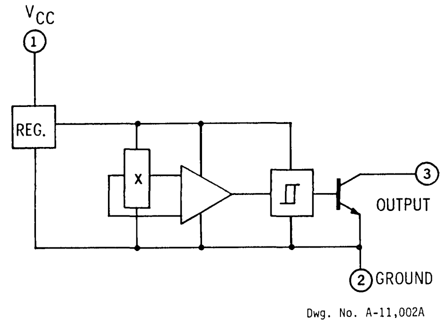
FEATURES

- 4.5 V to 24 V Operation
- Magnetically Driven Output
- High Reliability—No Moving Parts
- Small Size
- Output Compatible with All Digital Logic Families
- Constant Output Amplitude

OFFERING HIGHLY RESPONSIVE magnetic characteristics and fast, trouble-free switching at moderate cost, Type 3020 Hall Effect integrated circuits represent middle ground between less sensitive devices and those demanding premium prices. The magnetically activated electronic devices are available with two operating temperature ranges and in two three-pin plastic packages.

Each Hall Effect circuit includes a voltage regulator, Hall voltage generator, signal amplifier, Schmitt trigger, and open-collector output on a single silicon chip. The on-board regulator permits operation over the supply-voltage range of 4.5 to 24 V.

The switches' open-collector outputs can sink up to 20 mA at a conservatively rated repetition rate of 100 kHz. They can be used directly with bipolar or MOS logic circuits. Selected devices, with outputs capable of sinking 50 mA, are available on special order.



FUNCTIONAL BLOCK DIAGRAM

Types UGN-3020T and UGN-3020U are rated for operation over the temperature range of −20°C to +85°C. Types UGS-3020T and UGS-3020U have an operating range of −40°C to +125°C.

The Hall Effect switches are offered in two three-pin plastic packages—a 60-mil (1.54 mm) magnetically optimized "U" package, and one 80 mils (2.03 mm) thick specified by the suffix "T."

ABSOLUTE MAXIMUM RATINGS

Supply Voltage, V_{CC}	25 V
Magnetic Flux Density, B	Unlimited
Output OFF Voltage	25 V
Output ON Current, I_{SINK}	25 mA
Operating Temperature Range, T_A	
UGN-3020T	−20°C to +85°C
UGN-3020U	−20°C to +85°C
UGS-3020T	−40°C to +125°C*
UGS-3020U	−40°C to +125°C*
Storage Temperature Range, T_S	−65°C to +150°C

*Selected devices are available with a T_A range of −55°C to +150°C.

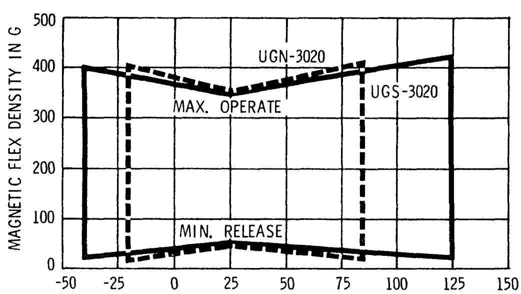
These Hall Effect sensors are also supplied in SOT 89 (TO-243AA) packages for surface-mount application. The regular SOT 89 package is specified by substituting an "LT" for the last character of the part number. The long leaded SOT 89 package is specified by substituting an "LL" for the last character of the part number and the Low profile "U" package is available by substituting "UA" for the last character of the part number (e.g., UGN-3XXXLT, UGN-3XXXLL, UGN-3XXXUA).

ELECTRICAL CHARACTERISTICS at $T_A = +25°C$, $V_{CC} = 4.5$ V to 24 V (unless otherwise noted)

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Operate Point*	B_{OP}		—	220	350	G
Release Point*	B_{RP}		50	165	—	G
Hysteresis*	B_H		20	55	—	G
Output Saturation Voltage	$V_{CE(SAT)}$	$B \geq 350$ G, $I_{SINK} = 20$ mA	—	85	400	mV
Output Leakage Current	I_{OFF}	$B \leq 50$ G, $V_{OUT} = 24$ V	—	0.05	10	μA
Supply Current	I_{CC}	$B \leq 50$ G, $V_{CC} = 4.5$ V, Output Open	—	2.3	5.0	mA
		$B \leq 50$ G, $V_{CC} = 24$ V, Output Open	—	3.0	5.0	mA
Output Rise Time	t_r	$V_{CC} = 12$ V, $R_L = 820\Omega$, $C_L = 20$ pF	—	150	—	ns
Output Fall Time	t_f	$V_{CC} = 12$ V, $R_L = 820\Omega$, $C_L = 20$ pF	—	400	—	ns

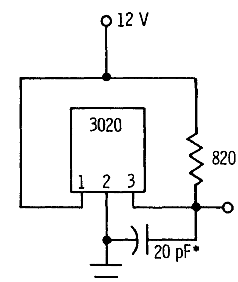
*Magnetic flux density is measured at most sensitive area of device located at 0.036" ±0.002" (0.91 mm ± 0.05 mm) below the branded face of the 'T' package and 0.016" ± 0.002" (0.41 mm ± 0.05 mm) below the branded face of the 'U' package.

GUARANTEED OPERATE AND RELEASE POINTS AS FUNCTIONS OF TEMPERATURE



Dwg.No. A-12,568

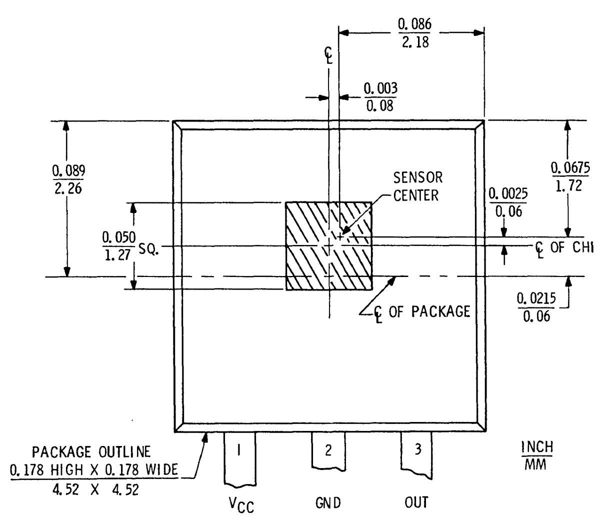
TEST CIRCUIT



DWG. NO. A-12,569

*Includes probe and test fixture capacitance.

SENSOR-CENTER LOCATION



Dwg. No. A-12,399A

OPERATION

The most common modes of operation are head-on and slide-by. As shown in the drawing at right, the magnet's polar axis is the centerline of the Hall Effect package. Change of operating states in the head-on mode is accomplished by decreasing or increasing the distance between the magnet and Hall cell.

The output transistor is OFF when the flux density of the magnetic field perpendicular to the surface of the chip is below threshold (the operate point). When flux density reaches the operate point, the output transistor switches ON and is capable of sinking 25 mA of current.

Note that the device is turned ON by presenting the south pole of the magnet to the branded face of the package, which is opposite the side with the ejector pin indentation. With the branded side facing you and the pins pointing down, pinouts are, from left to right: (1) V_{CC}, (2) GND, (3) V_{OUT}.

The output transistor is switched OFF when flux density of the magnetic field falls below the release point, which is less than the operate point. Hysteresis, as illustrated in the Transfer Characteristics graph, prevents ambiguity and oscillation.

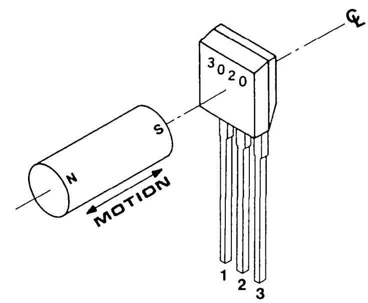
TOTAL EFFECTIVE AIR GAP

Type 3020 Hall Effect switches are offered in two packages. The "U" package is about 0.020" (0.05 mm) thinner than the "T" package. The difference is found in the distance from the surface of the Hall cell to the branded face of the package: The active area depth. The "T" pack's active area depth is 0.036" (0.9 mm); the "U" pack's is 0.016" (0.4 mm).

Total effective air gap is the sum of active area depth and the distance between the package's surface and the magnet's surface. The graph of Flux Density as a Function of Effective Air Gap illustrates the considerable increase in flux density at the sensor provided by the thinner package. The actual gain depends on the characteristic slope of flux density for a particular magnet.

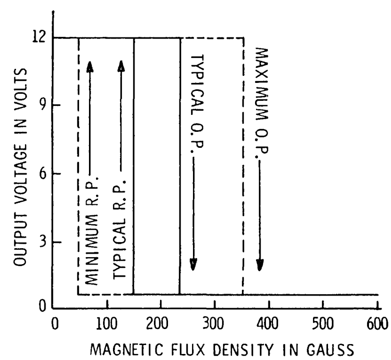
A wide variety of magnets is commercially available. Each type of magnet exhibits unique magnetic field characteristics. The magnets used to construct the Flux Density graph were measured for the head-on mode of operation, but the graph's information is valid for peak flux density in the slide-by mode of switch activation.

HEAD-ON MODE



DWG. NO. A-12,570

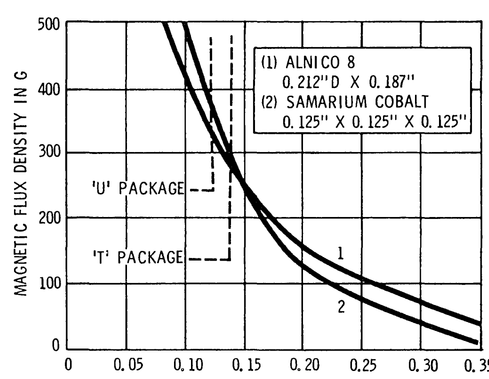
TRANSFER CHARACTERISTICS AT T_A = +25°C



Dwg.No. A-11,010A

MAGNETIC FLUX DENSITY AS A FUNCTION OF TOTAL EFFECTIVE AIR GAP

Air Gap = 0.1"

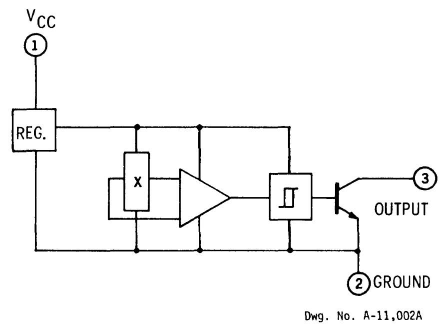


DWG. NO. A-12,571

UGN-3030T/U AND UGS-3030T/U BIPOLAR HALL EFFECT DIGITAL SWITCHES

FEATURES

- 4.5 V to 24 V Operation
- For Use with Multipole Ring Magnets
- High Reliability—No Moving Parts
- Small Size
- Output Compatible with All Digital Logic Families
- Constant Output Amplitude



FUNCTIONAL BLOCK DIAGRAM

BIPOLAR Type 3030 Hall Effect integrated circuits cleanly track rotation of multipole ring magnets as digital transducers in counter and control circuits. They provide logic-compatible output free of ringing or stuttering while operating in contaminated and electrically noisy environments. The magnetically activated electronic switches are available with two operating temperature ranges and in two three-pin plastic packages.

Each Hall Effect circuit includes a voltage regulator, Hall voltage generator, signal amplifier, Schmitt trigger, and open-collector output on a single silicon chip. The on-board regulator permits operation over the supply-voltage range of 4.5 V to 24 V.

The switches' open-collector outputs can sink up to 20 mA at a conservatively rated repetition rate of 100 kHz. They can be used directly with bipolar or MOS logic circuits. Selected devices, with outputs capable of sinking 50 mA, are available on special order.

Types UGN-3030T and UGN-3030U are rated for operation over the temperature range of −20°C to +85°C. Types UGS-3030T and UGS-3030U have an operating range of −40°C to +125°C.

The Hall Effect switches are offered in two three-pin plastic packages—a 60-mil (1.54 mm) magnetically optimized "U" package, and one 80 mils (2.03 mm) thick specified by the suffix "T."

ABSOLUTE MAXIMUM RATINGS

Supply Voltage, V_{CC}	25 V
Magnetic Flux Density, B	Unlimited
Output OFF Voltage	25 V
Output ON Current, I_{SINK}	25 mA
Operating Temperature Range, T_A	
UGN-3030T	−20°C to +85°C
UGN-3030U	−20°C to +85°C
UGS-3030T	−40°C to +125°C*
UGS-3030U	−40°C to +125°C*
Storage Temperature Range, T_S	−65°C to +150°F

*Selected devices are available with a T_A range of −55°C to +150°C.

These Hall Effect sensors are also supplied in SOT 89 (TO-243AA) packages for surface-mount application. The regular SOT 89 package is specified by substituting an "LT" for the last character of the part number. The long leaded SOT 89 package is specified by substituting an "LL" for the last character of the part number and the Low profile "U" package is available by substituting "UA" for the last character of the part number (e.g., UGN-3XXXLT, UGN-3XXXLL, UGN-3XXXUA).

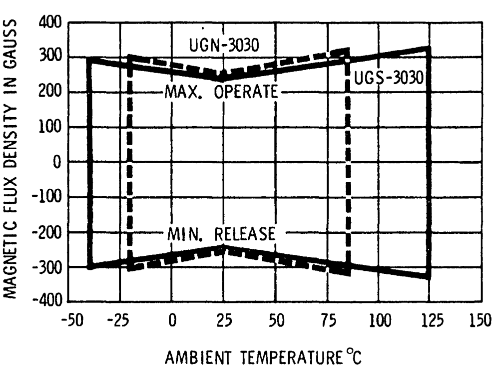
ELECTRICAL CHARACTERISTICS at T_A = +25°C, V_{CC} = 4.5 V to 24 V (unless otherwise noted)

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Operate Point*	B_{OP}		—	160	250	G
Release Point*	B_{RP}		−250	110†	—	G
Hysteresis*	B_H		20	50	—	G
Output Saturation Voltage	$V_{CE(SAT)}$	$B \geq 250$ G, $I_{SINK} = 20$ mA	—	85	400	mV
Output Leakage Current	I_{OFF}	$B \leq -250$ G, $V_{OUT} = 24$ V	—	0.05	10	μA
Supply Current	I_{CC}	$B \leq -250$ G, $V_{CC} = 4.5$ V, Output Open	—	2.3	5.0	mA
		$B \leq -250$ G, $V_{CC} = 24$ V, Output Open	—	3.0	5.0	mA
Output Rise Time	t_r	$V_{CC} = 12$ V, $R_L = 820\Omega$, $C_L = 20$ pF	—	150	—	ns
Output Fall Time	t_f	$V_{CC} = 12$ V, $R_L = 820\Omega$, $C_L = 20$ pF	—	400	—	ns

*Magnetic flux density is measured at most sensitive area of device located at 0.036″ ±0.002″ (0.91 mm ± 0.05 mm) below the branded face of the 'T' package and 0.016″ ± 0.002″ (0.41 mm ± 0.05 mm) below the branded face of the 'U' package.
†B_{RP} not guaranteed at positive flux density: Bipolar magnetic switching is recommended.

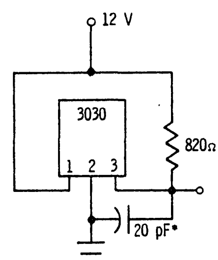
2

GUARANTEED OPERATE AND RELEASE POINTS AS FUNCTIONS OF TEMPERATURE



Dwg. No. A-12,567

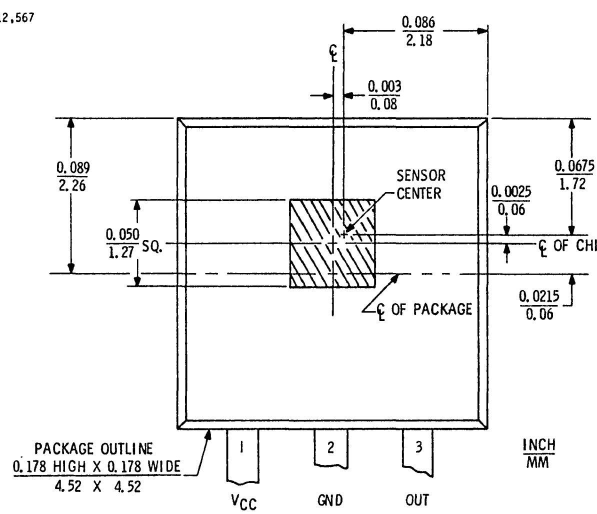
TEST CIRCUIT



Dwg.No. A-12,566

*Includes probe and test fixture capacitance.

SENSOR-CENTER LOCATION



Dwg. No. A-12,399A

OPERATION

The simplest form of magnet that will operate the Hall Effect bipolar digital switch is a multipole ring magnet as shown in Figure 1. The magnet must provide a +250 gauss to −250 gauss magnetic flux density range at the sensor to ensure reliable operation. Such magnets are commercially available and inexpensive.

Under power-up conditions, and in the absence of an externally applied magnetic field, the output transistor of most Type 3030 switches is ON and capable of sinking 25 mA of current. This is, however, a formally ambiguous state and should be treated as such.

In normal operation, the output transistor turns ON as the strength of the magnetic field perpendicular to the surface of the chip reaches the Operate Point. The output transistor switches OFF as magnetic field reversal takes magnetic flux density to the Release Point.

Note that the device is typically turned ON by presenting the south pole of a magnet to the branded face of the package, which is opposite the side with the ejector pin indentation. With the branded side facing you and the pins pointing down, pinouts are, from left to right: (1) V_{CC}, (2) GND, (3) V_{OUT}.

Type 3030 Hall Effect switches are offered in two packages. The "U" package is about 0.020″ (0.05 mm) thinner than the "T" package. The difference is found in the distance from the surface of the Hall cell to the branded face of the package: The active area depth. The "T" pack's active area depth is 0.036″ (0.9 mm); the "U" pack's is 0.016″ (0.4 mm).

Total effective air gap is the sum of active area depth and the distance between the package's surface and the magnet's surface. There is a considerable increase in flux density at the sensor provided by the thinner package. The actual gain depends on the characteristic slope of flux density for a particular magnet.

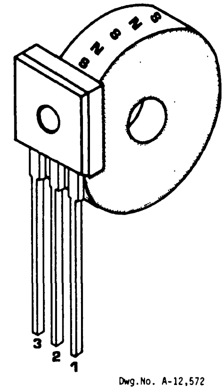
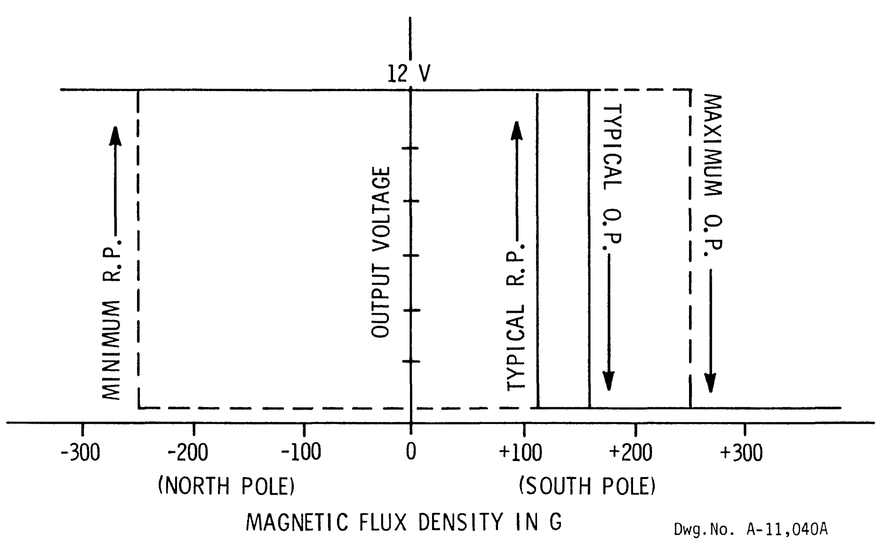


Figure 1

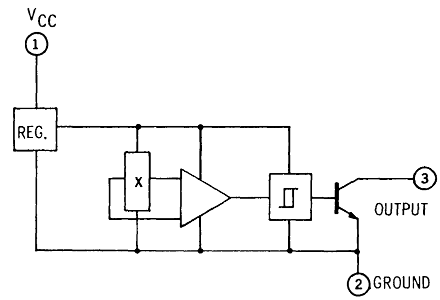
TRANSFER CHARACTERISTICS AT T_A = +25°C



UGN-3040T/U AND UGS-3040T/U ULTRA-SENSITIVE HALL EFFECT DIGITAL SWITCHES

FEATURES

- 4.5 V to 24 V Operation
- Switched by Small Permanent Magnets
- High Reliability—No Moving Parts
- Small Size
- Output Compatible with All Digital Logic Families
- Constant Output Amplitude



Dwg. No. A-11,002A

FUNCTIONAL BLOCK DIAGRAM

THE EXTREME SENSITIVITY of Type 3040 Hall Effect switches recommends their use with small, inexpensive magnets or in applications requiring relatively large distances between magnet and Hall cell. The magnetically activated electronic devices are available with two operating temperature ranges and in two three-pin plastic packages.

Each Hall Effect circuit includes a voltage regulator, Hall voltage generator, signal amplifier, Schmitt trigger, and open-collector output on a single silicon chip.

The on-board regulator permits operation over a wide range of supply voltages. All four ICs work with supply voltages of 4.5 to 24 V.

The switches' output can sink up to 20 mA at a conservatively rated repetition rate of 100 kHz. They can be used directly with bipolar or MOS logic circuits. Selected devices, with outputs capable of sinking 50 mA, are available on special order.

Types UGN-3040T and UGN-3040U are rated for operation over the temperature range of −20°C to +85°C. Types UGS-3040T and UGS-3040U have an operating range of −40°C to +125°C.

The Hall Effect switches are offered in two three-pin plastic packages—a 60-mil (1.54 mm) magnetically optimized "U" package, and one 80 mils (2.03 mm) thick specified by the suffix "T".

ABSOLUTE MAXIMUM RATINGS

Power Supply, V_{CC}	25 V
Magnetic Flux Density, B	Unlimited
Output OFF Voltage	25 V
Output ON Current, I_{SINK}	25 mA
Operating Temperature Range, T_A	
UGN-3040T	−20°C to +85°C
UGN-3040U	−20°C to +85°C
UGS-3040T	−40°C to +125°C*
UGS-3040U	−40°C to +125°C*
Storage Temperature Range, T_S	−65°C to +150°C

*Selected devices are available with a T_A range of −55°C to +150°C.

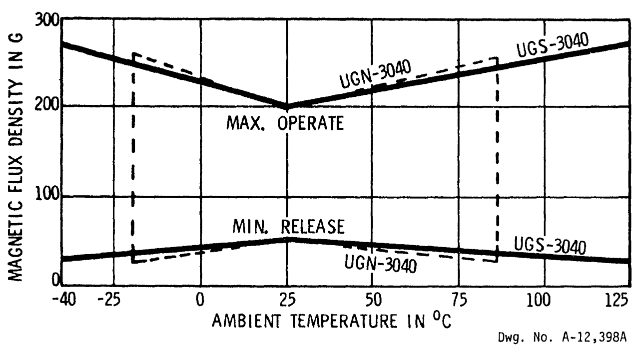
These Hall Effect sensors are also supplied in SOT 89 (TO-243AA) packages for surface-mount application. The regular SOT 89 package is specified by substituting an "LT" for the last character of the part number. The long leaded SOT 89 package is specified by substituting an "LL" for the last character of the part number and the Low profile "U" package is available by substituting "UA" for the last character of the part number (e.g., UGN-3XXXLT, UGN-3XXXLL, UGN-3XXXUA).

ELECTRICAL CHARACTERISTICS at $T_A = +25°C$, $V_{CC} = 4.5$ V to 24 V (unless otherwise noted)

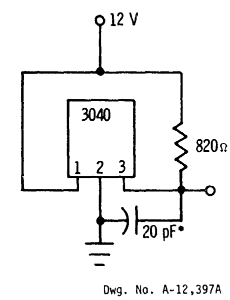
Characteristic	Symbol	Test Condtions	Min.	Typ.	Max.	Units
Operate Point*	B_{OP}		—	150	200	G
Release Point*	B_{RP}		50	100	—	G
Hysteresis*	B_H		20	50	—	G
Output Saturation Voltage	$V_{CE(SAT)}$	$B \geq 200$ G, $I_{SINK} = 20$ mA	—	85	400	mV
Output Leakage Current	I_{OFF}	$B \leq 50$ G, $V_{OUT} = 24$ V	—	0.05	10	μA
Supply Current	I_{CC}	$B \leq 50$ G, $V_{CC} = 4.5$ V, Output Open	—	2.3	5.0	mA
		$B \leq 50$ G, $V_{CC} = 24$ V, Output Open	—	3.0	5.0	mA
Output Rise Time	t_r	$V_{CC} = 12$ V, $R_L = 820\Omega$, $C_L = 20$ pF	—	150	—	ns
Output Fall Time	t_f	$V_{CC} = 12$ V, $R_L = 820\Omega$, $C_L = 20$ pF	—	400	—	ns

*Magnetic flux density is measured at most sensitive area of device located 0.036" ±0.002" (0.91 mm ±0.05 mm) below the branded face of the 'T' package and 0.016" ±0.002" (0.41 mm ±0.05 mm) below the branded face of the 'U' package.

OPERATE AND RELEASE POINTS AS FUNCTIONS OF TEMPERATURE

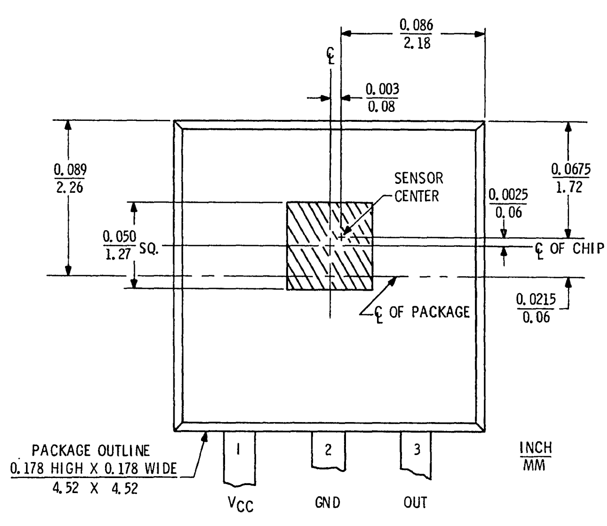


TEST CIRCUIT



*Includes probe and test fixture capacitance.

SENSOR-CENTER LOCATION



OPERATION

The most common modes of operation are head-on and slide-by. As shown in the drawing at right, the magnet's polar axis is the centerline of the Hall Effect package. Change of operating states in the head-on mode is accomplished by decreasing or increasing the distance between the magnet and Hall cell.

The output transistor is OFF when the flux density of the magnetic field perpendicular to the surface of the chip is below threshold (the operate point). When flux density reaches the operate point, the output transistor switches ON and is capable of sinking 25 mA of current.

Note that the device is turned ON by presenting the south pole of the magnet to the branded face of the package, which is opposite the side with the ejector pin indentation. With the branded side facing you and the pins pointing down, pinouts are, from left to right: (1) V_{CC}, (2) GND, (3) V_{OUT}.

The output transistor is switched OFF when flux density of the magnetic field falls below the release point, which is less than the operate point. Hysteresis, as illustrated in the Transfer Characteristics graph, prevents ambiguity and oscillation.

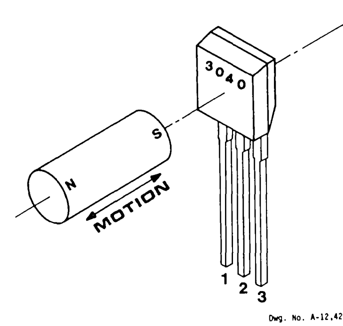
TOTAL EFFECTIVE AIR GAP

Type 3040 Hall Effect switches are offered in two packages, "T" and "U". The "U" package is about 0.020″ (0.05 mm) thinner than the "T" package. The difference is found in the distance from the surface of the Hall cell to the branded face of the package: The active area depth. The "T" pack's active area depth is 0.036″ (0.9 mm); the "U" pack's is 0.016″ (0.4 mm).

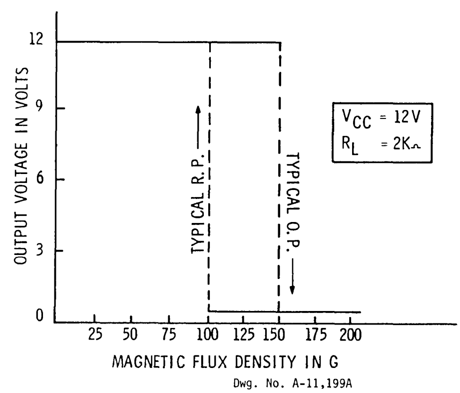
Total effective air gap is the sum of active area depth and the distance between the package's surface and the magnet's surface. The graph of Flux Density as a Function of Effective Air Gap illustrates the considerable increase in flux density at the sensor provided by the thinner package. The actual gain depends on the characteristic slope of flux density for a particular magnet.

A wide variety of magnets is commercially available. Each type of magnet exhibits unique magnetic field characteristics. The magnets used to construct the Flux Density graph were measured for the head-on mode of operation, but the graph's information is valid for peak flux density in the slide-by mode of switch activation.

HEAD-ON MODE

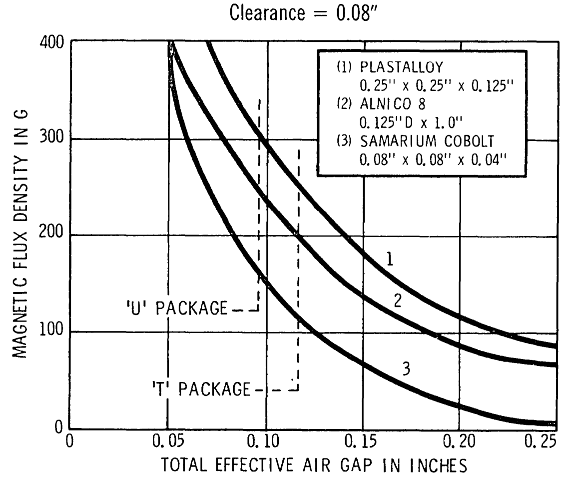


TRANSFER CHARACTERISTICS AT T_A = +25°C



MAGNETIC FLUX DENSITY AS A FUNCTION OF TOTAL EFFECTIVE AIR GAP

Clearance = 0.08″



2

UGN-3113T AND UGN-3113U HALL EFFECT SWITCHES

FEATURES

- 4.5 V to 24 V Operation
- High Reliability—No Moving Parts
- Constant Output Amplitude
- Output Compatible with All Digital Logic Families
- Superior Temperature Stability
- Highly Resistant to Physical Stress

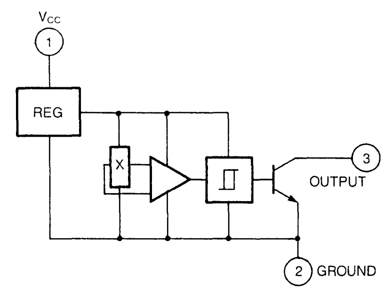
Type 3113 Hall Effect switches are highly temperature-stable and stress-resistant sensors best utilized in applications that provide steep magnetic slopes and low residual levels of magnetic flux density.

Each Hall Effect circuit includes a voltage regulator, quadratic Hall voltage generator, temperature stability circuit, signal amplifier, Schmitt trigger, and open-collector output on a single silicon chip. The on-board regulator permits operation with supply voltages of 4.5 to 24 V. The switches' output can sink up to 20 mA at a conservatively-rated repetition rate of 100 kHz. They can be used directly with bipolar or MOS logic circuits. Selected devices, with outputs capable of sinking 50 mA, are available on special order.

Types UGN-3113T and UGN-3113U are rated for operation over the temperature range of −20°C to +85°C.

The Hall Effect switches are offered in two three-pin plastic packages—a 60-mil (1.54 mm) magnetically-optimized "U" package, and one 80 mils (2.03 mm) thick specified by the suffix "T."

FUNCTIONAL BLOCK DIAGRAM



Dwg. No. A-11,002A

Type 3113 is also available in SOT89 (TO-243AA) for surface mount applications as UGN-3113LL and UGN-3113LT. Contact the factory for more information.

ABSOLUTE MAXIMUM RATINGS

Power Supply, V_{CC}	25 V
Magnetic Flux Density, B	Unlimited
Output OFF Voltage	25 V
Output ON Current, I_{SINK}	25 mA
Operating Temperature Range, T_A	
UGN-3113-T	−20°C to +85°C
UGN-3113-U	−20°C to +85°C
Storage Temperature Range, T_S	−65°C to +150°C*

*Devices can be stored at +200°C for short periods of time.

These Hall Effect sensors are also supplied in a Low profile "U" package. The low profile "U" is specified by substituting a "UA" for the last character of the part number.

ELECTRICAL CHARACTERISTICS at T_A = +25°C, V_{CC} = 4.5 V to 24 V (unless otherwise noted)

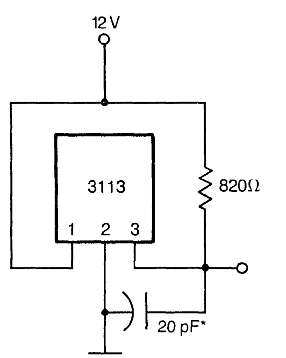
Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Supply Voltage	V_{CC}		4.5	—	24	V
Output Saturation Voltage	$V_{CE(sat)}$	$B \geq 200G$, $I_{SINK} = 20$ mA	—	150	400	mV
Output Leakage Currrent	I_{OFF}	$B \leq 50G$, $V_{OUT} = 24$ V	—	0.05	10	μA
Supply Current	I_{CC}	$B \leq 50G$, $V_{CC} = 4.5$ V, Output Open	—	4.7	8.0	mA
Output Rise Time	t_r	$V_{CC} = 12$ V, $R_L = 820\Omega$, $C_L = 20$ pF	—	0.04	2.0	μs
Output Fall Time	t_f	$V_{CC} = 12$ V, $R_L = 820\Omega$, $C_L = 20$ pF	—	0.18	2.0	μs

2

MAGNETIC CHARACTERISTICS

		T_A = +25°C		T_A = −20°C to +85°C		
Characteristic	Symbol	Min.	Max.	Min.	Max.	Units
Operate Point	B_{OP}		450		510	G
Release Point	B_{RP}	30		20		G
Hysteresis	B_H	20		10		G

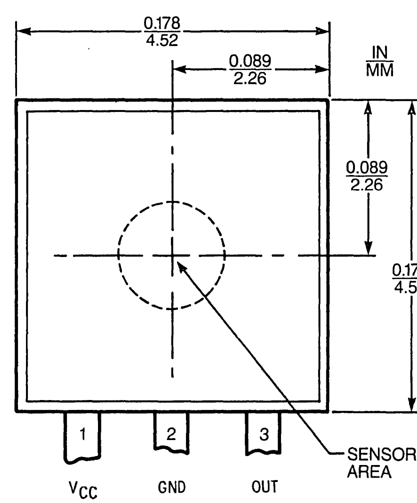
TEST CIRCUIT



Dwg. No. A-14,469

*Includes probe and text fixture capacitance.

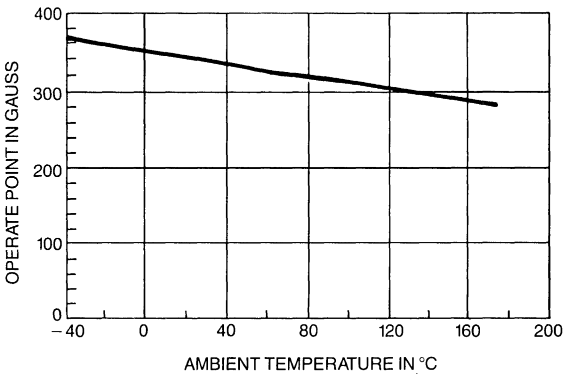
SENSOR LOCATION



Dwg. No. W-173A

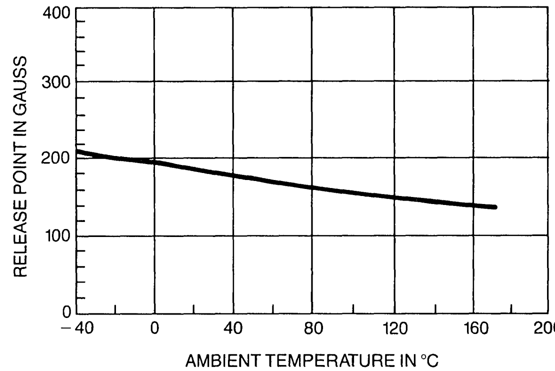
TYPICAL CHARACTERISTICS AS FUNCTIONS OF TEMPERATURE

OPERATE POINT



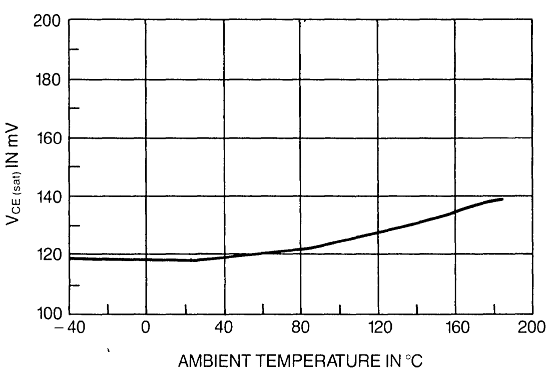
Dwg. No. W-199

RELEASE POINT



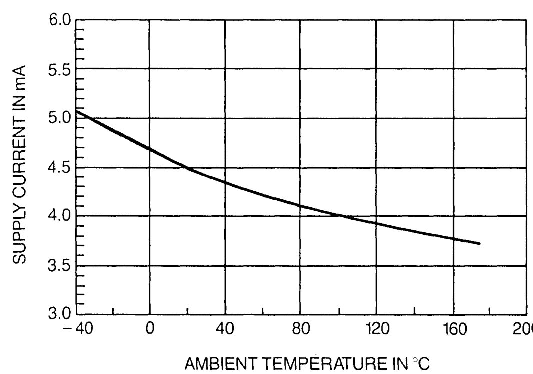
Dwg. No. W-200

OUTPUT SATURATION VOLTAGE



Dwg. No. W-176

SUPPLY CURRENT

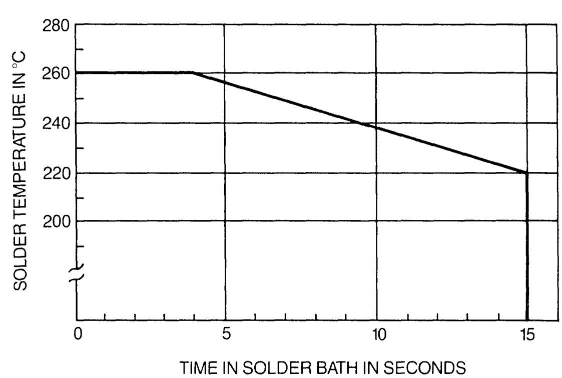


Dwg. No W-167

GUIDE TO INSTALLATION

1. All Hall Effect integrated circuits are susceptible to mechanical stress effects. Caution should be exercised to minimize the application of stress to the leads or the epoxy package. Use of epoxy glue is recommended. Other types may deform the epoxy package.

2. To prevent permanent damage to the Hall cell, heat-sink the leads during hand-soldering. Recommended maximum conditions for wave soldering are shown in the graph at right.



Dwg. No. A-12,062

UGN-3119T/U AND UGS-3119T/U HALL EFFECT SWITCHES

FEATURES

- 4.5V to 24V Operation
- High Reliability—No Moving Parts
- Constant Output Amplitude
- Output Compatible with All Digital Logic Families
- Superior Temperature Stability
- Highly Resistant to Physical Stress

Type 3119 Hall Effect switches are highly temperature-stable and stress-resistant sensors best utilized in applications that provide steep magnetic slopes and low residual levels of magnetic flux density. The magnetically activated integrated circuits are available with two operating temperature ranges and with several package options.

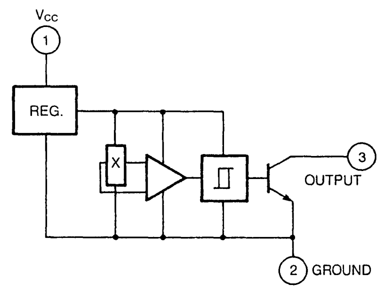
Each Hall Effect circuit includes a voltage regulator, quadratic Hall voltage generator, temperature stability circuit, signal amplifier, Schmitt trigger, and open-collector output on a single silicon chip. The on-board regulator permits operation with supply voltages of 4.5 to 24 V. The switches' output can sink up to 20 mA at a conservatively rated repetition rate of 100 kHz. They can be used directly with bipolar or MOS logic circuits. Selected devices, with outputs capable of sinking 50 mA, are available on special order.

Types UGN-3119T and UGN-3119U are rated for operation over the temperature range of $-20°C$ to $+85°C$. Types UGS-3119T and UGS-3119U have an operating range of $-40°C$ to $+125°C$.

The Hall Effect switches are offered in two three-pin plastic packages—a 60-mil (1.54 mm) magnetically optimized "U" package, and one 80 mils (2.03 mm) thick specified by the suffix "T."

Type 3119 is also available in SOT 89 (TO-243AA) for surface-mount applications as UGN-3119LT and UGN-3119LL and UGS-3119LT and UGS-3119LL, and in a hermetically sealed three-pin ceramic package. A high-temperature hermetic device supplied with Sprague HYREL® screening is available as UGS-3119HH. For more information on surface-mount and hermetic switches, contact the factory.

FUNCTIONAL BLOCK DIAGRAM



Dwg. No. A-11,002 A

ABSOLUTE MAXIMUM RATINGS

Power Supply, V_{CC}	25V
Magnetic Flux Density, B	Unlimited
Output OFF Voltage	25V
Output ON Current, I_{SINK}	25mA
Operating Temperature Range, T_A	
UGN-3119T	$-20°C$ to $+85°C$
UGN-3119U	$-20°C$ to $+85°C$
UGS-3119T	$-40°C$ to $+125°C$
UGS-3119U	$-40°C$ to $+125°C$
Storage Temperature Range, T_S	$-65°C$ to $+150°C$ *

*Devices can be stored at $+200°C$ for short periods of time.
**Selected devices available with T_A Range of $-55°C$ to $+170°C$.

These Hall Effect sensors are also supplied in a Low profile "U" package. The low profile "U" is specified by substituting a "UA" for the last character of the part number.

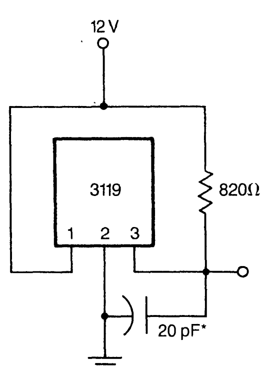
ELECTRICAL CHARACTERISTICS at $T_A = +25°C$, $V_{CC} = 4.5$ V to 24 V (unless otherwise noted)

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Supply Voltage	V_{CC}		4.5	—	24	V
Output Saturation Voltage	$V_{CE(sat)}$	$B \geq 200G$, $I_{SINK} = 20mA$	—	150	400	mV
Output Leakage Current	I_{OFF}	$B \leq 50G$, $V_{OUT} = 24V$	—	0.05	10	μA
Supply Current	I_{CC}	$B \leq 50G$, $V_{CC} = 4.5V$, Output Open	—	4.7	8.0	mA
Output Rise Time	t_r	$V_{CC} = 12V$, $R_L = 820\Omega$, $C_L = 20pF$	—	0.04	2.0	μs
Output Fall Time	t_f	$V_{CC} = 12V$, $R_L = 820\Omega$, $C_L = 20pF$	—	0.18	2.0	μs

MAGNETIC CHARACTERISTICS

		$T_A = +25°C$		$T_A = -20°C$ to $+85°C$		$T_A = -40°C$ to $+125°C$		
Characteristic	Symbol	Min.	Max.	Min.	Max.	Min.	Max.	Units
Operate Point	B_{OP}	175	500	100	545	45	575	G
Release Point	B_{RP}	125	450	50	495	25	555	G
Hysteresis	B_H	50	—	50	—	20	—	G

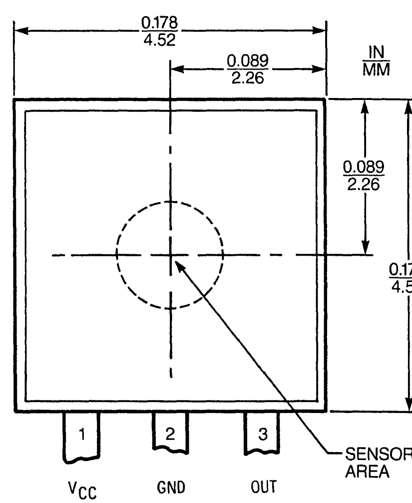
TEST CIRCUIT



Dwg. No. W-198

*Includes probe and test fixture capacitance.

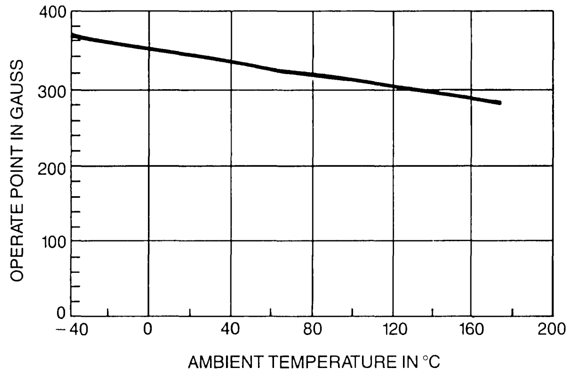
SENSOR LOCATION



Dwg. No. W-173A

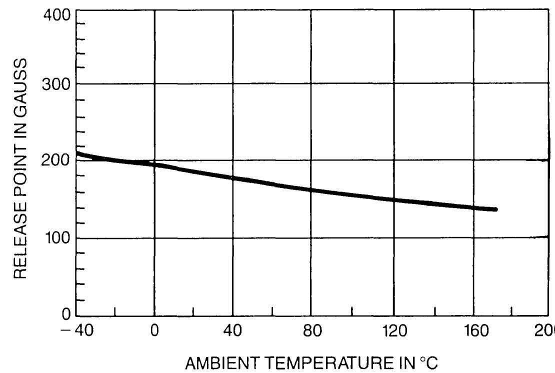
TYPICAL CHARACTERISTICS AS FUNCTIONS OF TEMPERATURE

OPERATE POINT



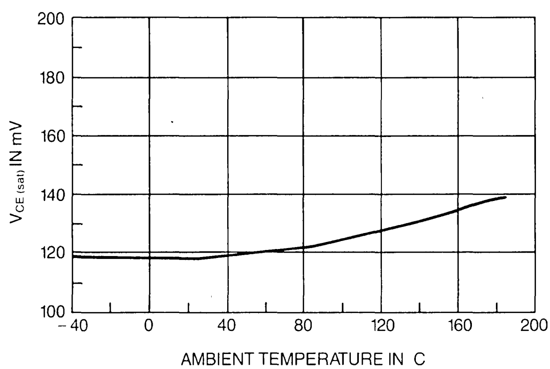
Dwg No W-199

RELEASE POINT



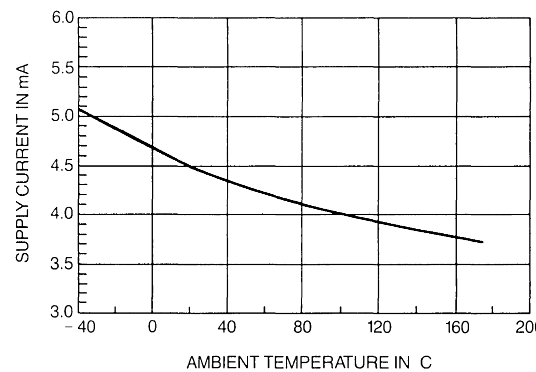
Dwg No. W-200

OUTPUT SATURATION VOLTAGE



Dwg No W-176

SUPPLY CURRENT

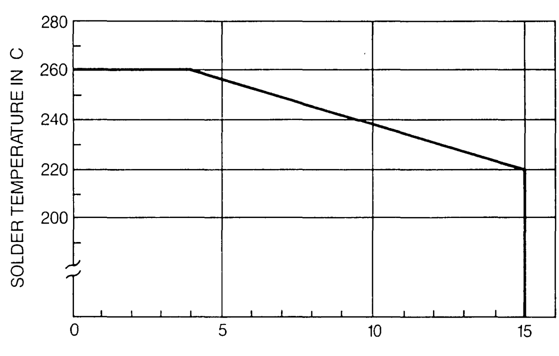


Dwg No W-167

GUIDE TO INSTALLATION

1. All Hall Effect integrated circuits are susceptible to mechanical stress effects. Caution should be exercised to minimize the application of stress to the leads or the epoxy package. Use of epoxy glue is recommended. Other types may deform the epoxy package.

2. To prevent permanent damage to the Hall cell, heat-sink the leads during hand-soldering. Recommended maximum conditions for wave soldering are shown in the graph at right.



Dwg No. A-12,062

UGN-3120T/U AND UGS-3120T/U HALL EFFECT SWITCHES

FEATURES

- 4.5 V to 24 V Operation
- High Reliability—No Moving Parts
- Constant Output Amplitude
- Output Compatible with All Digital Logic Families
- Superior Temperature Stability
- Highly Resistant to Physical Stress

Type 3120 Hall Effect switches are highly temperature-stable and stress-resistant sensors best utilized in applications that provide steep magnetic slopes and require precise switch points. The magnetically activated integrated circuits are available with two operating temperature ranges and with several package options.

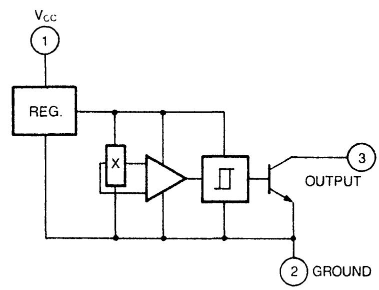
Each Hall Effect circuit includes a voltage regulator, quadratic Hall voltage generator, temperature stability circuit, signal amplifier, Schmitt trigger, and open-collector output on a single silicon chip. The on-board regulator permits operation with supply voltages of 4.5 to 24 V. The switches' output can sink up to 20 mA at a conservatively rated repetition rate of 100 kHz. They can be used directly with bipolar or MOS logic circuits. Selected devices, with outputs capable of sinking 50 mA, are available on special order.

Types UGN-3120T and UGN-3120U are rated for operation over the temperature range of −20°C to +85°C. Types UGS-3120T and UGS-3120U have an operating range of −40°C to +125°C.

The Hall Effect switches are offered in two three-pin plastic packages—a 60-mil (1.54 mm) magnetically optimized "U" package, and one 80 mils (2.03 mm) thick specified by the suffix "T".

Type 3120 is also available in SOT 89 (TO-243AA) for surface-mount applications as UGN-3120LT and UGN-3120LL and UGS-3120LT and UGS-3120LL, and in a hermetically sealed three-pin ceramic package. A high-temperature hermetic device supplied with Sprague HYREL® screening is available as UGS-3120HH. For more information on surface-mount and hermetic switches, contact the factory.

FUNCTIONAL BLOCK DIAGRAM



DWG NO A-11,002A

ABSOLUTE MAXIMUM RATINGS

Power Supply, V_{CC}	25V
Magnetic Flux Density, B	Unlimited
Output OFF Voltage	25V
Output ON Current, I_{SINK}	25mA
Operating Temperature Range, T_A	
UGN-3120T	−20°C to + 85°C
UGN-3120U	−20°C to + 85°C
UGS-3120T	−40°C to +125°C
UGS-3120U	−40°C to +125°C
Storage Temperature Range, T_S	−65°C to +150°C *

*Devices can be stored at +200°C for short periods of time.
**Selected devices available with T_A range of −55°C to +170°C.

These Hall Effect sensors are also supplied in a Low profile "U" package. The low profile "U" is specified by substituting a "UA" for the last character of the part number.

ELECTRICAL CHARACTERISTICS at $T_A = +25°C$, $V_{CC} = 4.5$ V to 24 V (unless otherwise noted)

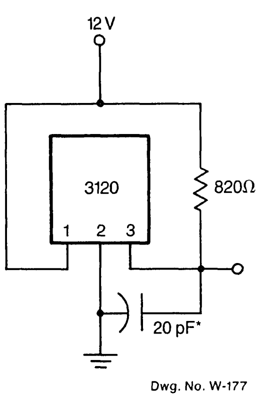
Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Supply Voltage	V_{CC}		4.5	—	24	V
Output Saturation Voltage	$V_{CE(sat)}$	$B \geq 200G$, $I_{SINK} = 20mA$	—	150	400	mV
Output Leakage Current	I_{OFF}	$B \leq 50G$, $V_{OUT} = 24V$	—	0.05	10	μA
Supply Current	I_{CC}	$B \leq 50G$, $V_{CC} = 4.5V$, Output Open	—	4.7	8.0	mA
Output Rise Time	t_r	$V_{CC} = 12V$, $R_L = 820\Omega$, $C_L = 20pF$	—	0.04	2.0	μs
Output Fall Time	t_f	$V_{CC} = 12V$, $R_L = 820\Omega$, $C_L = 20pF$	—	0.18	2.0	μs

2

MAGNETIC CHARACTERISTICS

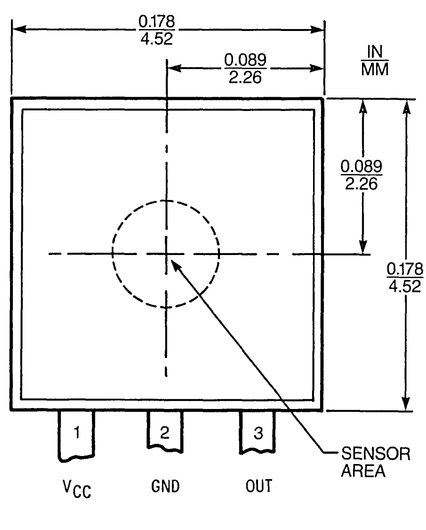
		$T_A = +25°C$		$T_A = -20°C$ to $+85°C$		$T_A = -40°C$ to $+125°C$		
Characteristic	Symbol	Min.	Max.	Min.	Max.	Min.	Max.	Units
Operate Point	B_{OP}	70	350	70	425	35	450	G
Release Point	B_{RP}	50	330	50	405	25	430	G
Hysteresis	B_H	20	—	20	—	20	—	G

TEST CIRCUIT

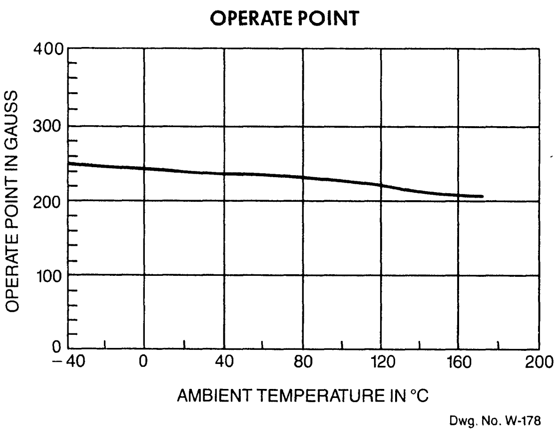


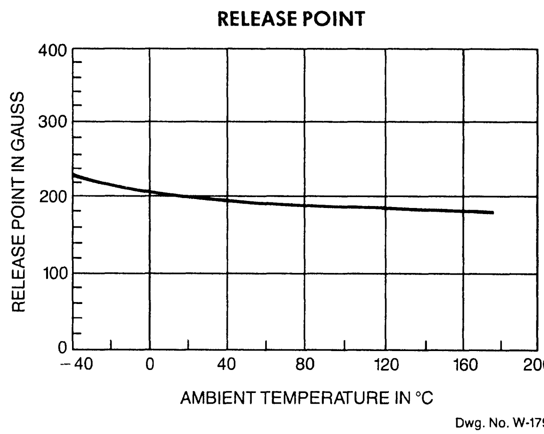
*Includes probe and test fixture capacitance.

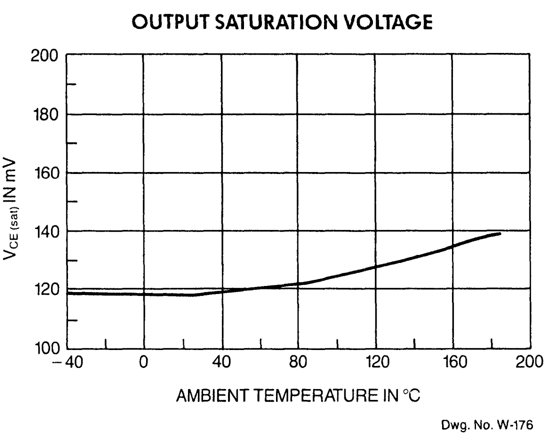
SENSOR LOCATION

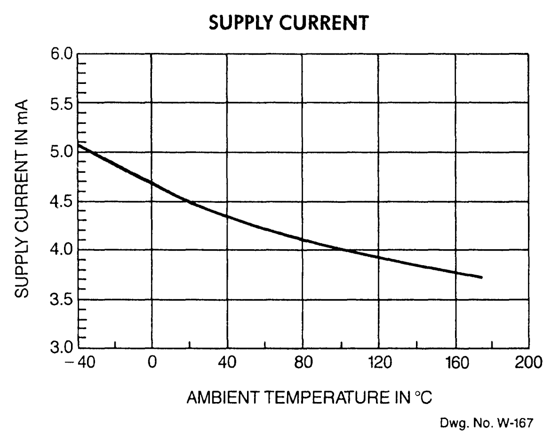


TYPICAL CHARACTERISTICS AS FUNCTIONS OF TEMPERATURE





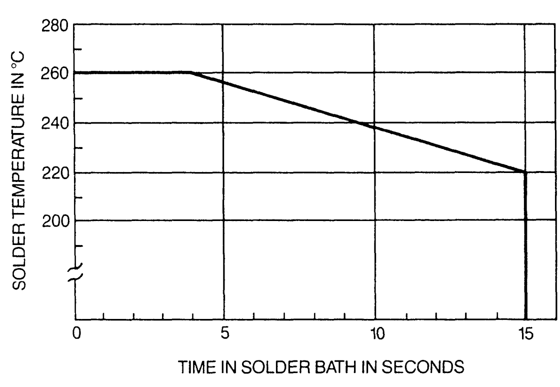




GUIDE TO INSTALLATION

1. All Hall Effect integrated circuits are susceptible to mechanical stress effects. Caution should be exercised to minimize the application of stress to the leads or the epoxy package. Use of epoxy glue is recommended. Other types may deform the epoxy package.

2. To prevent permanent damage to the Hall cell, heat-sink the leads during hand-soldering. Recommended maximum conditions for wave soldering are shown in the graph at right.



UGN-3130T/U AND UGS-3130T/U HALL EFFECT SWITCHES

FEATURES

- 4.5 V to 24 V Operation
- High Reliability—No Moving Parts
- Constant Output Amplitude
- Output Compatible with All Digital Logic Families
- Superior Temperature Stability
- Highly Resistant to Physical Stress

Type 3130 Hall Effect switches are highly temperature-stable and stress-resistant sensors best utilized in applications that provide steep magnetic slopes and require precise switch points. The magnetically activated integrated circuits are available with two operating temperature ranges and with several package options.

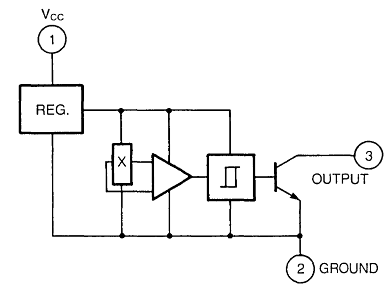
Each Hall Effect circuit includes a voltage regulator, quadratic Hall voltage generator, temperature stability circuit, signal amplifier, Schmitt trigger, and open-collector output on a single silicon chip. The on-board regulator permits operation with supply voltages of 4.5 to 24 V. The switches' output can sink up to 20 mA at a conservatively-rated repetition rate of 100 kHz. They can be used directly with bipolar or MOS logic circuits. Selected devices, with outputs capable of sinking 50 mA, are available on special order.

Types UGN-3130T and UGN-3130U are rated for operation over the temperature range of −20°C to +85°C. Types UGS-3130T and UGS-3130U have an operating range of −40°C to +125°C.

The Hall Effect switches are offered in two three-pin plastic packages—a 60-mil (1.54 mm) magnetically-optimized "U" package, and one 80 mils (2.03 mm) thick specified by the suffix "T".

Type 3130 is also available in SOT 89 (TO-243AA) for surface-mount applications as UGN-3130LT and UGN-3130LL and UGS-3130LT and UGS-3130LL, and in a hermetically sealed three-pin ceramic package. A high-temperature hermetic device supplied with Sprague HYREL® screening is available as UGS-3130HH. For more information on surface-mount and hermetic switches, contact the factory.

FUNCTIONAL BLOCK DIAGRAM



Dwg. No A-11,002A

ABSOLUTE MAXIMUM RATINGS

Power Supply, V_{CC}	25 V
Magnetic Flux Density, B	Unlimited
Output OFF Voltage	25 V
Output ON Current, I_{SINK}	25 mA
Operating Temperature Range, T_A	
UGN-3130T	−20°C to +85°C
UGN-3130U	−20°C to +85°C
UGS-3130T	−40°C to +125°C
UGS-3130U	−40°C to +125°C
Storage Temperature Range, T_S	−65°C to +150°C*

*Devices can be stored at +200°C for short periods of time.

These Hall Effect sensors are also supplied in a Low profile "U" package. The low profile "U" is specified by substituting a "UA" for the last character of the part number.

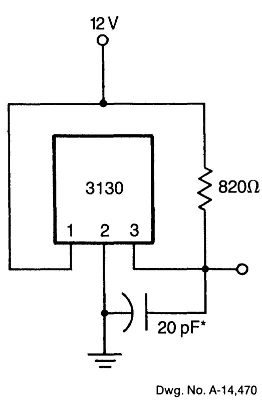
ELECTRICAL CHARACTERISTICS at T_A = +25°C, V_{CC} = 4.5 V to 24 V (unless otherwise noted)

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Supply Voltage	V_{CC}		4.5	—	24	V
Output Saturation Voltage	$V_{CE(sat)}$	$B \geq 200G$, $I_{SINK} = 20mA$	—	150	400	mV
Output Leakage Current	I_{OFF}	$B \leq 50G$, $V_{OUT} = 24V$	—	0.05	10	μA
Supply Current	I_{CC}	$B \leq 50G$, $V_{CC} = 4.5V$, Output Open	—	4.7	8.0	mA
Output Rise Time	t_r	$V_{CC} = 12V$, $R_L = 820\Omega$, $C_L = 20pF$	—	0.04	2.0	μs
Output Fall Time	t_f	$V_{CC} = 12V$, $R_L = 820\Omega$, $C_L = 20pF$	—	0.18	2.0	μs

MAGNETIC CHARACTERISTICS

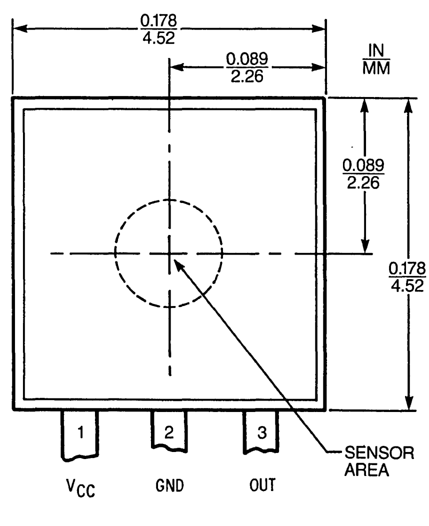
Characteristic	Symbol	T_A = +25°C		T_A = −20°C to +85°C		T_A = −40°C to +125°C		Units
		Min.	Max.	Min.	Max.	Min.	Max.	
Operate Point	B_{OP}	—	150	—	175	—	200	G
Release Point	B_{RP}	−150	—	−175	—	−200	—	G
Hysteresis	B_H	20	—	20	—	20	—	G

TEST CIRCUIT



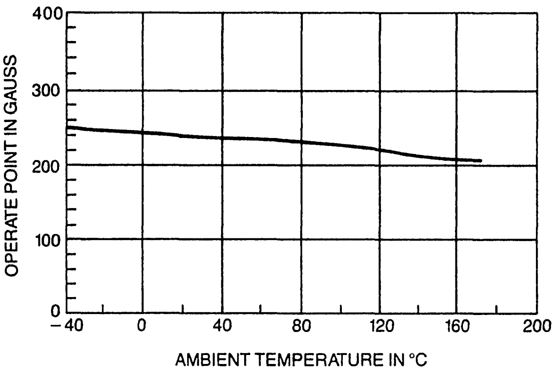
*Includes probe and test fixture capacitance.

SENSOR LOCATION



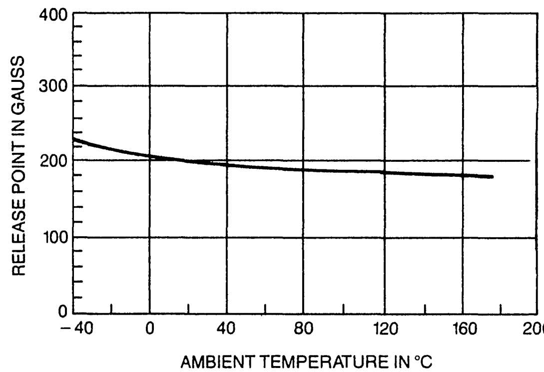
TYPICAL CHARACTERISTICS AS FUNCTIONS OF TEMPERATURE

OPERATE POINT



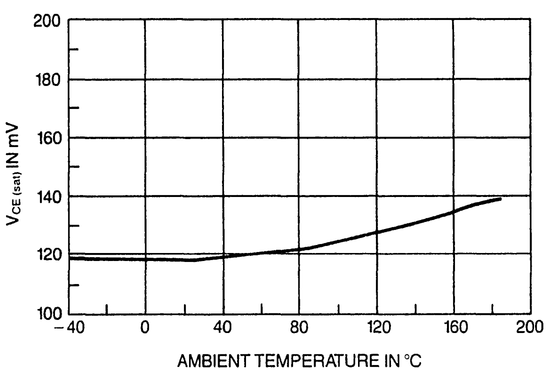
Dwg. No. W-178

RELEASE POINT



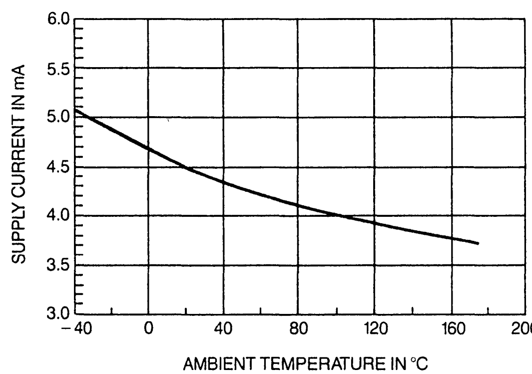
Dwg. No. W-179

OUTPUT SATURATION VOLTAGE



Dwg. No. W-176

SUPPLY CURRENT

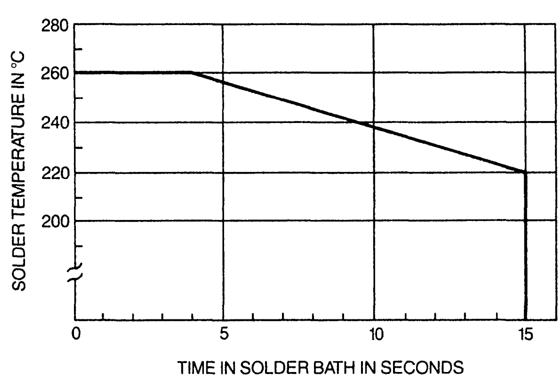


Dwg. No. W-167

GUIDE TO INSTALLATION

1. All Hall Effect integrated circuits are susceptible to mechanical stress effects. Caution should be exercised to minimize the application of stress to the leads or the epoxy package. Use of epoxy glue is recommended. Other types may deform the epoxy package.

2. To prevent permanent damage to the Hall cell, heat-sink the leads during hand-soldering. Recommended maximum conditions for wave soldering are shown in the graph at right.



Dwg. No. A-12,062

UGN-3131T/U AND UGS-3131T/U ULTRA-SENSITIVE HALL EFFECT BIPOLAR SWITCHES

FEATURES

- 4.5V to 24V Operation
- High Reliability—No Moving Parts
- Constant Output Amplitude
- Output Compatible with All Digital Logic Families
- Superior Temperature Stability
- Highly Resistant to Physical Stress

Type 3131 bipolar switches are extremely sensitive devices made possible by Sprague breakthroughs in Hall sensor design and technology. The sensors have superior magnetic characteristics, are less susceptible to mechanical stress than previous Hall Effect ICs, and are very stable over temperature. On-chip compensation closely maintains magnetic operate and release points and hysteresis limits over their operating temperature ranges.

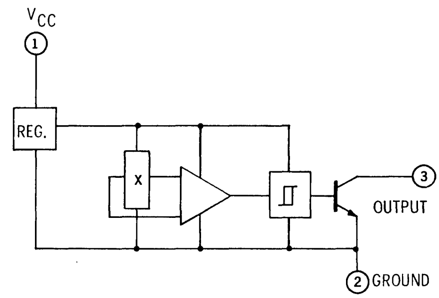
Each Hall Effect circuit includes a voltage regulator, quadratic Hall voltage generator, temperature stability circuit, signal amplifier, Schmitt trigger, and open-collector output on a single silicon chip. The on-board regulator permits operation with supply voltages of 4.5 to 30 V. The switches' output can sink up to 20 mA at a conservatively rated repetition rate of 100 kHz. They can be used directly with bipolar or MOS logic circuits. Selected devices, with outputs capable of sinking 50 mA, are available on special order.

Types UGN-3131T and UGN-3131U are rated for operation over the temperature range of −20°C to +85°C. Types UGS-3131T and UGS-3131U have an operating range of −40°C to +125°C.

The Hall Effect switches are offered in two three-pin plastic packages—a 60-mil (1.54 mm) magnetically optimized "U" package, and one 80 mils (2.03 mm) thick specified by the suffix "T".

Type 3131 is also available in SOT 89 (TO-243AA) for surface-mount applications as UGN-3131LT and UGN-3131LL and UGS-3131LT and UGS-3131LL, and in a hermetically sealed three-pin ceramic package. A high-temperature hermetic device supplied with Sprague HYREL® screening is available as UGS-3131HH. For more information on surface-mount and hermetic switches, contact the factory.

FUNCTIONAL BLOCK DIAGRAM



Dwg. No. A-11,002A

ABSOLUTE MAXIMUM RATINGS

Power Supply, V_{CC}	30V
Magnetic Flux Density, B	Unlimited
Output OFF Voltage	30V
Output ON Current, I_{SINK}	25mA
Operating Temperature Range, T_A	
UGN-3131T	−20°C to + 85°C
UGN-3131U	−20°C to + 85°C
UGS-3131T	−40°C to +125°C
UGS-3131U	−40°C to +125°C
Storage Temperature Range, T_S	−65°C to +150°C *

*Devices can be stored at +200°C for short periods of time.
**Selected devices available with T_A range of −55°C to +170°C.

These Hall Effect sensors are also supplied in a Low profile "U" package. The low profile "U" is specified by substituting a "UA" for the last character of the part number.

ELECTRICAL CHARACTERISTICS at T_A = +25°C, V_{CC} = 4.5 V to 30 V (unless otherwise noted)

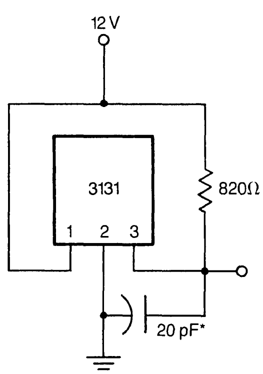
Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Supply Voltage	V_{CC}		4.5	—	30	V
Output Saturation Voltage	$V_{CE(sat)}$	$B \geq 95G$, $V_{CC} = 30V$, $I_{SINK} = 20mA$	—	—	400	mV
Output Leakage Current	I_{OFF}	$B \leq -95G$, $V_{OUT} = 30V$, $V_{CC} = 30V$	—	—	10	μA
Supply Current	I_{CC}	$B \leq -95G$, $V_{CC} = 30V$, Output Open	—	—	7.0	mA
Output Rise Time	t_r	$V_{CC} = 12V$, $R_L = 820\Omega$, $C_L = 20pF$	—	0.04	2.0	μs
Output Fall Time	t_f	$V_{CC} = 12V$, $R_L = 820\Omega$, $C_L = 20pF$	—	0.18	2.0	μs

2

MAGNETIC CHARACTERISTICS

		T_A = +25°C		T_A = −20°C to +85°C		T_A = −40°C to +125°C		
Characteristic	Symbol	Min.	Max.	Min.	Max.	Min.	Max.	Units
Operate Point	B_{OP}	−75	95	−75	95	−115	135	G
Release Point	B_{RP}	−95	75	−95	75	−135	115	G
Hysteresis	B_H	20	—	20	—	15	—	G

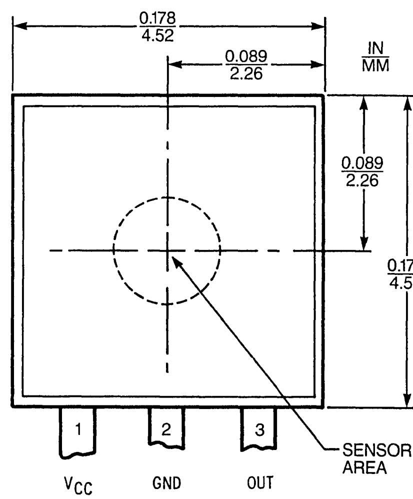
TEST CIRCUIT



Dwg. No. W-241

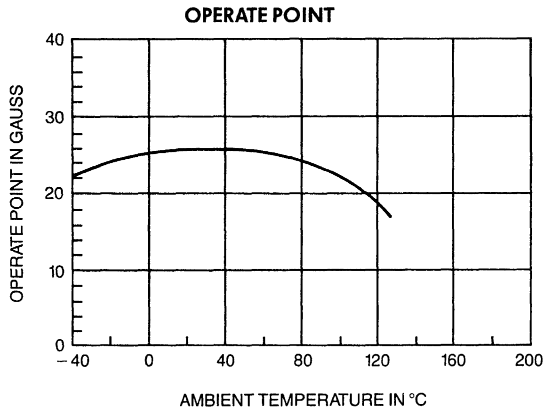
*Includes probe and test fixture capacitance.

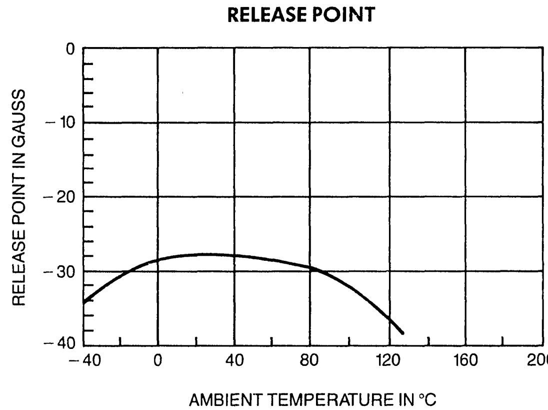
SENSOR LOCATION



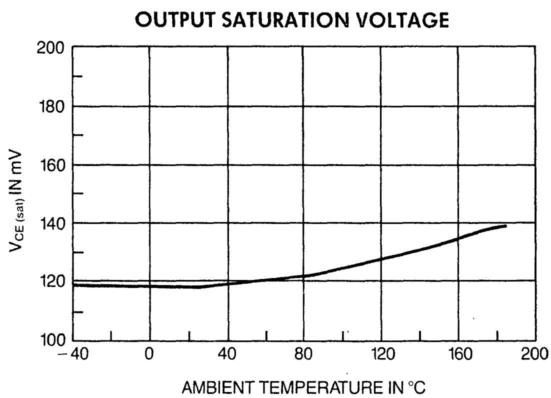
Dwg. No. W-173A

TYPICAL CHARACTERISTICS AS FUNCTIONS OF TEMPERATURE

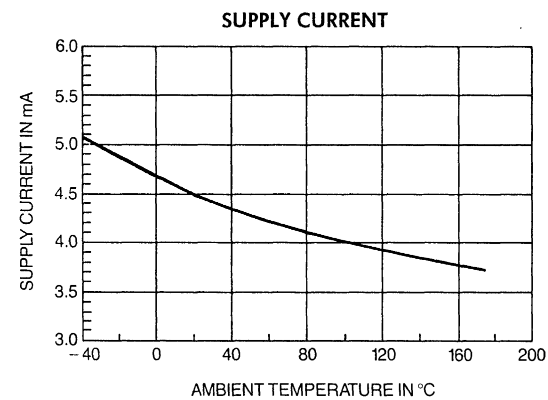




Dwg. No. W-243



Dwg. No. W-176

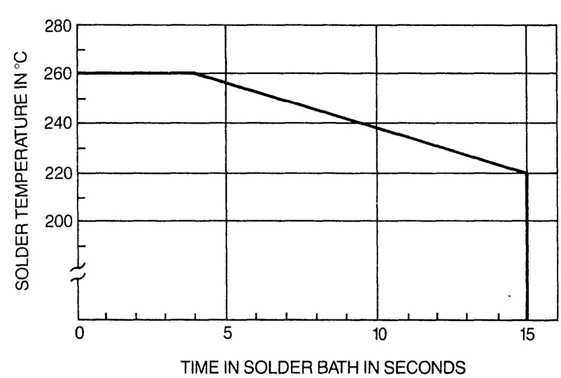


Dwg. No. W-167

GUIDE TO INSTALLATION

1. All Hall Effect integrated circuits are susceptible to mechanical stress effects. Caution should be exercised to minimize the application of stress to the leads or the epoxy package. Use of epoxy glue is recommended. Other types may deform the epoxy package.

2. To prevent permanent damage to the Hall cell, heat-sink the leads during hand-soldering. Recommended maximum conditions for wave soldering are shown in the graph at right.



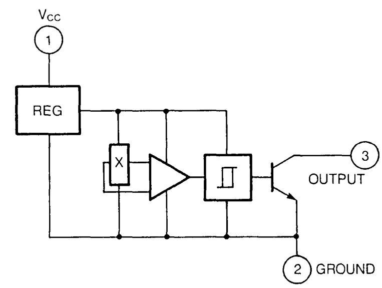
Dwg. No. A-12,062

UGN-3140T/U AND UGS-3140T/U ULTRA-SENSITIVE HALL EFFECT SWITCHES

FEATURES

- 4.5 V to 24 V Operation
- High Reliability—No Moving Parts
- Constant Output Amplitude
- Output Compatible with All Digital Logic Families
- Superior Temperature Stability
- Highly Resistant to Physical Stress

FUNCTIONAL BLOCK DIAGRAM



Dwg No. A-11,002 A

The extreme sensitivity of Type 3140 Hall Effect switches recommends their use with small, inexpensive magnets or in applications requiring relatively large distances between magnet and Hall cell. The magnetically activated electronic devices are available with two operating temperature ranges and with several package options.

Each Hall Effect circuit includes a voltage regulator, quadratic Hall voltage generator, temperature stability circuit, signal amplifier, Schmitt trigger, and open-collector output on a single silicon chip.

The on-board regulator permits operation with supply voltages of 4.5 to 24 V. The switches' output can sink up to 20 mA at a conservatively rated repetition rate of 100 kHz. They can be used directly with bipolar or MOS logic circuits. Selected devices, with outputs capable of sinking 50 mA, are available on special order.

Types UGN-3140T and UGN-3140U are rated for operation over the temperature range of −20°C to +85°C. Types UGS-3140T and UGS-3140U have an operating range of −40°C to +125°C.

The Hall Effect switches are offered in two three-pin plastic packages—a 60-mil (1.54 mm) magnetically optimized "U" package, and one 80 mils (2.03 mm) thick specified by the suffix "T".

Type 3140 is also available in SOT 89 (TO-243AA) for surface-mount applications as UGN-3140LT and UGN-3140LL and UGS-3140LT and UGS-3140LL, and in a hermetically sealed three-pin ceramic package. A high-temperature hermetic device supplied with Sprague HYREL® screening is available as UGS-3140HH. For more information on surface-mount and hermetic switches, contact the factory.

ABSOLUTE MAXIMUM RATINGS

Power Supply, V_{CC}	25 V
Magnetic Flux Density, B	Unlimited
Output OFF Voltage	25 V
Output ON Current, I_{SINK}	25 mA
Operating Temperature Range, T_A	
UGN-3140T	−20°C to +85°C
UGN-3140U	−20°C to +85°C
UGS-3140T	−40°C to +125°C
UGS-3140U	−40°C to +125°C
Storage Temperature Range, T_S	−65°C to +150°C *

*Devices can be stored at +200°C for short periods of time.
**Selected devices available with T_A range of −55°C to +170°C.

These Hall Effect sensors are also supplied in a Low profile "U" package. The low profile "U" is specified by substituting a "UA" for the last character of the part number.

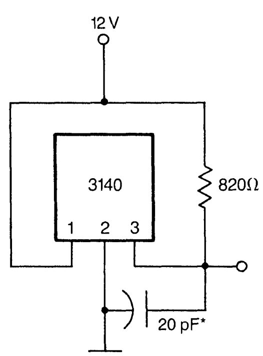
ELECTRICAL CHARACTERISTICS at T_A = +25°C, V_{CC} = 4.5 V to 24 V (unless otherwise noted)

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Supply Voltage	V_{CC}		4.5	—	24	V
Output Saturation Voltage	$V_{CE(sat)}$	$B \geq 200G$, $I_{SINK} = 20mA$	—	150	400	mV
Output Leakage Current	I_{OFF}	$B \leq 50G$, $V_{OUT} = 24V$	—	0.05	10	μA
Supply Current	I_{CC}	$B \leq 50G$, $V_{CC} = 4.5V$, Output Open	—	4.7	8.0	mA
Output Rise Time	t_r	$V_{CC} = 12V$, $R_L = 820\Omega$, $C_L = 20pF$	—	0.04	2.0	μs
Output Fall Time	t_f	$V_{CC} = 12V$, $R_L = 820\Omega$, $C_L = 20pF$	—	0.18	2.0	μs

MAGNETIC CHARACTERISTICS

		T_A = +25°C		T_A = −20°C to +85°C		T_A = −40°C to +125°C		
Characteristic	Symbol	Min.	Max.	Min.	Max.	Min.	Max.	Units
Operate Point	B_{OP}	70	200	45	260	45	270	G
Release Point	B_{RP}	50	180	25	240	25	250	G
Hysteresis	B_H	20	—	20	—	20	—	G

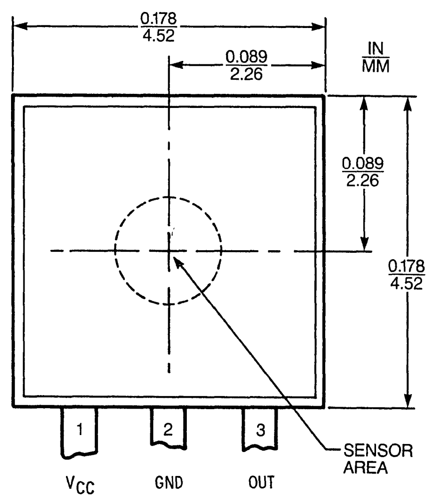
TEST CIRCUIT



Dwg. No. W-172

*Includes probe and test fixture capacitance.

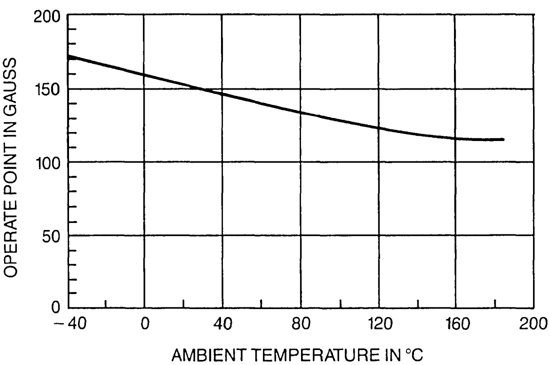
SENSOR LOCATION



Dwg. No. W-173A

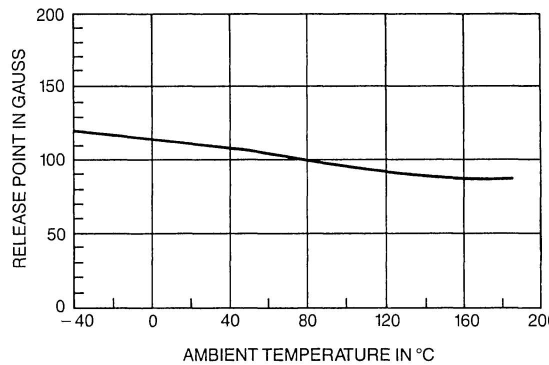
TYPICAL CHARACTERISTICS AS FUNCTIONS OF TEMPERATURE

OPERATE POINT



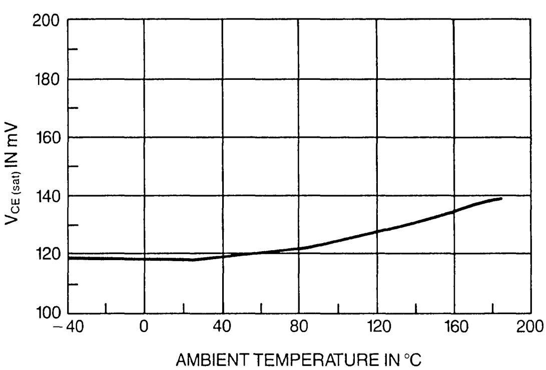
Dwg. No. W-174

RELEASE POINT



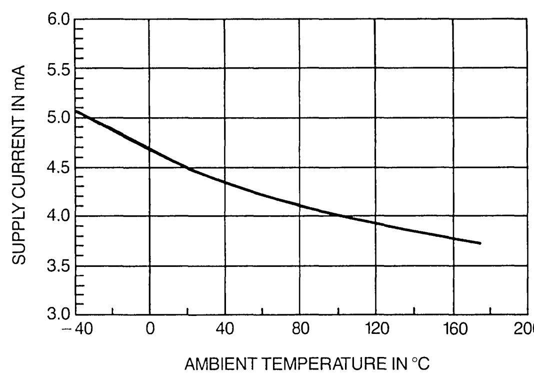
Dwg. No. W-175

OUTPUT SATURATION VOLTAGE



Dwg. No. W-176

SUPPLY CURRENT

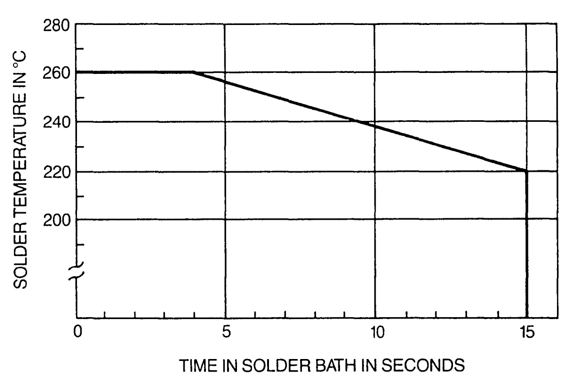


Dwg. No. A W-167

GUIDE TO INSTALLATION

1. All Hall Effect integrated circuits are susceptible to mechanical stress effects. Caution should be exercised to minimize the application of stress to the leads or the epoxy package. Use of epoxy glue is recommended. Other types may deform the epoxy package.

2. To prevent permanent damage to the Hall cell, heat-sink the leads during hand-soldering. Recommended maximum conditions for wave soldering are shown in the graph at right.



Dwg. No. A-12,062

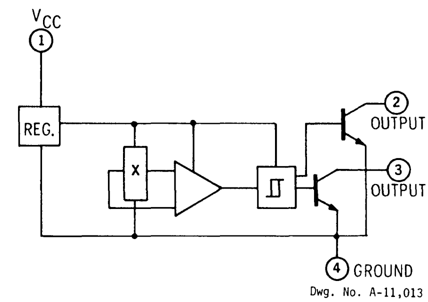
UGN-3201K
DUAL OUTPUT HALL EFFECT DIGITAL SWITCH

FEATURES

- Operate with a Small Permanent Magnet
- High Reliability—No Contact Wear or Bounce
- Small Size—4-Pins SIP
- Constant Amplitude Output
- Dual Open-Collector Outputs

Intended for use in position sensing and contactless switching applications, the UGN-3201K switch utilizes the Hall Effect for detecting a magnetic field.

It is supplied in a four-pin single in-line plastic package. The switch was originally introduced as ULN-3006.



FUNCTIONAL BLOCK DIAGRAM

ABSOLUTE MAXIMUM RATINGS

Power Supply, V_{CC} .... 20 V
Magnetic Flux Density, B .... Unlimited
Output OFF Voltage, $V_{OUT(OFF)}$ .... 20 V
Output ON Current, I_{SINK} .... 25 mA
Operating Temperature Range, T_A .... −20°C to +85°C
Storage Temperature Range, T_S .... −65°C to +150°C

ELECTRICAL CHARACTERISTICS at T_A = +25°C, V_{CC} = 4.5 V to 16 V

Characteristic	Symbol	Test Conditions	Limits Min.	Typ.	Max.	Units
Operate Point	B_{OP}		—	450	750	G
Release Point	B_{RP}		100	300	—	G
Hysteresis	B_H		—	150	—	G
Output Saturation Voltage	$V_{CE(SAT)}$	B ≥ 450 G, I_{SINK} = 20 mA	—	—	400	mV
Output Leakage Current	I_{OFF}	B ≤ 100 G	—	—	10	μA
Supply Current	$I_{CC(1)}$	B ≤ 100 G, Outputs Open	—	20	25	mA
	$I_{CC(2)}$	B ≥ 450 G, Outputs Open	—	20	25	mA
Supply Voltage	V_{CC}		4.5	—	16	V

OPERATION

The output transistors are normally OFF when the magnetic field perpendicular to the surface of the chip is below the threshold or operate point. As magnetic flux density passes the operate point, the output transistors switch ON and will each sink 20 mA.

The output transistors switch OFF as magnetic flux density falls below the release point, which is less than the operate point. This is illustrated graphically in the transfer characteristic curves. The hysteresis characteristic provides for unambiguous and non-oscillatory switching, regardless of the rate of change of the magnetic field.

The simplest form of magnet that will operate the Hall Effect digital sensor is a bar magnet as shown. Other methods are possible. In the illustration, the magnet's axis is on the center line of the packaged device and the magnet is moved toward and away from the device. Also note the orientation of the magnet's south pole in relation to the face of the package.

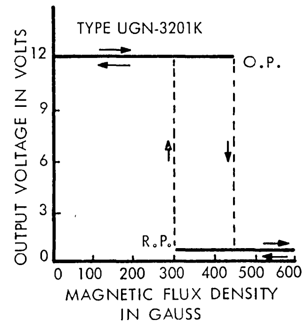
The magnetic flux density is indicated for the most sensitive area of the device. This area is centrally located and 0.016″ ±0.002″ (0.4 mm ±0.05 mm) below the top surface of the package.

For reference purposes, both an Alnico VIII magnet, 0.212″ (5.38 mm) in diameter and 0.187″ (4.75 mm) long and a samarium cobalt magnet, 0.100″ (2.54 mm) square and 0.040″ (1.02 mm) thick, are approximately 1200 gauss at their surfaces. The flux density decays at a high rate as the distance from a pole increases.

As an example, using the Alnico VIII magnet in good alignment and with the pole surface in contact with the branded surface of the package, the flux density at the active Hall sensing area of the device would be approximately 1150 gauss (0.016″ below the package surface).

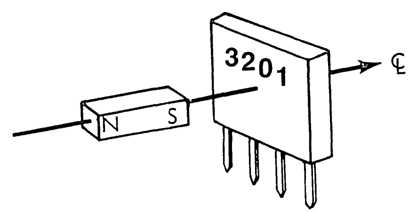
The flux density would drop to approximately 1000 gauss with an air-gap between the package and the magnet of 0.031″ (0.79 mm).

TYPICAL TRANSFER CHARACTERISTICS



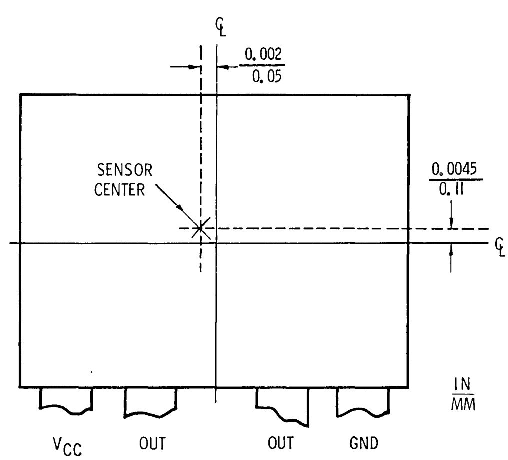
Dwg No. A-10,307A

BASIC HEAD-ON MODE OF OPERATION



Dwg No. A-11,008A

LOCATION OF SENSOR CENTER



Dwg. No. A-11,009B

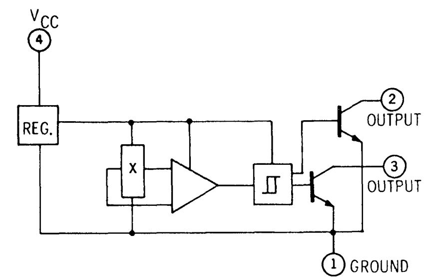
UGN-3220K
LOW-COST DUAL OUTPUT HALL EFFECT SWITCH

FEATURES

- Operable with a Small Permanent Magnet
- High Reliability—Eliminates Contact Wear, Contact Bounce
- No Moving Parts
- Small Size
- Outputs Compatible with All Logic Families
- Operation to 100 kHz.
- Dual Output Transistors Can Drive Independent Loads

UGN-3220K integrated circuits are low-cost magnetically activated electronic switches that utilize the Hall Effect for sensing a magnetic field. Each circuit consists of a voltage regulator, Hall sensor, signal amplifier, Schmitt trigger, and current-sinking output stage, integrated onto a single monolithic silicon chip.

FUNCTIONAL BLOCK DIAGRAM



Dwg No A-11.007

This device is supplied in a 4-pin single in-line molded package.

ABSOLUTE MAXIMUM RATINGS

Power Supply, V_{CC} . . . . . 17 V
Magnetic Flux Density, B . . . . . Unlimited
Output OFF Voltage, $V_{OUT(OFF)}$ . . . . . 17 V
Output ON Current, I_{SINK} . . . . . 30 mA
Operating Temperature Range, T_A . . . . . $-20°C$ to $+85°C$
Storage Temperature Range, T_S . . . . . $-65°C$ to $+125°C$

ELECTRICAL CHARACTERISTICS at $T_A = +25°C$, $V_{CC} = 4.5$ V to 16 V (unless otherwise noted)

Characteristic	Symbol	Test Conditions	Limits Min.	Limits Typ.	Limits Max.	Units
Operate Point	B_{OP}		—	220	350	Gauss
Release Point	B_{RP}		50	160	—	Gauss
Hysteresis	B_H		20	60	—	Gauss
Output Saturation Voltage	$V_{CE(SAT)}$	$B \geq 350$ Gauss, $I_{SINK} = 15$ mA	—	110	400	mV
Output Leakage Current	I_{OFF}	$B \leq 50$ Gauss, $V_{CC} = 16$ V	—	0.1	20	μA
Supply Current	I_{CC}	$B \leq 50$ Gauss, $V_{CC} = 5$ V	—	3.5	9.0	mA
Operating Voltage Range	V_{CC}		4.5	—	16	V

OPERATION

The output transistors are normally OFF when the magnetic field perpendicular to the surface of the chip is below the threshold or operate point. As magnetic flux density surpasses the operate point, the output transistors switch ON and are each capable of sinking 15 mA of current. Selections with 30 mA constant current ratings are available.

The output transistors switch OFF as the magnetic flux density falls below the release point (which is less than the operate point). This is illustrated graphically in the transfer characteristic curve. The hysteresis characteristic provides for unambiguous and non-oscillatory switching.

The simplest form of magnet that will operate the Hall Effect digital switch is a bar magnet as shown. Other methods are possible. In the illustration, the magnet's axis is on the center line of the packaged device and the magnet is moved toward and away from the device. Also note the orientation of the magnet's south pole in relation to the branded surface of the package.

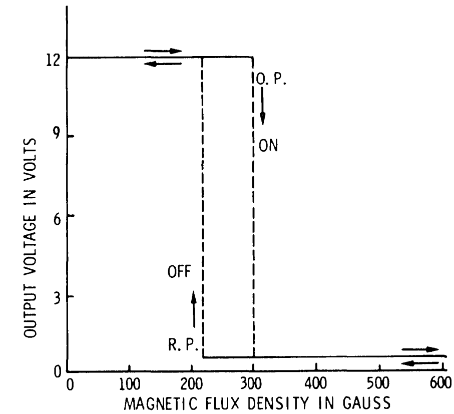
The magnetic flux density is indicated for the most sensitive area of the device. This area is centrally located and 0.016″ ±0.002″ (0.4 mm ±0.05 mm) below the branded surface of the package.

For reference purposes, both an Alnico VIII magnet, 0.212″ (5.38 mm) in diameter and 0.187″ (4.75 mm) long, and a samarium cobalt magnet, 0.100″ (2.54 mm) square and 0.040″ (1.02 mm) thick, are approximately 1200 gauss at their surfaces. The flux density decays at a high rate as the distance from a pole increases.

As an example, using the Alnico VIII magnet in good alignment and with the pole surface in contact with the branded surface of the package, the flux density at the active Hall sensing area of the device would be approximately 1150 gauss (0.016″ below the package surface).

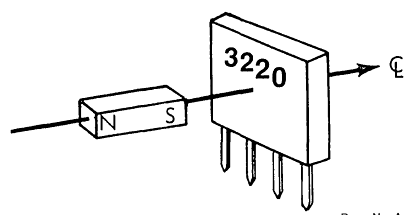
The flux density would drop to approximately 1000 gauss with an air-gap between the package and the magnet of 0.031″ (0.79 mm).

TRANSFER CHARACTERISTICS



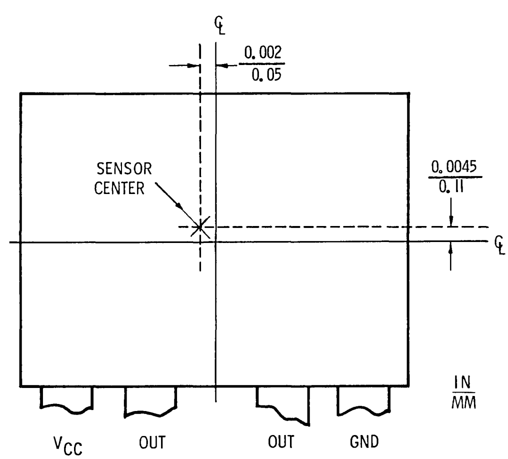
Dwg. No A-11,006 A

BASIC HEAD-ON MODE OF OPERATION



Dwg No A-14,471

LOCATION OF SENSOR CENTER



Dwg. No. A-11,009B

SECTION 3—HALL EFFECT LATCHES

SINGLE AND DUAL OUTPUT BIPOLAR LATCHES

The Sensor Division of Sprague Electric Company manufactures a unique family of Hall Effect sensors—magnetically activated latches. These devices have open-collector outputs that turn ON when the Hall cell is exposed to a south magnetic pole perpendicular to the face of the package. The output remains ON when the magnetic south pole is removed and doesn't release (turn OFF) until a north magnetic pole is presented to the face of the sensor.

Both single and dual output devices are available. Sensors with dual complementary outputs have electrical and magnetic characteristics almost identical to those of single output types. One of two output transistors saturates (turns ON) when the Hall cell is exposed to a south magnetic pole. The other half of the pair is OFF under these conditions. The pair remains ON/OFF until the sensor is presented with a north magnetic pole: The complementary pair then switches to an OFF/ON configuration.

In addition to Hall Effect latches shown in this section, Sprague designs and fabricates customer-specified sensors with this operating format. For more information, contact our Customer Service Center in Concord, New Hampshire.

SELECTION GUIDE

(In Order of Operate Threshold)

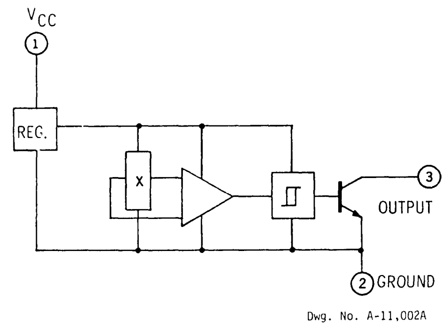
Max. Operate	Min. Release	Min. Hysteresis	Output	Max. I_{OUT}	Device Type	Page
50G	−50G	20G	Open-Collector	25 mA	UGN-3035U	3-3
150G	−150G	100G	Open-Collector	50 mA	UGN/S-3077T/U	3-13
150G	−150G	100G	Dual Open-Collector	50 mA	UGN/S-3277T/U	3-16
250G	−250G	100G	Open-Collector	50 mA	UGN/S-3075T/U	3-7
250G	−250G	100G	Dual Open-Collector	50 mA	UGN/S-3275T/U	3-16
350G	−350G	100G	Open-Collector	50 mA	UGN/S-3076T/U	3-10
350G	−350G	100G	Dual Open-Collector	50 mA	UGN/S-3276T/U	3-16

NOTE: Magnetic characteristics are guaranteed minimum/maximum values at +25°C.
Output current ratings are absolute maximum values.

UGN-3035U HALL EFFECT ASSEMBLY —Magnetically Biased Bipolar Digital Latch

FEATURES

- Extreme Sensitivity
- For Use with Multipole Ring Magnets
- High Reliability—No Moving Parts
- Small Size
- Output Compatible with All Digital Logic Families
- Symmetrical Output



FUNCTIONAL BLOCK DIAGRAM

DEVELOPED for use with multipole ring magnets in applications requiring extreme sensitivity to magnetic field reversal, the Type UGN-3035U Hall Effect latch assembly provides rugged, reliable interface between electromechanical equipment and bipolar or MOS logic circuits at switching frequencies of up to 100 kHz.

The bipolar output of the magnetically biased device saturates when the Hall cell is exposed to a magnetic flux density greater than the ON threshold (25 G typical, 50 G maximum). The output transistor remains in the ON state until magnetic field reversal exposes the Hall cell to a magnetic flux density below the OFF threshold (−25 G typical, −50 G minimum). Because the operating state switches only with magnetic field reversal, and not merely with a change in its strength, the integrated circuit qualifies as a true Hall Effect latch.

Each circuit consists of a voltage regulator, Hall voltage generator, signal amplifier, Schmitt trigger circuit, and an open-collector output driver on a single silicon chip. The on-board regulator permits operation over a wide range of supply voltages. The components of the monolithic circuit are carefully matched to provide accurate operation with wide variations in temperature.

The Type UGN-3035U assembly is a single-output Hall Effect digital latch in a three-pin plastic "U" package with a bias magnet (0.065" or 1.65 mm long) epoxy-glued to its rear surface.

Note that the operational symmetry of this sensitive device will be lost if the latch is exposed to magnetic flux density greater than 500 Gauss. Symmetry can also be affected by ferrous materials near the assembly.

ABSOLUTE MAXIMUM RATINGS

Power Supply, V_{CC}	25 V
Magnetic Flux Density, B	500 G
Output OFF Voltage	25 V
Output ON Current, I_{SINK}	25 mA
Operating Temperature Range, T_A	−20°C to +85°C
Storage Temperature Range, T_S	−65°C to +150°C

*Selected devices are available with a maximum T_A rating of +150°C.

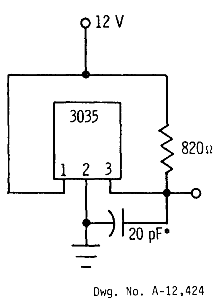
3

ELECTRICAL CHARACTERISTICS at T_A = +25°C, V_{CC} = 4.5 V to 24 V (unless otherwise noted)

Characteristic	Symbol	Test Conditions	Limits Min.	Limits Typ.	Limits Max.	Units
Operate Point*	B_{OP}		—	+25	+50	Gauss
Release Point*	B_{RP}		−50	−25	—	Gauss
Hysteresis*	B_H		20	50	—	Gauss
Output Saturation Voltage	V_{SAT}	$B \geq +50$ Gauss, $I_{SINK} = 15$ mA	—	85	400	mV
Output Leakage Current	I_{OFF}	$B \leq -50$ Gauss, $V_{OUT} = 24$ V	—	0.05	10	μA
Supply Current	I_{CC}	$B \leq 50$ Gauss, $V_{CC} = 4.5$ V, Output open	—	2.3	5.0	mA
		$B \leq 50$ Gauss, $V_{CC} = 24$ V, Output open	—	3.0	5.0	mA
Output Rise Time	t_r	$V_{CC} = 12$ V, $R_L = 820\Omega$, $C_L = 20$ pF	—	150	—	ns
Output Fall Time	t_f	$V_{CC} = 12$ V, $R_L = 820\Omega$, $C_L = 20$ pF	—	400	—	ns

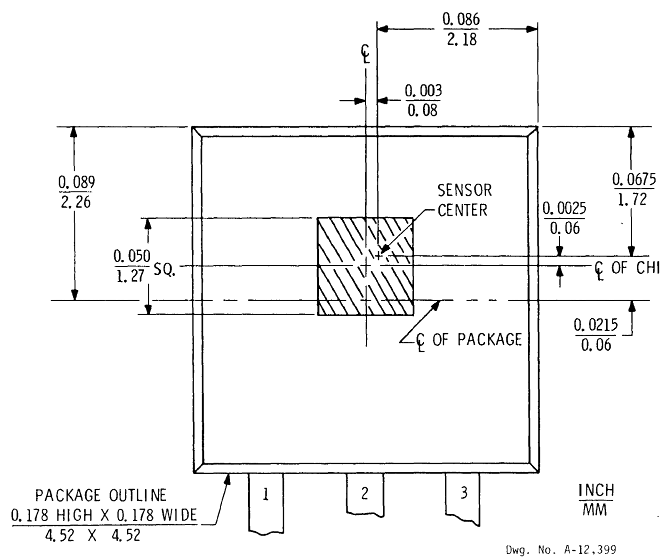
*Magnetic flux density is measured at most sensitive area of device located 0.016" ±0.002" (0.41 mm ±0.05 mm) below the branded face of the package.

TEST CIRCUIT



*Includes probe and test fixture capacitance.

SENSOR-CENTER LOCATION



OPERATION

Under power-up conditions, and in the absence of an externally applied magnetic field, the output transistor of most UGN-3035U assemblies is ON and capable of sinking 25 mA of current. This is, however, a formally ambiguous state and should be treated as such.

In normal operation, the output transistor turns ON as the strength of the magnetic field perpendicular to the surface of the chip reaches the Operate Point. The output transistor switches OFF as magnetic field reversal takes magnetic flux density to the Release Point.

Note that the device latches: That is, a south pole of sufficient strength, presented to the branded face of the assembly, turns the device ON. Removal of the south pole leaves the device ON. The presence of a north magnetic pole of sufficient strength is required to turn the switch OFF.

The UGN-3035U digital latch is primarily intended for operation with a multipole ring magnet, as shown in Figure 1. Other methods of operation are possible.

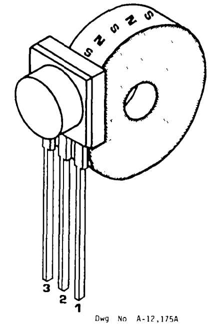
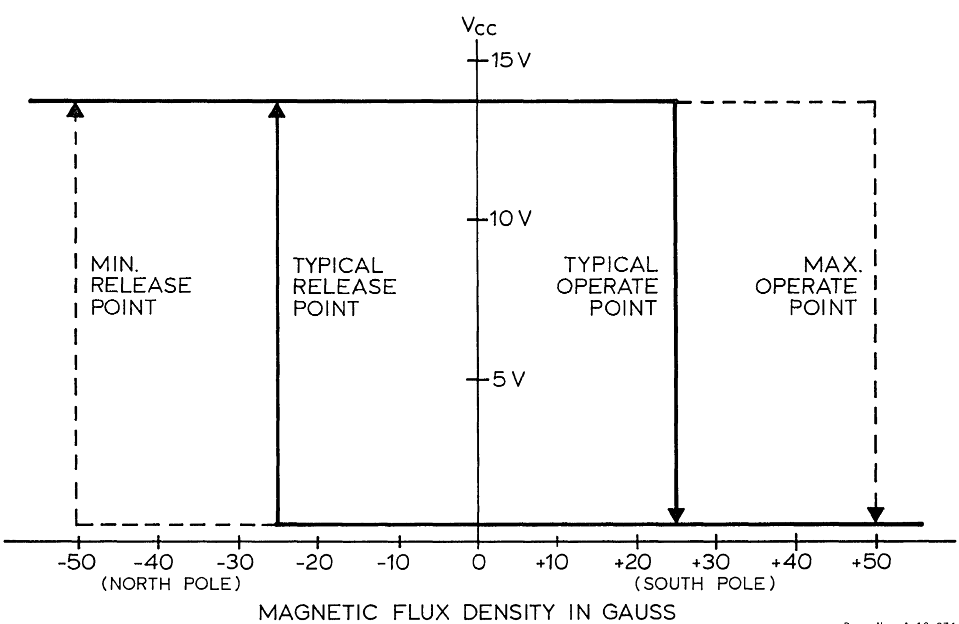


Figure 1

With the branded surface of the assembly facing you, and with pins pointing down, "U" package pinouts are: 1—V_{CC}, 2—Ground, 3—V_{OUT}.

The magnetic flux densities indicated in the operating-points graph below are measured at the active area of the device, which is 0.016 in. (0.41 mm) below the branded surface of the "U" package.

TYPICAL TRANSFER CHARACTERISTICS AT T_A = +25°C

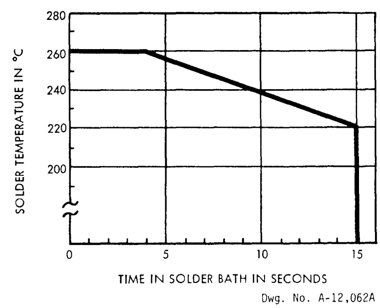


3

GUIDE TO INSTALLATION

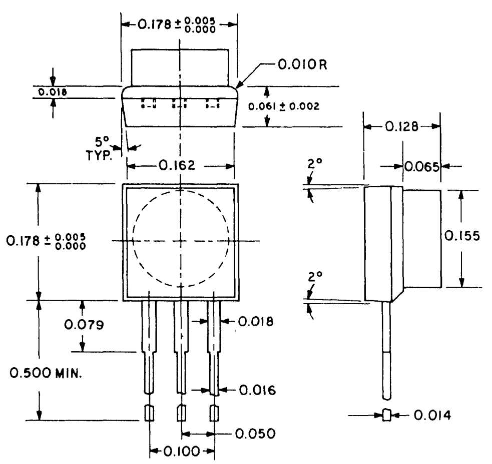
1. All Hall Effect integrated circuits are susceptible to mechanical stress effects. Caution should be exercised to minimize the application of stress to the leads or the epoxy package. Use of epoxy glue is recommended. Other types may deform the epoxy package.

2. To prevent permanent damage to the Hall cell, heat-sink the leads during hand-soldering. Recommended maximum conditions for wave soldering are shown in the graph at right. Solder flow should be no closer than 0.125" (3.18 mm) to the epoxy package.

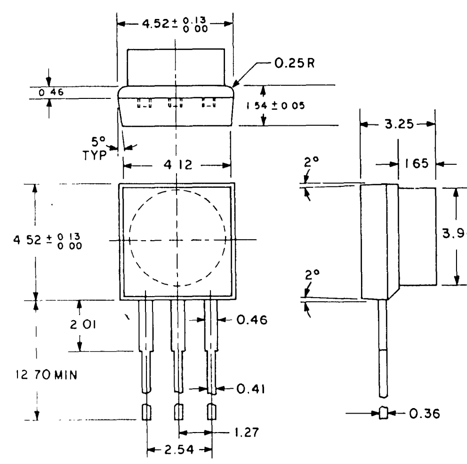


'U' PACKAGE/MAGNET ASSEMBLY

DIMENSIONS IN INCHES



DIMENSIONS IN MILLIMETRES
Based on 1" = 25.4 mm

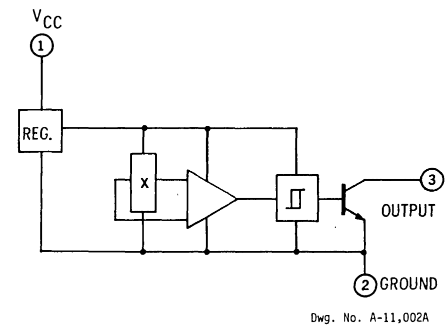


NOTES:
1. Tolerances on package height and width represent allowable mold offsets. Dimensions given are measured at the widest point (parting line).
2. Tolerances, unless otherwise specified, are ±0.005" (0.13 mm) and ±½°.

UGN-3075T/U AND UGS-3075T/U BIPOLAR HALL EFFECT DIGITAL LATCHES

FEATURES

- Operable with Inexpensive Multipole Ring Magnets
- High Reliability — No Moving Parts
- Small Size
- Output Compatible with All Digital Logic Families
- Symmetrical Output
- High Hysteresis Level Minimizes Stray-Field Problems



FUNCTIONAL BLOCK DIAGRAM

THESE MAGNETICALLY-ACTIVATED, solid-state latches are designed for use with inexpensive multipole ring magnets and brushless d-c motors. They provide effective, reliable interface between electromechanical equipment and bipolar or MOS logic circuits at switching frequencies of up to 100 kHz.

The bipolar output of these devices saturates when the Hall cell is exposed to a magnetic flux density greater than the ON threshold (100 G typical, 250 G maximum). The output transistor remains in the ON state until magnetic field reversal exposes the Hall cell to a magnetic flux density below the OFF threshold (−100 G typical, −250 G minimum). Because the operating state switches only with magnetic field reversal, and not merely with a change in its strength, these integrated circuits qualify as true Hall Effect latches.

Type UGN-3075T/U is rated for operation over the temperature range of −20°C to +85°C. For applications in more severe environments, Type UGS-3075T/U has an operating temperature range of −55°C to +125°C. Both types work with supply voltages of 4.5 to 24 V.

Both Hall Effect latches are supplied in either the 80-mil (2.03 mm) three-pin plastic "T" package or the magnetically optimized 60.5-mil (1.54 mm) three-pin plastic "U" package.

ABSOLUTE MAXIMUM RATINGS

Power Supply, V_{CC}	25 V
Magnetic Flux Density, B	Unlimited
Output OFF Voltage	25 V
Output ON Current, I_{SINK}	50 mA
Operating Temperature Range, T_A	
UGS-3075T/U*	−55°C to +125°C
UGN-3075T/U	−20°C to +85°C
Storage Temperature Range, T_S	−65°C to +150°C

*Selected devices are available with a maximum T_A rating of +150°C.

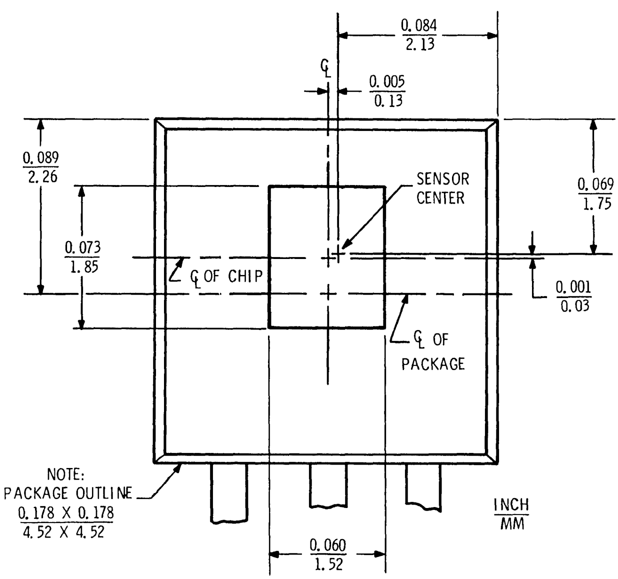
These Hall Effect sensors are also supplied in SOT 89 (TO-243AA) packages for surface-mount applications. The regular SOT-89 package is specified by substituting an "LT" for the last character of the part number. The long leaded SOT 89 package is specified by substituting an "LL" for the last character of the part number and the Low profile "U" package is available by substituting "UA" for the last character of the part number (E.G., UGN3XXXLT, UGN3XXXLL, UGN3XXXUA).

ELECTRICAL CHARACTERISTICS at $T_A = +25°C$, $V_{CC} = 4.5$ V to 24 V (unless otherwise noted)

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Operate Point*	B_{OP}		50	100	250	Gauss
Release Point*	B_{RP}		−250	−100	−50	Gauss
Hysteresis*	B_H		100	200	—	Gauss
Output Saturation Voltage	V_{SAT}	$B \geq 250$ Gauss, $I_{SINK} = 20$ mA	—	85	400	mV
Output Leakage Current	I_{OFF}	$B \leq -250$ Gauss, $V_{OUT} = 24$ V	—	0.2	1.0	μA
Supply Current	I_{CC}	$B \leq -250$ Gauss, $V_{CC} = 24$ V, Output Open	—	3.0	7.0	mA
Output Rise Time	t_r	$V_{CC} = 12$ V, $R_L = 820\Omega$, $C_L = 20$ pF	—	100	—	ns
Output Fall Time	t_f	$V_{CC} = 12$ V, $R_L = 820\Omega$, $C_L = 20$ pF	—	200	—	ns

*Magnetic flux density is measured at most sensitive area of device located 0.032″ ±0.002″ (0.81 mm ±0.05 mm) below the branded face of the 'T' package and 0.012″ ±0.002″ (0.31 mm ±0.05 mm) below the branded face of the 'U' package.

SENSOR-CENTER LOCATION



Dwg.No. A-11,896A

GUIDE TO INSTALLATION

1. All Hall Effect integrated circuits are susceptible to mechanical stress effects. Caution should be exercised to minimize the application of stress to the leads or the epoxy package.

2. To prevent permanent damage to the Hall cell, heat sink the leads during hand soldering. For wave soldering, the part should not experience more than 260°C for more than five seconds. Solder flow should be no closer than 0.125″ (3.18 mm) to the epoxy package.

OPERATION

The output transistor is normally OFF when the strength of the magnetic field perpendicular to the surface of the chip is below threshold or the Operate Point. When the field strength exceeds the Operate Point, the output transistor switches ON and is capable of current sinking 50 mA of current.

The output transistor switches OFF when magnetic field reversal results in a magnetic flux density below the OFF threshold. This is illustrated in the transfer characteristics graph.

The simplest form of magnet that will operate Types UGN-3075T/U and UGS-3075T/U is a ring magnet, as shown in Figure 1. Other methods of operation are possible.

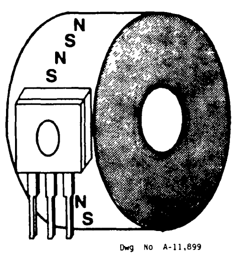


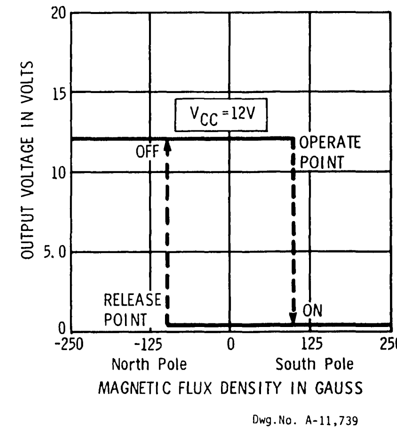
Figure 1

Note that the device latches; that is, a south pole of sufficient strength will turn the device ON. Removal of the south pole will leave the device ON. The presence of a north pole of sufficient strength is required to turn the device OFF.

ACTIVE AREA DEPTH (AAD)

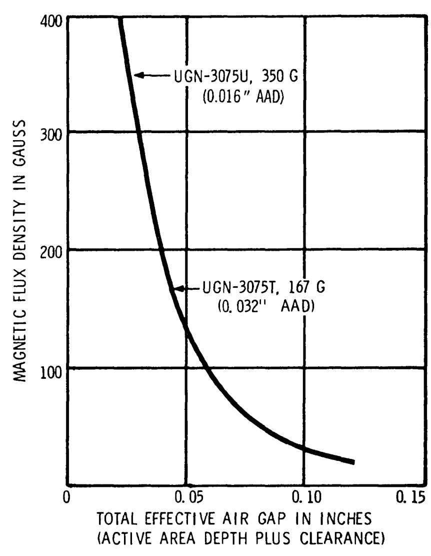
The magnetic flux density is indicated in the operating-points graph for the active area of the device, which is located 0.032" (0.81 mm) below the branded surface of the "T" package and 0.016" (0.4 mm) below the branded surface of the "U" package. Note that, as shown in the plot of magnetic flux density as a function of total effective air gap, the "U" package offers a significant advantage in marginal flux density conditions for certain magnetic configurations.

TYPICAL TRANSFER CHARACTERISTICS



PEAK FLUX DENSITY AS A FUNCTION OF TOTAL EFFECTIVE AIR GAP

Plastic 20-Pole Pair Ring (Radial Poles)
1" (25.4 mm) in diameter
and 0.2" (5.1 mm) long
with 0.01" (0.25 mm) clearance



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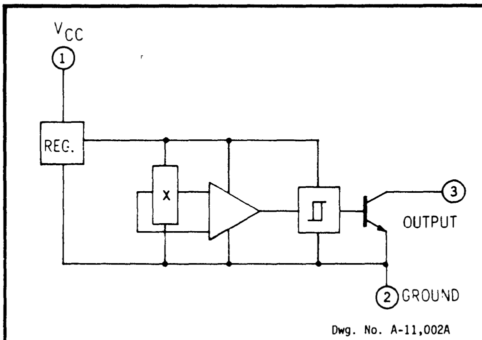
UGN-3076T/U AND UGS-3076T/U BIPOLAR HALL EFFECT DIGITAL LATCHES

FEATURES

- Operable with Inexpensive Multipole Ring Magnets
- High Reliability — No Moving Parts
- Small Size
- Output Compatible with All Digital Logic Families
- Symmetrical Output
- High Hysteresis Level Minimizes Stray-Field Problems



FUNCTIONAL BLOCK DIAGRAM

THESE SOLID-STATE, magnetically-activated latches, designed for use with brushless d-c motors and inexpensive multipole ring magnets, operate as effective, reliable interface between electromechanical equipment and bipolar or MOS logic circuits at switching frequencies of up to 100 kHz.

The bipolar output of these devices saturates when the Hall cell is exposed to a magnetic flux density greater than the ON threshold (100 G typical, 350 G maximum). The output transistor remains in the ON state until magnetic field reversal exposes the Hall cell to a magnetic flux density below the OFF threshold (−100 G typical, −350 G minimum). Because the operating state switches only with magnetic field reversal, and not merely with a change in its strength, these integrated circuits qualify as true Hall Effect latches.

Type UGN-3076T/U is rated for operation over the temperature range of −20°C to +85°C. For applications in more severe environments, Type UGS-3076T/U has an operating temperature range of −55°C to +125°C. Both types work with supply voltages of 4.5 to 24 V.

Both Hall Effect latches are supplied in either the 80-mil (2.03 mm) three-pin plastic "T" package or the magnetically optimized 60.5-mil (1.54 mm) three-pin plastic "U" package.

ABSOLUTE MAXIMUM RATINGS

Power Supply, V_{CC}	25 V
Magnetic Flux Density, B	Unlimited
Output OFF Voltage	25 V
Output ON Current, I_{SINK}	50 mA
Operating Temperature Range, T_A	
UGS-3076T/U*	−55°C to +125°C
UGN-3076T/U	−20°C to +85°C
Storage Temperature Range, T_S	−65°C to +150°C

*Selected devices are available with a maximum T_A rating of +150°C.

These Hall Effect sensors are also supplied in SOT 89 (TO-243AA) packages for surface-mount applications. The regular SOT-89 package is specified by substituting an "LT" for the last character of the part number. The long leaded SOT 89 package is specified by substituting an "LL" for the last character of the part number and the Low profile "U" package is available by substituting "UA" for the last character of the part number (E.G., UGN3XXXLT, UGN3XXXLL, UGN3XXXUA).

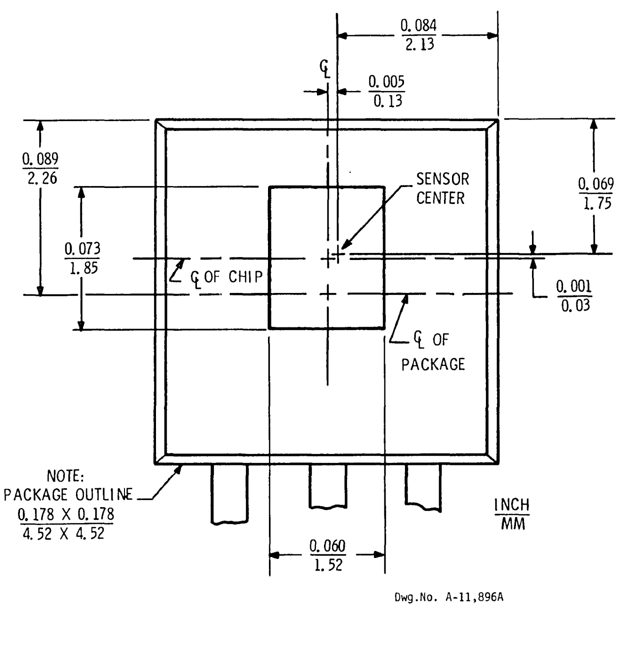
ELECTRICAL CHARACTERISTICS at T_A = +25°C, V_{CC} = 4.5 V to 24 V (unless otherwise noted)

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Operate Point*	B_{OP}		50	100	350	Gauss
Release Point*	B_{RP}		−350	−100	−50	Gauss
Hysteresis*	B_H		100	200	—	Gauss
Output Saturation Voltage	V_{SAT}	$B \geq 350$ Gauss, $I_{SINK} = 20$ mA	—	85	400	mV
Output Leakage Current	I_{OFF}	$B \leq -350$ Gauss, $V_{OUT} = 24$ V	—	0.2	1.0	μA
Supply Current	I_{CC}	$V_{CC} = 24$ V, Output Open, $B \leq -350$ Gauss	—	3.0	7.0	mA
Output Rise Time	t_r	$V_{CC} = 12$ V, $R_L = 820\Omega$, $C_L = 20$ pF	—	100	—	ns
Output Fall Time	t_f	$V_{CC} = 12$ V, $R_L = 820\Omega$, $C_L = 20$ pF	—	200	—	ns

*Magnetic flux density is measured at most sensitive area of device located 0.032″ ±0.002″ (0.81 mm ±0.05 mm) below the branded face of the 'T' package and 0.012″ ±0.002″ (0.31 mm ±0.05 mm) below the branded face of the 'U' package.

3

SENSOR-CENTER LOCATION



Dwg.No. A-11,896A

GUIDE TO INSTALLATION

1. All Hall Effect integrated circuits are susceptible to mechanical stress effects. Caution should be exercised to minimize the application of stress to the leads or the epoxy package.

2. To prevent permanent damage to the Hall cell, heat sink the leads during hand soldering. For wave soldering, the part should not experience more than 260°C for more than five seconds. Solder flow should be no closer than 0.125″ (3.18 mm) to the epoxy package.

OPERATION

The output transistor is normally OFF when the strength of the magnetic field perpendicular to the surface of the chip is below threshold or the Operate Point. When the field strength exceeds the Operate Point, the output transistor switches ON and is capable of sinking 50 mA of current.

The output transistor switches OFF when magnetic field reversal results in a magnetic flux density below the OFF Threshold. This is illustrated in the transfer characteristics graph.

The simplest form of magnet that will operate Types UGN-3076T/U and UGS-3076T/U is a ring magnet, as shown in Figure 1. Other methods of operation are possible.

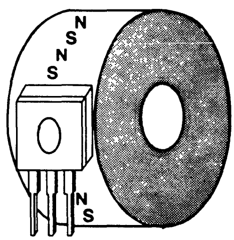


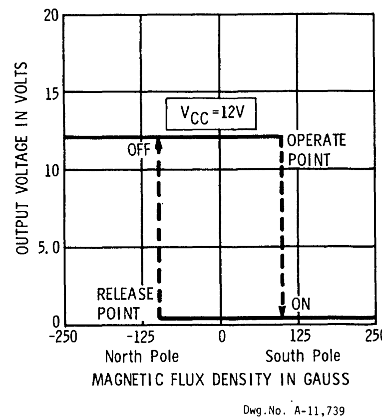
Figure 1

Note that the device latches; that is, a south pole of sufficient strength will turn the device ON. Removal of the south pole will leave the device ON. The presence of a north pole of sufficient strength is required to turn the device OFF.

ACTIVE AREA DEPTH (AAD)

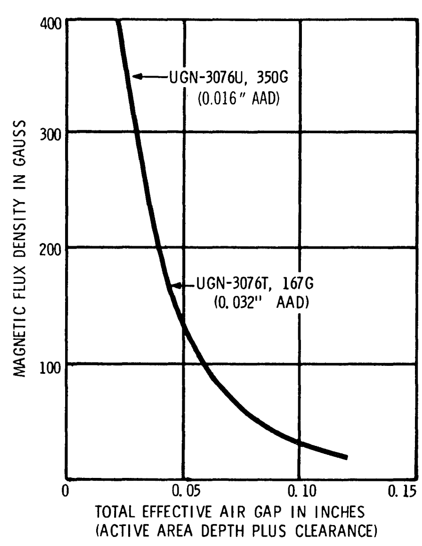
The magnetic flux density is indicated in the operating-points graph for the active area of the device, which is located 0.032″ (0.81 mm) below the branded surface of the "T" package and 0.016″ (0.4 mm) below the branded surface of the "U" package. Note that, as shown in the plot of magnetic flux density as a function of total effective air gap, the "U" package offers a significant advantage in marginal flux density conditions for certain magnetic configurations.

TYPICAL TRANSFER CHARACTERISTICS



PEAK FLUX DENSITY AS A FUNCTION OF TOTAL EFFECTIVE AIR GAP

Plastic 20-Pole Pair Ring (Radial Poles)
1″ (25.4 mm) in diameter
and 0.2″ (5.1 mm) long
with 0.01″ (0.25 mm) clearance

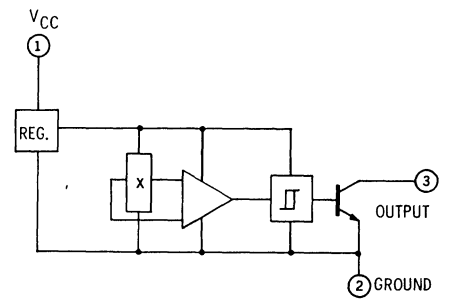


UGN-3077T/U AND UGS-3077T/U
HALL EFFECT LATCHES FOR BRUSHLESS DC MOTOR CONTROL
—Symmetrical Duty Cycle

FEATURES

- Symmetrical Output
- For Use with Multipole Ring Magnets
- High Reliability—No moving Parts
- Small Size
- Output Compatible with All Digital Logic Families
- 4.5 V to 24 V Operation
- High Hysteresis Level Minimizes Stray-Field Problems

FUNCTIONAL BLOCK DIAGRAM



Dwg. No. A-11,002A

The Sprague Type 3077 latching Hall Effect sensor is a bipolar integrated circuit designed for applications requiring a symmetrical duty cycle, such as control of high-efficiency brushless dc motors. Typically, the latch is used to sense the matched flux densities of alternating polarity created by small, inexpensive multipole ring magnets.

The integrated circuit includes a Hall voltage generator, operational amplifier, Schmitt trigger, bipolar output transistor, and voltage regulator. The regulator allows use of the IC with supply voltages ranging from 4.5 V to 24 V.

The output transistor saturates when the Hall element is exposed to a magnetic flux density equal to or greater than its ON threshold. The NPN output remains ON until magnetic flux density of equal strength but opposite polarity crosses the sensor's OFF threshold.

Types UGN-3077T and UGN-3077U are rated for operation over the temperature range of −20°C to +85°C. Types UGS-3077T and UGS-3077U have an operating range of −40°C to +125°C.

The Hall Effect switches are offered in two three-pin plastic packages—a 60-mil (1.54 mm) magnetically-optimized "U" package, and one 80 mils (2.03 mm) thick specified by the suffix "T."

A high-temperature hermetic device supplied with Sprague HYREL® screening is available as UGS-3077HH. For more information on surface-mount and hermetic switches, contact the factory.

ABSOLUTE MAXIMUM RATINGS

Power Supply, V_{CC}	25 V
Magnetic Flux Density, B	Unlimited
Output OFF Voltage	25 V
Output ON Current, I_{SINK}	50 mA
Operating Temperature Range, T_A	
UGN-3077	−20°C to +85°C
UGS-3077*	−40°C to +125°C
Storage Temperature Range, T_S	−65°C to +150°C

*Selected devices are available with a maximum T_A rating of +150°C.

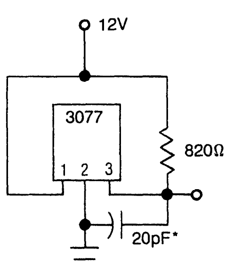
These Hall Effect sensors are also supplied in SOT 89 (TO-243AA) packages for surface-mount applications. The regular SOT-89 package is specified by substituting an "LT" for the last character of the part number. The long leaded SOT 89 package is specified by substituting an "LL" for the last character of the part number and the Low profile "U" package is available for substituting "UA" for the last character of the part number (e.g., UGN3XXXLT, UGN3XXXLL, UGN3XXXUA).

ELECTRICAL CHARACTERISTICS at $T_A = +25°C$, $V_{CC} = 4.5$ V to 24 V (unless otherwise noted)

Characteristic	Test Conditions	Limits Min.	Limits Typ.	Limits Max.	Units
Operate Point, B_{OP}*	$T_A = +25°C$	50	100	150	Gauss
	$-20°C < T_A < +85°C$	25	100	200	Gauss
	$-40°C < T_A < +125°C$	25	100	200	Gauss
Release Point, B_{RP}*	$T_A = +25°C$	−150	−100	−50	Gauss
	$-20°C < T_A < +85°C$	−200	−100	−25	Gauss
	$-40°C < T_A < +125°C$	−200	−100	−25	Gauss
Hysteresis, B_H*	$T_A = +25°C$	100	200	—	Gauss
	$-20°C < T_A < +85°C$	100	200	—	Gauss
	$-40°C < T_A < +125°C$	100	200	—	Gauss
Output Saturation Voltage, $V_{CE(sat)}$	$B > 200$ G, $I_{OUT} = 20$ mA, $-40°C < T_A < +125°C$	—	85	400	mV
Output Leakage Current, I_{OFF}	$B < -200$ G, $V_{OUT} = 24$ V, $-40°C < T_A < +125°C$	—	0.2	1.0	μA
Supply Current, I_{CC}	$B < -200$ G, $V_{CC} = 24$ V, Output Open, $-40°C < T_A < +125°C$	—	3.0	7.0	mA
Output Rise Time, t_r	$V_{CC} = 12$ V, $R_L = 820\Omega$, $C_L = 20$ pF, $-40°C < T_A < +125°C$	—	100	—	ns
Output Fall Time, t_f	$V_{CC} = 12$ V, $R_L = 820\Omega$, $C_L = 20$ pF, $-40°C < T_A < +125°C$	—	200	—	ns

*Magnetic flux density is measured at the most sensitive area of the device.

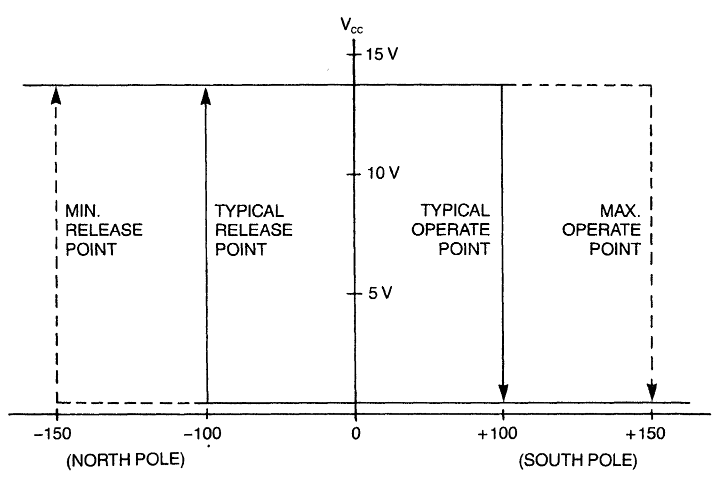
TEST CIRCUIT



Dwg. No. D-1011

*Includes probe and test fixture capacitance.

TRANSFER CHARACTERISTICS AT $T_A = +25°C$



Dwg. No. D-1012

OPERATION

Under power-up conditions, and in the absence of an externally applied magnetic field, the output transistor of most Type 3077 latches is ON and capable of sinking 25 mA of current. This is, however, a formally ambiguous state and should be treated as such.

In normal operation, the output transistor turns ON as the strength of the magnetic field perpendicular to the surface of the chip reaches the Operate Point. The output transistor switches OFF as magnetic field reversal takes magnetic flux density to the Release Point.

Note that the device latches: That is, a south pole of sufficient strength, presented to the branded face of the assembly, turns the device ON. Removal of the south pole leaves the device ON. The presence of a north magnetic pole of sufficient strength is required to turn the switch OFF.

The Type 3077 digital latch is primarily intended for operation with a multipole ring magnet, as shown in Figure 1. Other methods of operation are possible.

With the branded surface of the assembly facing you, and with pins pointing down, "T" and "U" package pinouts are: 1—V_{CC}, 2—Ground, 3—V_{OUT}.

3

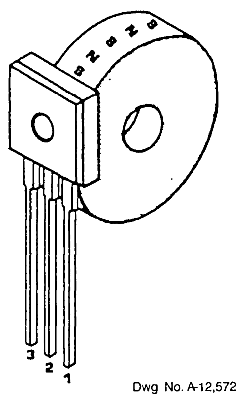
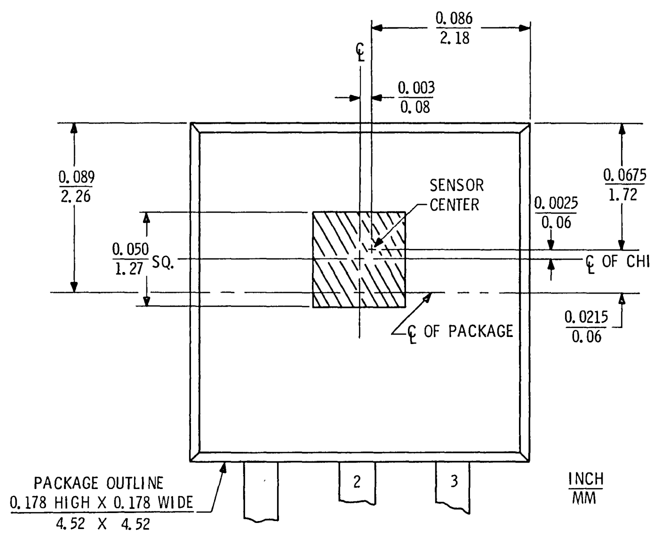


Figure 1

SENSOR-CENTER LOCATION



GUIDE TO INSTALLATION

1. All Hall Effect integrated circuits are susceptible to mechanical stress effects. Caution should be exercised to minimize the application of stress to the leads or the epoxy package. Use of epoxy glue is recommended. Other types may deform the epoxy package.

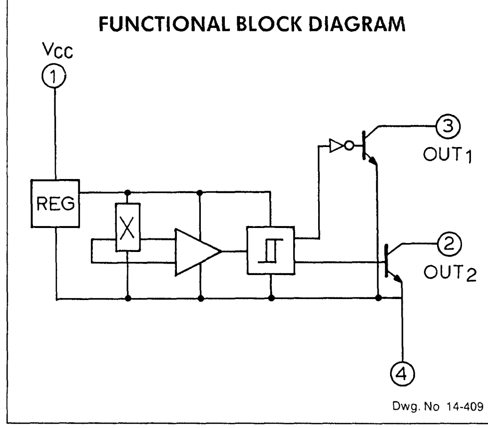
2. To prevent permanent damage to the Hall cell, heat-sink the leads during hand-soldering. Recommended maximum conditions for wave soldering are shown in the graph at right. Solder flow should be no closer than 0.125" (3.18 mm) to the epoxy package.

UGN-3275K THROUGH UGS-3277K HALL EFFECT LATCHES

With Dual Complementary Output

FEATURES

- Operable with Multipole Ring Magnets
- High Reliability
- Small Size
- Output Compatible with All Digital Logic Families
- 4.5 V to 24 V Operation
- High Hysteresis Level Minimizes Stray-Field Problems
- Dual Complementary Output



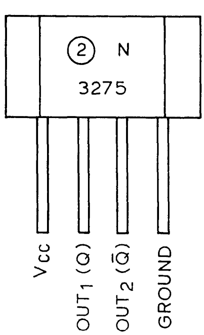
Sprague Type 3275, 3276 and 3277 latching Hall Effect sensors are bipolar integrated circuits designed for electronic commutation in brushless dc motors. All three types feature dual complementary output. The latches are typically used to sense matched magnetic flux densities of alternating polarity from multipole ring magnets.

Each sensor IC includes a Hall voltage generator, operational amplifier, Schmitt trigger, voltage regulator, and dual bipolar output transistors. The regulator allows use of the integrated circuit with supply voltages of 4.5 V to 24 V.

One of the pair of NPN open-collector output stages saturates when the Hall element is exposed to flux density equal to or greater than the operate threshold. The other output transistor is OFF. This ON/OFF operating mode continues until magnetic flux of equal density but opposite polarity crosses the sensor's release threshold. The output pair then switches to an OFF/ON configuration. This mode is also latched.

Types UGN-3275K, UGN-3276K and UGN-3277K are rated for operation over the temperature range of −20°C to +85°C. UGS-3275K, UGS-3276K and UGS-3277K have an operating range of −40°C to +125°C.

The dual output Hall Effect latches are supplied in a four-pin plastic SIP, 0.200″ (5.08 mm) wide, 0.130″ (3.3 mm) high, and 0.060″ (1.54 mm) thick.



Dwg No A-14,407

ABSOLUTE MAXIMUM RATINGS

Power Supply, V_{CC}	25 V
Magnetic Flux Density, B	Unlimited
Output OFF Voltage	25 V
Output ON Current, I_{SINK}	50 mA
Operating Temperature Range, T_A	
(UGN)	−20°C to +85°C
(UGS)*	−40°C to +125°C
Storage Temperature Range, T_S	−65°C to +150°C

*Selected devices are available with a maximum T_A rating of +150°C.

ELECTRICAL CHARACTERISTICS at $T_A = +25°C$, $V_{CC} = 4.5$ V to 24 V (unless otherwise noted)

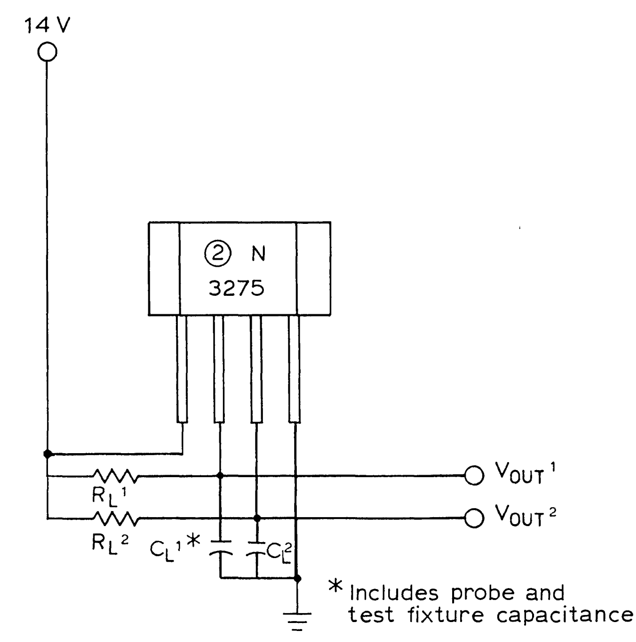
Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Supply Voltage	V_{CC}		4.5	—	24	V
Output Saturation Voltage	$V_{CE(sat)}$	$V_{CC} = 24$ V, $I_{SINK} = 20$ mA	—	—	400	mV
Output Leakage Current	I_{OFF}	$V_{OUT} = 24$ V, $V_{CC} = 24$ V	—	—	10	μA
Supply Current	I_{CC}	$V_{CC} = 24$ V, Output Open	—	—	7.0	mA
Output Rise Time	t_r	$V_{CC} = 14$ V, $R_L = 820\Omega$, $C_L = 20$ pF	—	0.04	0.4	μs
Output Fall Time	t_f	$V_{CC} = 14$ V, $R_L = 820\Omega$, $C_L = 20$ pF	—	0.18	0.4	μs
Switch Time Differential	Δt	$V_{CC} = 14$ V, $R_L = 820\Omega$, $C_L = 20$ pF	—	0.685	0.8	μs

MAGNETIC CHARACTERISTICS

Characteristic	Device Type*	$T_A = +25°C$		$T_A = -20°C$ to $+85°C$		$T_A = -40°C$ to $+125°C$		Units
		Min.	Max.	Min.	Max.	Min.	Max.	
Operate Point, B_{OP}	3275	50	250	50	250	50	250	G
	3276	50	350	50	350	50	350	G
	3277	50	150	50	175	50	200	G
Release Point, B_{RP}	3275	−250	−50	−250	−50	−250	−50	G
	3276	−350	−50	−350	−50	−350	−50	G
	3277	−150	−50	−175	−50	−200	−50	G
Hysteresis, B_H	All	100	—	100	—	100	—	G

*Complete part number includes a prefix denoting operating temperature range ("UGN-" or "UGS-") and a suffix ("K") denoting package type.

TEST CIRCUIT



3

NOTES

NOTES

NOTES

SECTION 4—HALL EFFECT LINEARS

4

LINEAR OUTPUT HALL EFFECT SENSORS

The output of all Hall Effect sensors described in this section is proportional to the applied magnetic field, i.e., linear. The devices fall into two broad categories—basic Hall elements and integrated circuits.

Basic Hall cells are silicon-based, no-frills, encapsulated devices with very small differential output signals that vary with supply current, applied magnetic field, and temperature. Their variability enables useful application in design, analysis and calibration of magnetic circuits. Under conditions of constant current and temperature, the sensors exhibit linear response to an extremely broad range of magnetic flux densities (to 4 kG).

Hall Effect ICs with linear output add operational circuitry such as a voltage regulator, linear amplifier, and NPN emitter-follower output to the basic Hall cell. Output signals are about 10 times larger than those of basic Hall cells. The integrated circuits, available with single or differential dual output stages, accurately track minute changes in magnetic flux densities of up to 1 kG over a wide range of operating conditions.

SELECTION GUIDE

(In Order of Device Sensitivity)

Sensitivity Min.	Sensitivity Typ.	Output	V_{CC} Limits	Device	Page
0.75 mV/G*	1.3 mV/G*	Emitter-Follower	4.5-6.0 V	UGN/S-3503U	4-9
0.7 mV/G	1.4 mV/G	Dual Differential	8.0-16 V	UGN-3501K/LI	4-3
0.35 mV/G	0.7 mV/G	Emitter-Follower	8.0-12 V	UGN-3501T/U	4-6
—	0.04 mV/G†	Dual Differential	3.0-7.0 V	UGN-3604K	4-12
—	0.06 mV/G‡	Dual Differential	3.0-7.0 V	UGN-3605K	4-12

* AT $V_{CC} = 5$ V. This device does not include a voltage regulator and exhibits ratiometric output.

† Function of supply voltage. With $V_{CC} = 5$ V, typical sensitivity is 0.04 mV/G.

‡ Function of control current. With constant current source of 3 mA, typical sensitivity is 0.06 mV/G. I_{CC} is limited to a value that produces a 7 V drop across internal resistance of the Hall cell.

UGN-3501K AND UGN-3501LI
LINEAR DIFFERENTIAL OUTPUT HALL EFFECT SENSORS

FEATURES

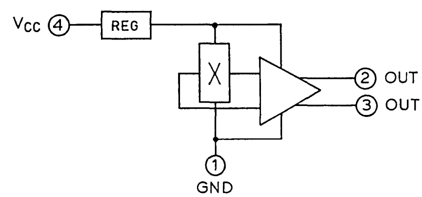
- Excellent Sensitivity
- Flat Response to 25 kHz (Typ.)
- Internal Voltage Regulation
- Excellent Temperature Stability

UGN-3501K and UGN-3501LI are Hall Effect integrated circuits that provide linear differential output as a function of magnetic flux density at the sensor. They are principally used to sense relatively small changes in a magnetic field—changes too small to operate a Hall Effect switch. Applications include accurate measurement of electrical current with negligible system loading and fine control of mechanical attributes such as position, weight, thickness and velocity.

Each device includes a Hall cell, linear differential amplifier, differential emitter-follower output stage, and voltage regulator on a monolithic silicon chip. Both are rated for operation over a supply voltage range of 8.0 V to 16 V and over a temperature range of 0°C to +70°C. The pinout of UGN-3501LI includes provisions for output offset nulling with the addition of an external resistor.

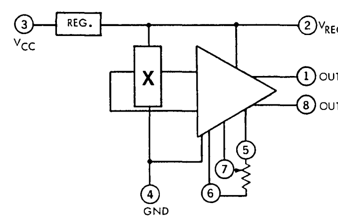
UGN-3501K is supplied in a four-lead single in-line plastic package. UGN-3501LI is furnished in an eight-lead SO-8 surface-mount plastic package that conforms to JEDEC registration MS-102AA.

FUNCTIONAL BLOCK DIAGRAMS



Dwg. No. A-14,412

UGN-3501K



Dwg. No. A-10,526A

UGN-3501LI

ABSOLUTE MAXIMUM RATINGS

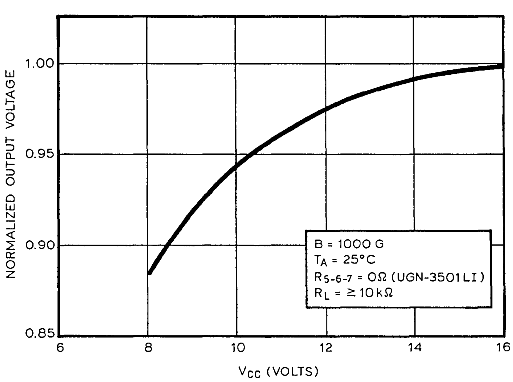
Supply Voltage, V_{CC}	+16 V
Output Current, I_{OUT}	4 mA
Magnetic Flux Density, B	Unlimited
Operating Temperature Range, T_A	0°C to +70°C
Storage Temperature Range, T_S	−65°C to +150°C

ELECTRICAL CHARACTERISTICS at T_A = +25°C, V_{CC} = 12 V (unless otherwise noted)

Characteristic	Test Conditions	Limits Min.	Limits Typ.	Limits Max.	Units
Operating Voltage		8.0	—	16	V
Supply Current	V_{CC} = 16 V	—	10	18	mA
Output Offset Voltage	UGN-3501K, B = 0G	—	100	400	mV
	UGN-3501LI, B = 0G, R_{5-6-7} = 0Ω	—	100	400	mV
Output Common-Mode Voltage	B = 0G	—	3.6	—	V
Sensitivity	UGN-3501K, B = 1000 G	0.7	1.4	—	mV/G
	UGN-3501LI, B = 1000 G, R_{5-6-7} = 0 Ω	0.7	1.4	—	mV/G
	UGN-3501LI, B = 1000 G, R_{5-6} = 15 Ω	0.65	1.3	—	mV/G
Frequency Response (−3 dB Down)	R_{5-6-7} = 0 Ω (UGN-3501LI)	23	25	—	kHz
Broadband Output Noise	3 dB Bandwidth, 10 Hz to 10 kHz, R_{5-6-7} = 0 Ω (UGN-3501LI)	—	0.15	—	mV
Offset Temperature Coefficient	R_{5-6-7} = 0 Ω (UGN-3501LI)	—	1.0	—	mV/°C

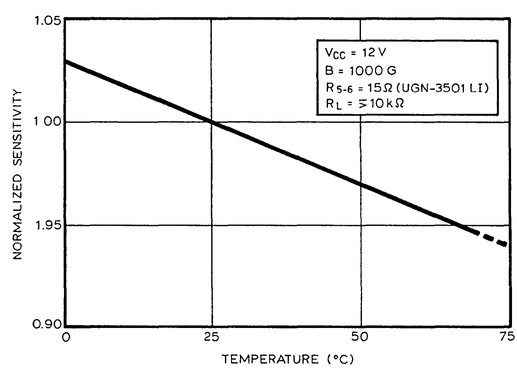
NOTES:
1. All output voltage measurements are made with a voltmeter having an input impedance of 10 kΩ or greater and a common-mode rejection ratio greater than 60 dB.
2. Magnetic flux density is measured at the most sensitive area of the device. For the UGN-3501LI, that is at top center, 0.015" ±0.001" (0.38 mm ±0.03 mm) below the surface. For the UGN-3501K, it is 0.017" ±0.001" (0.43 mm ±0.03 mm) below the center of the branded surface.

NORMALIZED SENSITIVITY AS A FUNCTION OF V_{CC}



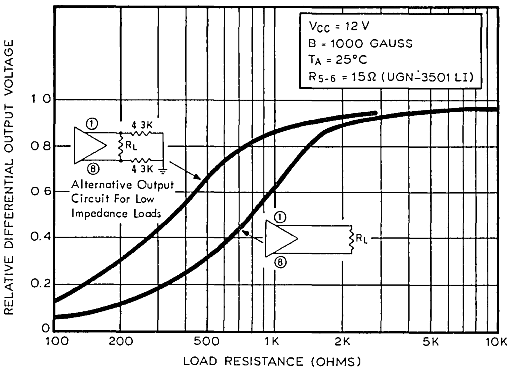
Dwg No A-10,529A

NORMALIZED SENSITIVITY AS A FUNCTION OF TEMPERATURE



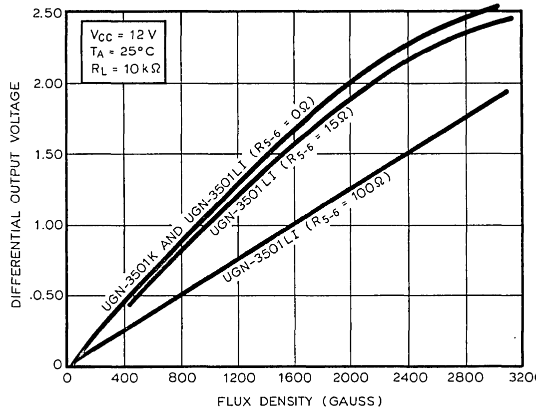
Dw. No A-10,530A

RELATIVE OUTPUT VOLTAGE AS A FUNCTION OF LOAD RESISTANCE



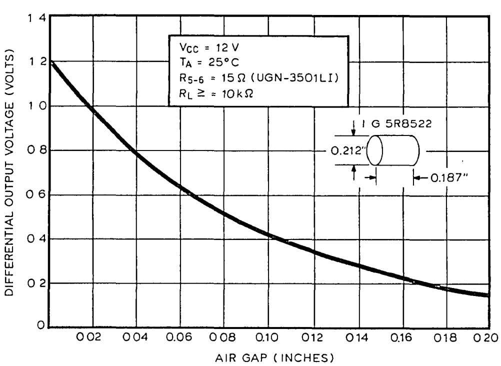
Dwg No. A-10,533A

OUTPUT VOLTAGE AS A FUNCTION OF MAGNETIC FLUX DENSITY



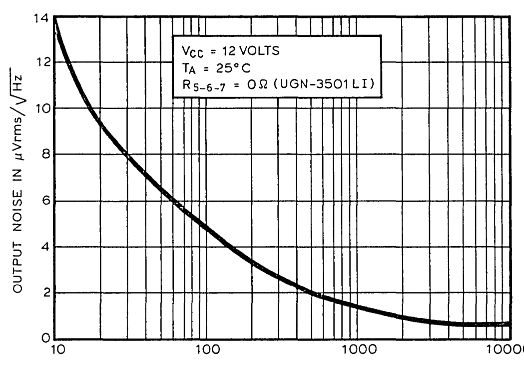
A-10,528 A

OUTPUT VOLTAGE AS A FUNCTION OF AIR GAP



Dwg. No. A-10,531A

NOISE SPECTRAL DENSITY AS A FUNCTION OF FREQUENCY



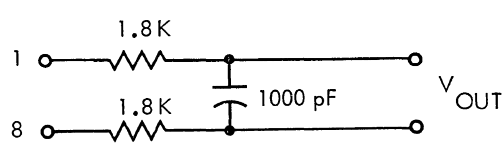
Dwg. No. A-10,532A

GUIDE TO INSTALLATION

1. All Hall Effect integrated circuits are susceptible to mechanical stress effects. Caution should be exercised to minimize the application of stress to the leads or the epoxy package.

2. To prevent permanent damage to the Hall cell IC, heat sink the leads during hand soldering. For wave soldering, the part should not experience more than 230°C for more than 5 seconds and no closer than 0.125″ to the epoxy poackage.

3. If a zeroing potentiometer is used with UGN-3501LI, minimize lead lengths from it and isolate these leads from output leads if possible. In some cases, it may be more practical to limit the frequency response with an output RC network to prevent oscillation:



Dwg. No. A-10,536

UGN-3501T AND UGN-3501U
LINEAR OUTPUT HALL EFFECT SENSORS

FEATURES

- Excellent Sensitivity
- Flat Response to 25 kHz (typ.)
- Internal Voltage Regulation
- Excellent Temperature Stability

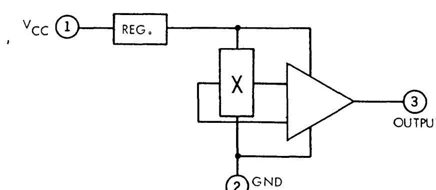
Utilizing the Hall Effect for sensing a magnetic field, UGN-3501T and UGN-3501U integrated circuits provide a linear single-ended output that is a function of magnetic field intensity.

These devices can sense relatively small changes in a magnetic field—changes that are too small to operate a Hall effect switch. They can be capacitively coupled to an amplifier, to boost the output to a higher level.

UGN-3501T and UGN-3501U each include a Hall cell, linear amplifier, emitter-follower output, and a voltage regulator. Integrating the Hall cell and the amplifier into one monolithic device minimizes problems related to the handling of millivolt analog signals

Both devices are rated for continuous operation over the temperature range of 0°C to +70°C and over a supply voltage range of 8 V to 12 V.

FUNCTIONAL BLOCK DIAGRAM



Dwg. No. A-10,524

Packaging options include two three-pin SIPs: the "T" package (UGN-3501T), which is 80 mils (2.03 mm) thick, and the magnetically optimized "U" package, which is 60 mils (1.52 mm) thick.

ABSOLUTE MAXIMUM RATINGS

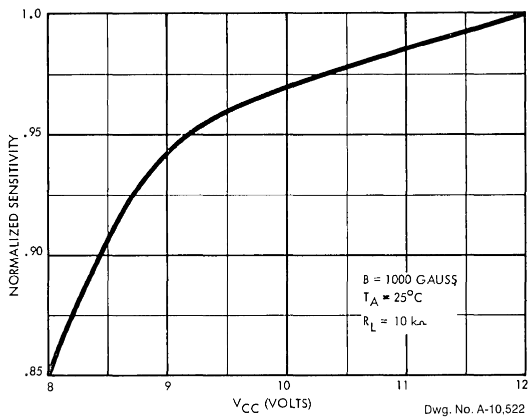
Supply Voltage, V_{CC} .... 16 V
Output Current, I_{OUT} .... 4 mA
Magnetic Flux Density, B .... Unlimited
Operating Temperature Range, T_A .... 0°C to +70°C
Storage Temperature Range, T_S .... −65°C to +150°C

ELECTRICAL CHARACTERISTICS at T_A = +25°C, V_{CC} = 12 VDC

Characteristic	Symbol	Test Conditions	Limits			Units
			Min.	Typ.	Max.	
Operating Voltage	V_{CC}		8.0	—	12	V
Supply Current	I_{CC}	V_{CC} = 12 V	—	10	20	mA
Quiescent Output Voltage	V_{OUT}	B = 0 Gauss, Note 1	2.5	3.6	5.0	V
Sensitivity	ΔV_{OUT}	B = 1000 Gauss, Notes 1, 2	0.35	0.7	—	mV/G
Frequency Response	BW	$f_H - f_L$ at −3 dB	—	25	—	kHz
Broadband Output Noise	e_n	f = 10 Hz to 10 kHz	—	0.1	—	mV
Output Resistance	R_0		—	100	—	Ω

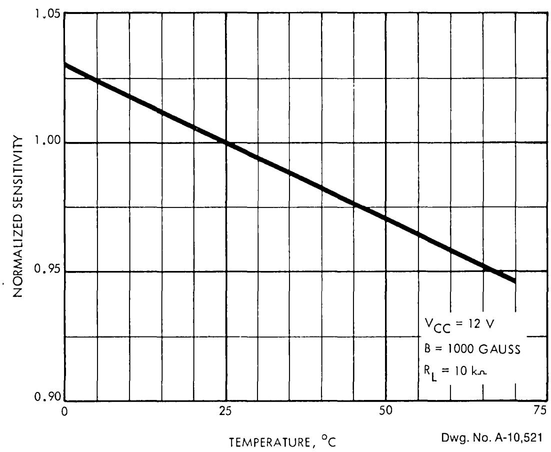
NOTE 1. All output voltage measurements are made with a voltmeter having an input impedance of 10 kΩ or greater.
NOTE 2. Magnetic flux density is measured at the most sensitive area of the device, which is centered on the branded side of the T package, 0.037 ± 0.001" (0.94 ± 0.03 mm) below the surface and 0.017" ± 0.001" (0.43 ± 0.03 mm) below the branded side of the U package.

NORMALIZED SENSITIVITY AS A FUNCTION OF V_{CC}



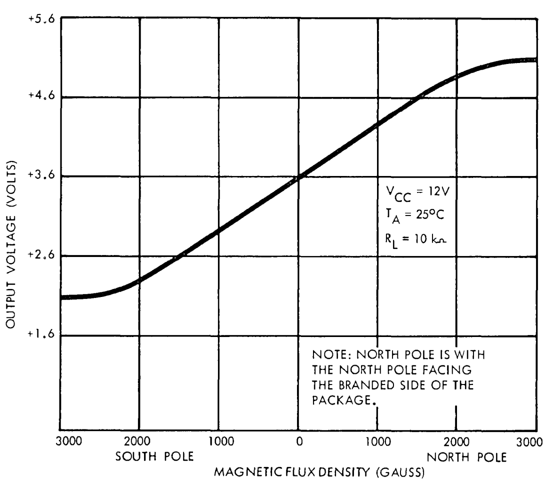
Dwg. No. A-10,522

NORMALIZED SENSITIVITY AS A FUNCTION OF TEMPERATURE



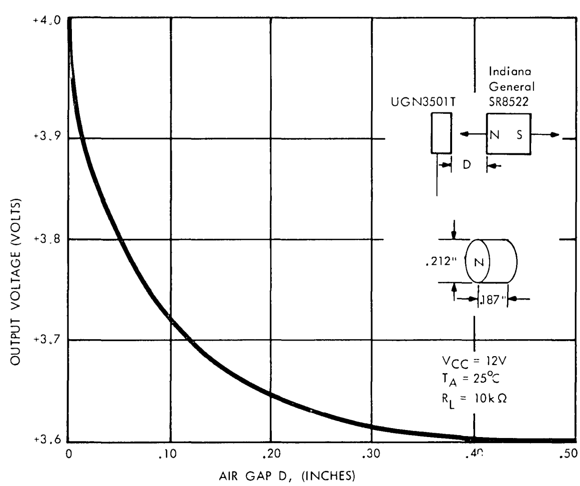
Dwg. No. A-10,521

OUTPUT VOLTAGE AS A FUNCTION OF MAGNETIC FLUX DENSITY



Dwg No A-10,523

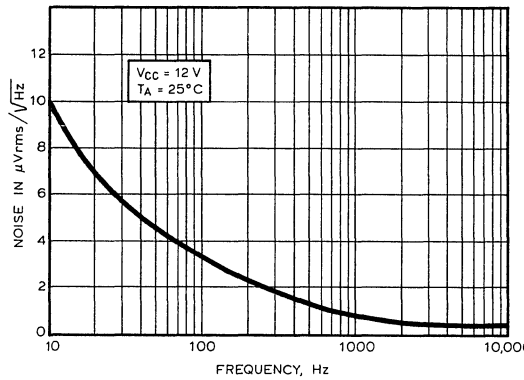
OUTPUT VOLTAGE AS A FUNCTION OF AIR GAP



Dwg. No A-10,519

These Hall Effect sensors are also supplied in a low profile "U" package. The low profile "U" is specified by substituting a "UA" for the last character of the part number.

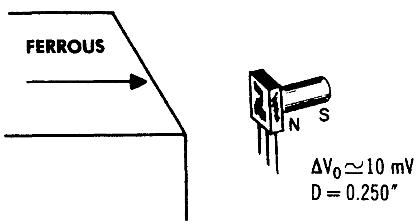
NOISE SPECTRAL DENSITY AS A FUNCTION OF FREQUENCY



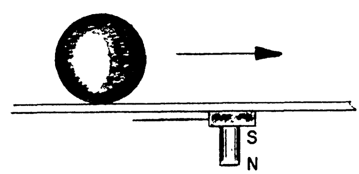
Dwg. No A-10,520A

TYPICAL APPLICATIONS

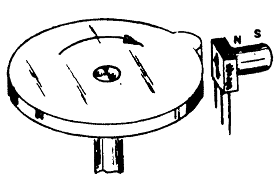
SENSITIVE PROXIMITY DETECTOR



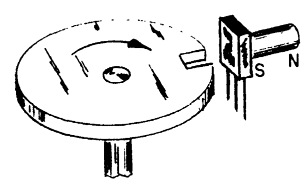
FERROUS METAL SENSOR



LOBE OR COG SENSOR



NOTCH OR HOLE SENSOR

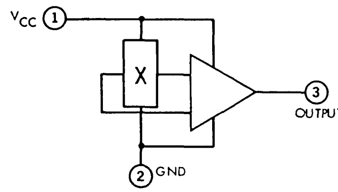


For reference only—an Alnico VIII permanent magnet, 0.212″ (5.38 mm) in diameter and 0.187″ (4.75 mm) long is approximately 800 gauss at the surface. A samarium cobalt permanent magnet, 0.100″ (2.54 mm) square and 0.040″ (1.02 mm) thick is approximately 1200 gauss at its surface.

UGN-3503U AND UGS-3503U RATIOMETRIC, LINEAR HALL EFFECT SENSORS

FEATURES

- Extremely Sensitive
- Flat Response to 23 kHz
- Low-Noise Output
- 4.5 V to 6 V Operation
- Magnetically Optimized Package



Dwg. No. A-12,538

FUNCTIONAL BLOCK DIAGRAM

TYPE UGN-3503U AND UGS-3503U Hall Effect sensors accurately track extremely small changes in magnetic flux density—changes generally too small to operate Hall Effect switches.

As motion detectors, gear tooth sensors, and proximity detectors, they are magnetically driven mirrors of mechanical events. As sensitive monitors of electromagnets, they can effectively measure a system's performance with negligible system loading while providing isolation from contaminated and electrically noisy environments.

Each Hall Effect integrated circuit includes a Hall sensing element, linear amplifier, and emitter-follower output stage. Problems associated with handling tiny analog signals are minimized by having the Hall cell and amplifier on a single chip.

The sensors are supplied in a three-pin plastic package only 61 mils (1.54 mm) thick. Type UGN-3503U is rated for continuous operation over the temperature range of −20°C to +85°C. Type UGS-3503U operates over an extended temperature range of −40°C to +125°C.

4

ABSOLUTE MAXIMUM RATINGS

Supply Voltage, V_{CC} .... 8 V
Magnetic Flux Density, B .... Unlimited
Operating Temperature Range, T_A
  UGN-3503U .... −20°C to +85°C
  UGS-3503U .... −40°C to +125°C
Storage Temperature Range, T_S .... −65°C to +150°C

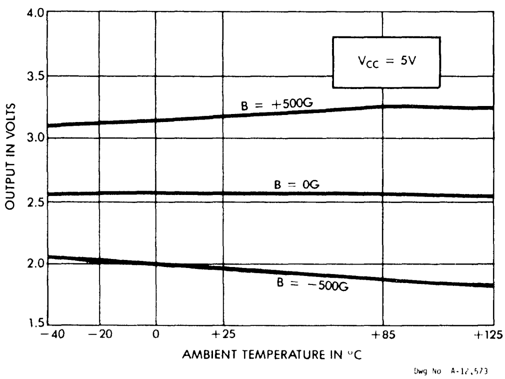
ELECTRICAL CHARACTERISTICS at T_A = +25°C, V_{CC} = 5 V

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Operating Voltage	V_{CC}		4.5	—	6.0	V
Supply Current	I_{CC}		—	9.0	14	mA
Quiescent Output Voltage	V_{OUT}	B = 0G	2.25	2.50	2.75	V
Sensitivity	ΔV_{OUT}	B = 0G to ±900G	0.75	1.30	1.72	mV/G
Bandwidth (−3 dB)	BW		—	23	—	kHz
Broadband Output Noise	V_{out}	BW = 10 Hz to 10 kHz	—	90	—	μV
Output Resistance	R_{OUT}		—	50	—	Ω

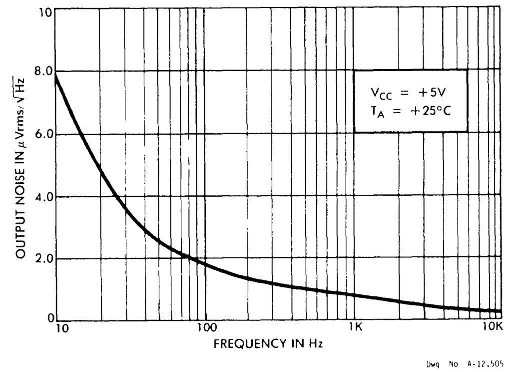
All output voltage measurements are made with a voltmeter having an input impedance of 10 kΩ.
Magnetic flux density is measured at the most sensitive area of the device located 0.017″ ±0.001″ (0.43 mm ±0.03 mm) below the branded face of the 'U' package.

These Hall Effect sensors are also supplied in a low profile "U" package. The low profile "U" is specified by substituting a "UA" for the last character of the part number.

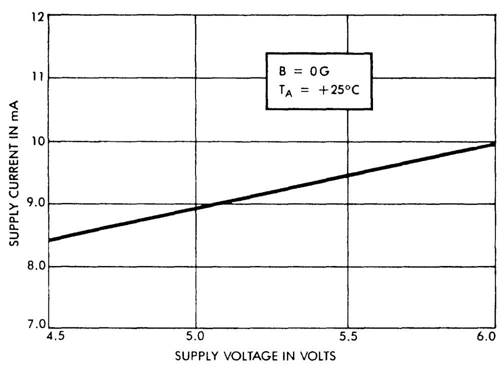
OUTPUT VOLTAGE AS A FUNCTION OF TEMPERATURE



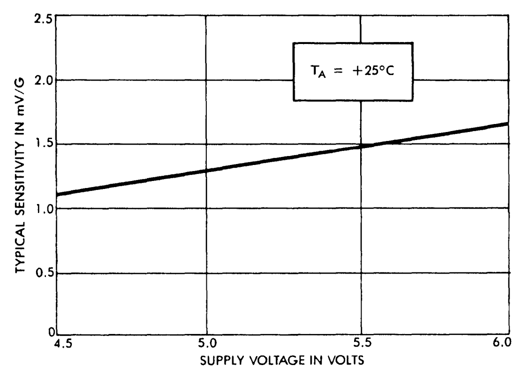
OUTPUT NOISE AS A FUNCTION OF FREQUENCY



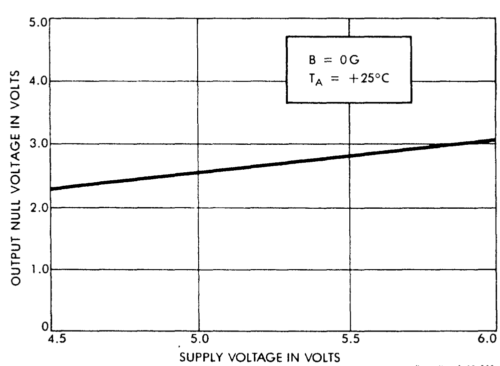
SUPPLY CURRENT AS A FUNCTION OF SUPPLY VOLTAGE



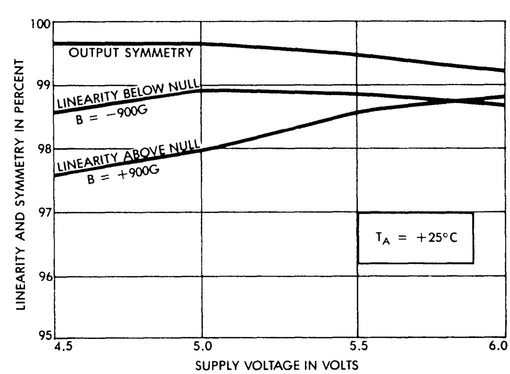
DEVICE SENSITIVITY AS A FUNCTION OF SUPPLY VOLTAGE



OUTPUT NULL VOLTAGE AS A FUNCTION OF SUPPLY VOLTAGE



LINEARITY AND SYMMETRY AS A FUNCTION OF SUPPLY VOLTAGE



OPERATION

The output null voltage (see preceding graph) is nominally one-half the supply voltage. A south magnetic pole, presented to the branded face of the Hall Effect sensor, will drive the ouput higher than the null voltage level. A north magnetic pole will drive the output below the null level.

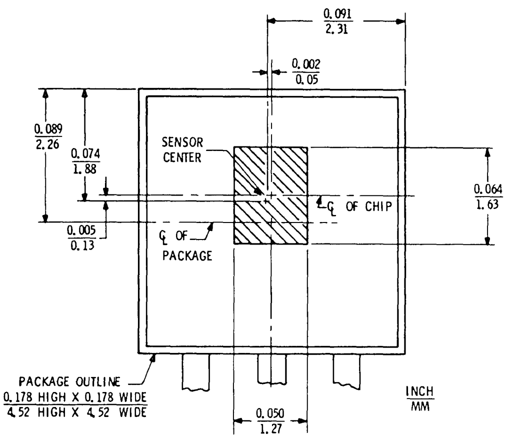
In operation, instantaneous and proportional output-voltage levels are dependent on magnetic flux density at the most sensitive area of the device. Greatest sensitivity is obtained with a supply voltage of 6 V, but at the cost of increased supply current and a slight loss of output symmetry. The sensor's output is usually capacitively coupled to an amplifier that boosts the output above the millivolt level.

In two applications shown below, a permanent bias magnet is attached with epoxy glue to the back of the epoxy package. The presence of ferrous material at the face of the package acts as a flux concentrator.

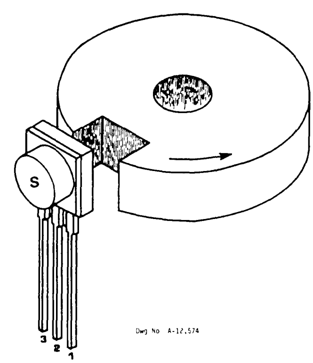
The south pole of a magnet is attached to the back of the package if the Hall Effect IC is to sense the presence of ferrous material. The north pole of a magnet is attached to the back surface if the integrated circuit is to sense the absence of ferrous material.

Calibrated linear Hall devices, which can be used to determine the actual flux density presented to the Type 3503 sensor in a particular application, are available from Hall Effect Applications Engineering, Sprague Electric Co., Concord, N.H.

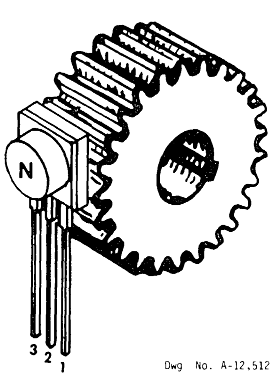
SENSOR-CENTER LOCATION



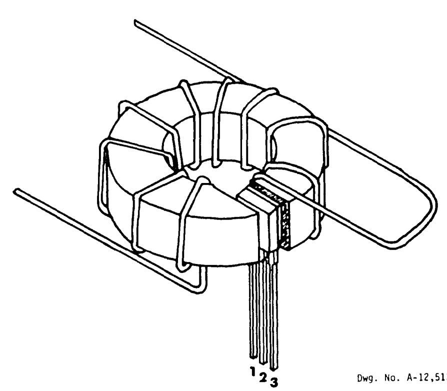
NOTCH SENSOR



GEAR TOOTH SENSOR



CURRENT MONITOR



UGN-3604K AND UGN-3605K
LINEAR DIFFERENTIAL OUTPUT HALL EFFECT SENSORS

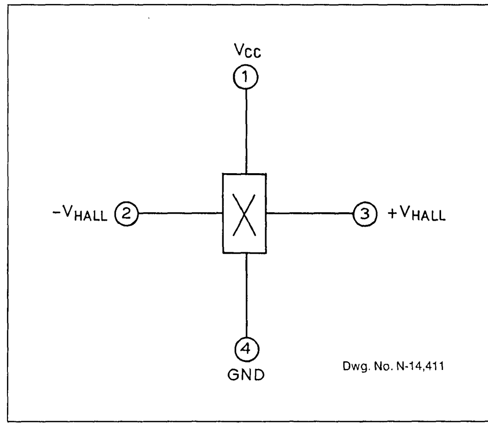
The most basic Hall Effect sensors are the UGN-3604K and UGN-3605K. The differential output of the devices is a function of the magnetic flux density present at the sensor. Sensitivity is a function of the control current: Sensitivity increases as the control current increase.

The UGN-3604K and UGN-3605K are most often used for magnetic circuit design, analysis, testing and alignment, and for calibrating magnetic sensing devices.

The UGN-3604K is supplied in a four-pin SIP, and with a calibration chart. The UGN-3605K is the same device without the calibration chart.

Each UGN-3604K Hall Effect sensor is individually calibrated at a temperature of +25°C using a supply voltage of 5 V. The calibration chart indicates differential output values for a magnetic flux density range from 0 gauss to 1000 gauss. Sensitivity at this supply voltage level is typically 40 mV per 1000 gauss.

Since the differential output voltage is a linear function of the magnetic flux density, other readings are easily interpolated.



The UGN-3605K is intended to be used primarily as a sensing device. When operated from a constant current source of 3 mA the device provides a typical sensitivity of 60 mV per 1000 gauss. This is the preferred biasing method, to achieve the most stable output voltage over temperature.

ABSOLUTE MAXIMUM RATINGS

Supply Voltage, V_{CC}	7 V
Supply Current, I_{CC}	10 mA
Magnetic Flux Density, B	Unlimited
Operating Temperature Range, T_A	0°C to +70°C
Storage Temperature Range, T_S	−65°C to +150°C

ELECTRICAL CHARACTERISTICS at $T_A = +25°C$

Characteristic	Symbol	Test Conditions	Limits Min.	Limits Typ.	Limits Max.	Units
Control Current	I_{CC}	Notes 1, 2	—	3.0	7.0	mA
Control Resistance	R_{1-4}	—	1.0	2.2	4.5	kΩ
Control Resistance vs. Temperature	$\Delta R_{1-4}/\Delta T$	—	—	+0.8	—	%/°C
Differential Output Resistance	R_{2-3}	—	2.0	4.4	9.0	kΩ
Output Offset Voltage	V_{OFF}	B = 0 Gauss	—	5.0	—	mV
Output Offset Voltage vs. Temperature	$\Delta V_{OFF}/\Delta T$	B = 0 Gauss	—	30	—	μV/°C
Sensitivity	$\Delta V_{OUT}/\Delta B$	Note 1	—	0.06	—	mV/G
Sensitivity vs. Temperature	$\frac{\Delta V_{OUT}/\Delta B}{\Delta T}$	I_{CC} = 1.5 mA	—	+0.1	—	%/°C
Product Sensitivity	V/A × kG	Note 1	—	20	—	—

1. I_{CC} is limited to a maximum value which produces a 7 V drop across the control resistance, R_{1-4}.
2. Terminal 1 must always be positive in relation to terminal 4.

GUIDE TO INSTALLATION

1. All Hall Effect integrated circuits are susceptible to mechanical stress effects. Caution should be exercised to minimize the application of stress to the leads or the epoxy package.

2. To prevent permanent damage to the Hall cell integrated circuit, heat-sink the leads during hand-soldering. For wave soldering, the part should not experience more than 260°C for more than five seconds. Solder flow should be no closer than 0.125" (3.18 mm) to the epoxy package.

3. The magnetic flux density is indicated for the most sensitive area of the device. This area is centrally located and 0.017" ±0.001" (0.43 ±0.03 mm) below the top surface of the package.

4. For reference purposes, an Alnico VIII magnet, 0.212" (5.38 mm) in diameter and 0.187" (4.75 mm) long or a samarium cobalt magnet, 0.100" (2.54 mm) square and 0.040" (1.02 mm) thick, is approximately 1200 gauss at its surface.

Note that the flux density decays at a high rate as the distance from a pole increases. In most cases, this is a relatively linear decrease in the region of interest, and it may range from 5 to 20 gauss/mil.

SECTION 5—OPTOELECTRONIC SENSORS

5

SELECTION GUIDE

OPTOELECTRONIC SWITCHES

Device Type	Output	Typical E_{ON}*	Typical Hysteresis	Supply Range	Page
ULN-3330	Open-Collector	55 $\mu W/cm^2$	12%	4.0-15 V	5-11
ULN-3332	Dual Open-Collector	55 $\mu W/cm^2$	12%	4.0-15 V	5-16
ULN-3333	Triple Open-Collector	55 $\mu W/cm^2$	12%	4.0-15 V	5-17
ULN-3360	Open-Coll./5.4 k Pull-Up	55 $\mu W/cm^2$	12%	4.0-15 V	5-11
ULN-3363	Inverted Open-Collector	55 $\mu W/cm^2$	12%	4.0-15 V	5-11
ULN-3390	Open-Collector	14 $\mu W/cm^2$	50%	4.0-16 V	5-21
ULN-3395	Open-Coll./10 k Pull-Up	350 $\mu W/cm^2$	20%	4.5-16 V	5-25

*λ = 880 nm, peak.

OPTOELECTRONIC LINEARS

Device Type	Sensitivity* Min.	Sensitivity* Max.	Initial Accuracy*	Output Linearity§	Supply Range	Page
ULN-3311D	240 nA/$\mu W/cm^2$	320 nA/$\mu W/cm^2$	±7.2%	±7.2%	2.7-24 V	5-4
ULN-3311T	280 nA/$\mu W/cm^2$	350 nA/$\mu W/cm^2$	±7.2%	±7.2%	2.7-24 V	5-4
ULN-3312D	280 nA/$\mu W/cm^2$	360 nA/$\mu W/cm^2$	±7.2%	±7.2%	2.7-24 V	5-4
ULN-3312T	350 nA/$\mu W/cm^2$	420 nA/$\mu W/cm^2$	±7.2%	±7.2%	2.7-24 V	5-4

*At λ = 880 nm, peak.
†At E = 100 $\mu W/cm^2$.
§At E = 10 to 10,000 $\mu W/cm^2$.

INTRODUCTION TO OPTOELECTRONICS

Light sensing has traditionally been used for a variety of transducing applications, including absolute light measurement, position encoding, rotary speed encoding, optical communications, and electrical isolation. The Sensor Division of Sprague Electric Company offers a wide variety of low-cost, calibrated precision optical sensors that are suited to these specific applications.

The typical Sprague integrated circuit optical sensor consists of a p-n junction photodiode that feeds a bipolar current amplifier. This amplified signal is then fed into a Schmitt trigger (in the case of digital devices) or into a high-gain current amplifier (in the case of linear detectors). The switch points/gain of the secondary circuits are factory trimmed to produce a high-quality, precision light detector. The supply to these devices is regulated by on-chip voltage regulators, resulting in wide operating voltage ranges and low susceptibility to line noise.

LINEAR OUTPUT PHOTODETECTORS

Many situations exist in which it is necessary to convert light energy into electrical energy. This conversion is often accomplished by devices like photocells, phototransistors, and photodiodes; however, for precision light measurements, these are poor solutions. Photocells are slow, exhibit light memory, and are strongly temperature-dependent. Phototransistors are fast, but have outputs that may vary by as much as 50 percent and are non-linear. Photodiodes are highly linear, but have lower light currents and have sensitivity variations of as much as 25 percent.

The Sprague ULN-3311 and ULN-3312 sensors share the linearity advantages of the photodiode, but add calibrated amplification to provide a greater current output. They linearly respond to changes in light intensity but maintain tight control over variations in sensitivity (maximum changes are ± 11 percent). Tighter specifications can be factory selected.

DIGITAL OUTPUT PHOTODETECTORS

Sprague optical switches provide highly sensitive, precision digital light-level detection at a low price. These devices are used in encoding, speed detection, and measurement of absolute light levels.

The ULN-3330 series of light sensors have digital outputs that switch at a typical light level of 55 $\mu W/cm^2$ with a hysteresis of 10 to 14 percent. The on-chip amplifier/Schmitt trigger is adjusted to maintain a switch point tolerance of ± 18 percent. Tighter tolerances are available on special order. Control over the switch points makes this family of devices ideal for precision low-speed encoding and bar-code reading applications.

Series ULN-3330 consists of three device types: ULN-3330, ULN-3360, and ULN-3363. The three device types are identical, except for the configuration of the output stages.

The ULN-3390 sensor takes advantage of the linearity of the photodiode to provide temperature-compensated switch points of 10 and 20 $\mu W/cm^2$ to facilitate sensing of dawn and dusk. On-chip hysteresis of 55 percent minimizes the effects of optical feedback from extraneous light sources. The high sensitivity of this device makes it ideal for use in twilight sensing applications, such as street lighting and other outdoor lighting control. It provides a low-cost alternative to CdS-based lighting designs, offering higher reliability through integration of components.

The ULN-3395 medium speed optical sensor provides reliable switching for use in communication applications. Its temperature compensation to an AlGaAs LED makes its use in optocoupler applications attractive.

MULTICHANNEL SENSORS

The ULN-3332M and ULN-3333M are Type 3330-based devices packaged as two-and three-channel optical encoders. These devices eliminate the need for placement accuracy in the manufacture of optical encoders.

PACKAGING

Sprague optical sensors are available in flat, clear plastic three-lead packages (''T'') for low-cost sensing. They are also available in top-looking hermetic metal cans (''D'') for high-reliability applications. Multichannel sensors are in top-looking, eight-lead, clear plastic DIPs.

TESTING

All Sprague optical sensors are 100 percent tested using an AlGaAs LED light source, along with standards, based on NBS specifications. Computerized test controllers are used to maintain testing accuracy. Optoelectronic standards are available on request from the factory in the form of calibrated ULN-3311T linear sensors.

QUALITY ASSURANCE AND RELIABILITY

An aggressive QAR program is maintained by Sprague to assure the accuracy and reliability of shipped products. Long-term tests on the effects of humidity, high-temperature life, storage life, soldering, and package characteristics are continuous and on-going. Contact the factory for further information.

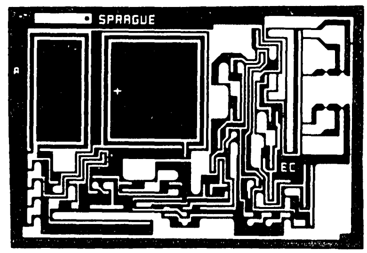
ULN-3311D/T AND ULN-3312D/T
PRECISION LIGHT SENSORS
With Calibrated Current Amplifiers

FEATURES

- Two-Terminal Operation
- Linear Over a Wide Range
- Precalibrated
- Wide Operating Voltage Range
- High Output

Direct replacements for photocells and phototransistors, the ULN-3311D/T and ULN-3312D/T precision light sensors are two-terminal monolithic integrated circuits that linearly convert light level into electrical current. The light-controlled current sources are linear over a wide range of supply voltages and light levels and require no external calibration.

Each precision light sensor (PLS) consists of a photodiode and a calibrated current amplifier. The design of the amplifier allows derivation of its supply current from the same terminal as the photodiode cathode and the amplifier output. Since this supply current is a linear function of the photodiode current, it acts as part of the signal current. On-chip resistor-trimming techniques are used during manufacture to adjust each PLS to specified sensitivity. A 100 μW/cm² GaAlAs LED emission provides the light source for this calibration.

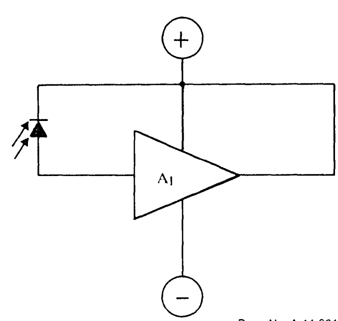


The ULN-3311D and ULN-3312D are furnished in a hermetically sealed metal package with glass end cap conforming to JEDEC outline TO-52 (TO-206AC). The ULN-3311T and ULN-3312T are supplied in an inexpensive clear plastic package. Both devices are rated for operation over the temperature range of −40°C to +70°C.

ABSOLUTE MAXIMUM RATINGS

Supply Voltage .... 24 V
Operating Temperature Range .... −40°C to +70°C
Storage Temperature Range
(ULN-3311D and ULN-3312D) ...... −55°C to +150°C
(ULN-3311T and ULN-3312T) .... −55°C to +110°C

FUNCTIONAL BLOCK DIAGRAM



Dwg No A-11,991

APPLICATIONS INFORMATION

ULN-3311D/T and ULN-3312D/T precision light sensors can be used to replace several types of light sensors:

Photocells exhibit a change in resistance proportional to light intensity. However, they are highly inaccurate. They exhibit light memory, which makes their response dependent on the previous light level.

Phototransistors exhibit no light memory, but show as much as 50% variation in sensitivity among parts of the same type due to process and beta variations. Output current as a function of light level is linear only over a very small range.

Photodiodes have an output current that is a linear function of illumination, but the output is very small. The output current is typically in the range of tens of nanoamperes. These devices also show wide unit-to-unit sensitivity variations.

Sprague Electric precision light sensors are two-terminal replacements for photocells, phototransistors, and photodiodes. They are internally calibrated, have relatively high output currents, and are linear over a very wide range of light levels. Low-level amplifiers and adjustable controls can be eliminated. The precision light sensors are also ideal for use in arrays where matched characteristics are often required. Unpackaged chips are available on special order.

Both the hermetically sealed ULN-3311D and ULD-3312D sensors and the low-cost ULN-3311T and ULN-3312T plastic-encapsulated sensors are cost-effective solutions to precise light-sensing or light-measurement applications.

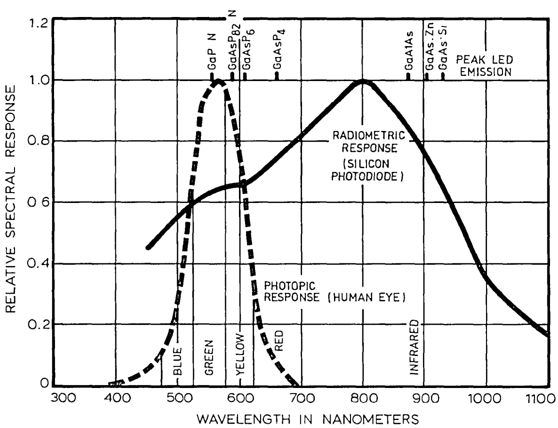
ELECTRICAL CHARACTERISTICS at $T_A = +25°C$, $V_{CC} = 12$ V

Characteristic	Device Type	Limits Min.	Typ.	Max.	Units
Initial Accuracy at 100 μW/cm²	All	—	—	±7.2	%
Sensitivity	ULN-3311D	240	—	320	nA/μW/cm²
	ULN-3311T	280	—	350	nA/μW/cm²
	ULN-3312D	280	—	360	nA/μW/cm²
	ULN-3312T	350	—	420	nA/μW/cm²
Operating Voltage Range	All	2.7	12	24	V
Output Linearity, 10 to 10k μW/cm²	All	—	—	±7.2	%
Dark Current	All	—	—	100	nA
Power Supply Rejection, $(\Delta I_0/I_0)\Delta V$	All	40	50	—	dB
Temperature Coefficient of Sensitivity	All	—	3500	—	ppM/°C

NOTE: Light source is an infrared LED with a peak output wavelength of 880 nm.

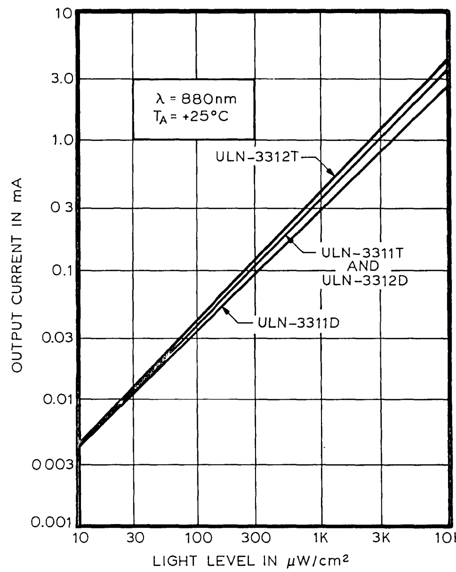
TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL RESPONSE AS A FUNCTION OF WAVELENGTH OF LIGHT



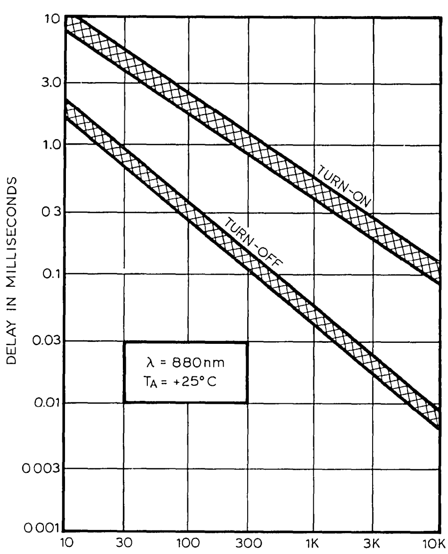
Dwg No A-12,135A

OUTPUT CURRENT AS A FUNCTION OF ILLUMINANCE



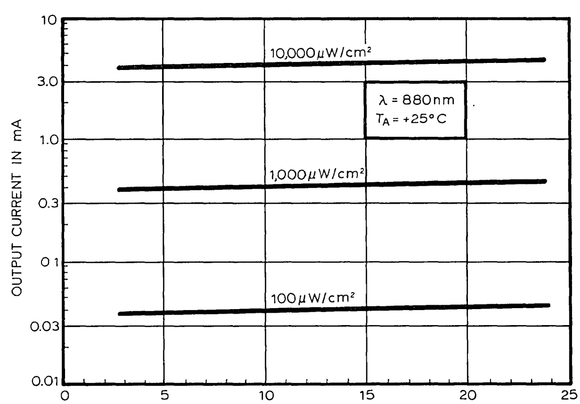
Dwg No A-14,271

PROPAGATION DELAY AS A FUNCTION OF ILLUMINANCE



Dwg No. A-12,138A

OUTPUT CURRENT AS A FUNCTION OF SUPPLY VOLTAGE



Dwg No A-12,137A

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TYPICAL APPLICATIONS

Figure 1 shows a ULN-3311D/T or ULN-3312D/T integrated circuit replacing a photocell or phototransistor for the precise linear detection of a light level. Use of the precision light sensor eliminates the need for external calibration because it is calibrated to an initial accuracy of better than 7.2% during manufacture.

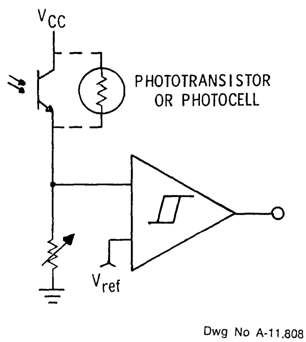


Figure 1A
LIGHT-LEVEL DETECTOR
REQUIRING EXTERNAL CALIBRATION

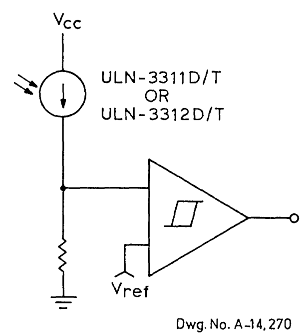
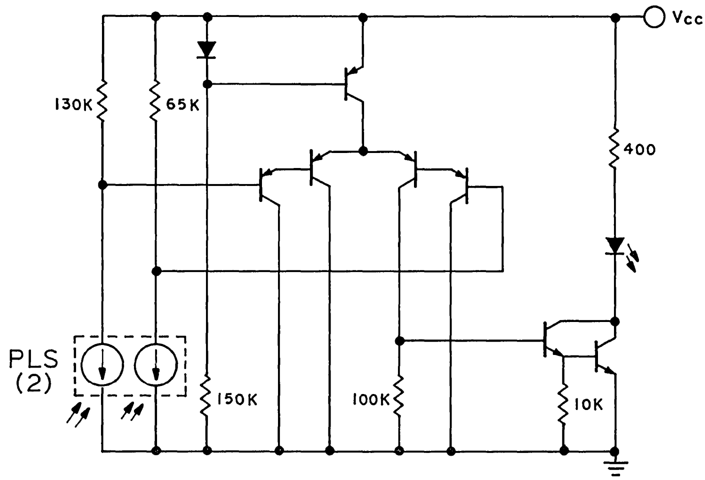


Figure 1B
LIGHT-LEVEL DETECTOR USING PLS

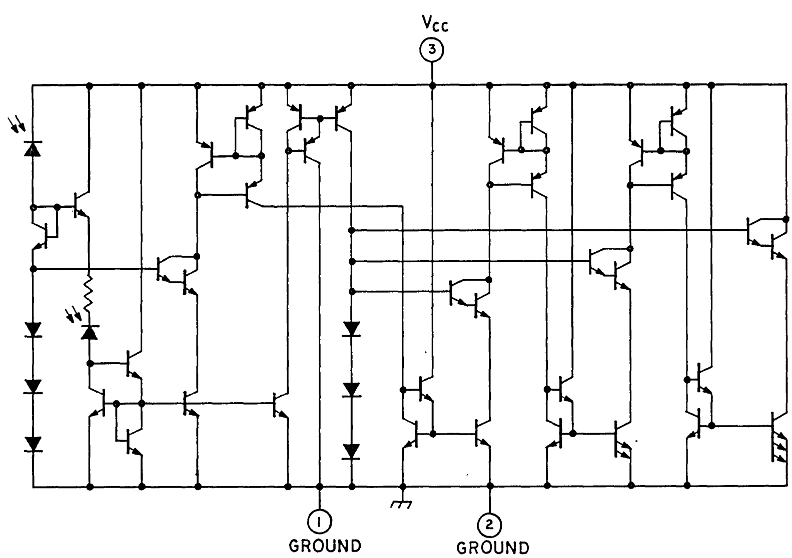
In Figure 2, two precision light sensors are used in a differential configuration to detect the edge of an object. When the light level on the first sensor is half of that on the second, the circuit switches. This circuit operates over a wide range of ambient light levels. No external calibration is required.



Dwg No. A-11,995

Figure 2
DIFFERENTIAL EDGE DETECTOR

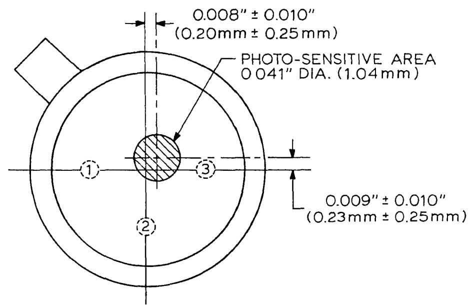
SCHEMATIC



Dwg. No A-11,996

ULN-3311D AND ULN-3312D

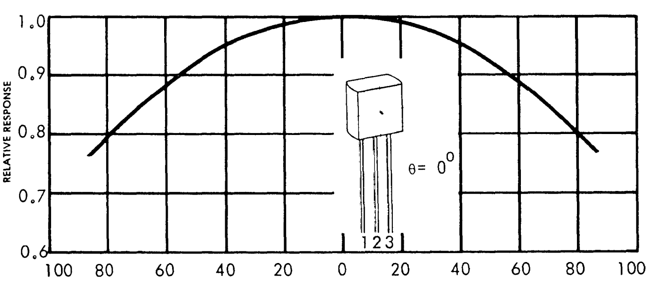
SENSOR-CENTER LOCATION



Dwg. No A-14,274

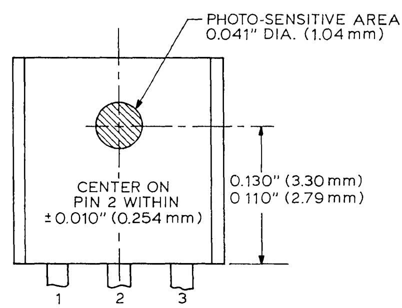
ULN-3311T AND ULN-3312T

RELATIVE RESPONSE AS A FUNCTION OF THE ANGLE OF INCIDENCE



Dwg No A-12,134

SENSOR-CENTER LOCATION



Dwg. No A-14,275

ULN-3330, ULN-3360, AND ULN-3363 OPTOELECTRONIC SWITCHES

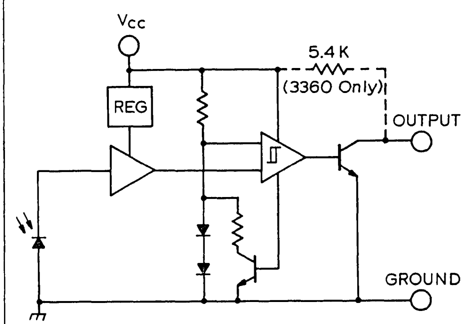
FEATURES

- Photodiode with:
  On-Chip Amplifier
  On-Chip Comparator with Hysteresis
  On-Chip Power Driver
  On-Chip Voltage Regulator
- Sensitive Switch Points
- Operation to 30 kHz
- Plastic or Hermetic Package

SPRAGUE SERIES ULN-3330, ULN-3360, and ULN-3363 optoelectronic switches provide light detection and low-level signal processing in single three-lead packages. The monolithic integrated circuits, requiring no external components, meet the need for cost-effective light-sensing devices in consumer and industrial applications. Their high sensitivity makes them ideal for low-level light detection in optically noise-free environments.

Each optoelectronic IC includes a 30-mil by 30-mil photodiode, a high-gain current amplifier, a comparator with 12% hysteresis, output driver stage, and voltage regulator.

FUNCTIONAL BLOCK DIAGRAM



Dwg. No. A-13,264

Series ULN-3330 and Series ULN-3360 switches turn ON as illumination of the photodiode falls below 55 μW/cm² at 880 nm. An internal latch provides hysteresis: The output turns OFF when illumination surpasses the turn-on threshold by approximately 12%.

(Continued next page)

5

Device Type	Output	Package*	Pinout (1-2-3)
ULN-3330D	Open Collector	D	OUT—GND—V_{cc}
ULN-3330T	Open Collector	T	OUT—GND—V_{cc}
ULN-3360D	5.4 kΩ Pull-Up	D	OUT—GND—V_{cc}
ULN-3360T	5.4 kΩ Pull-Up	T	OUT—GND—V_{cc}
ULN-3363D	Inv. Open Collector	D	OUT—GND—V_{cc}
ULN-3363T	Inv. Open Collector	T	OUT—GND—V_{cc}

*Also available in chip form as ULN-3330C, ULN-3360C, or ULN-3363C.

Series ULN-3363 switches have inverted output characteristics. They turn OFF as illumination falls below 55 $\mu W/cm^2$ at 880 nm; they remain OFF until increasing illumination at the photodiode typically reaches 62 $\mu W/cm^2$.

Devices in Series ULN-3330 and ULN-3363 have buffered open-collector outputs for current-sink applications. Typical loads include incandescent lamps, LEDs, sensitive relays, or dc motors.

Output circuitry for switches in Series ULN-3360 includes an internal 5.4 kΩ pull-up resistor that enables their direct use with microprocessors and TTL logic.

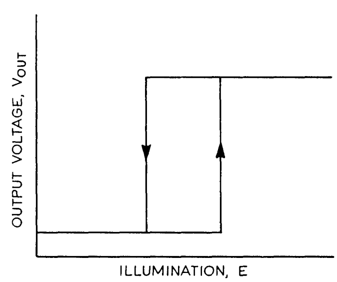
Series ULN-3330, ULN-3360, and ULN-3363 ICs are each offered in two packages with two pinout options. Package options are specified by a suffix added to the basic part number (e.g., ULN-3330*D*). The hermetically sealed, three-pin metal "D" package with a glass end-cap conforms to JEDEC outline TO-52 (TO-206AC). The miniature, clear plastic three-lead "T" package is only 0.080" (2.03 mm) thick.

ABSOLUTE MAXIMUM RATINGS

Supply Voltage, V_{CC} . . . . 15 V
Output Voltage, V_{OUT} . . . . 15 V
Output Current, I_{OUT} . . . . 25 mA
Operating Temperature Range, T_A . . . . $-40°C$ to $+70°C$
Storage Temperature Range, T_S
Suffix 'D' . . . . $-55°C$ to $+150°C$
Suffix 'T' . . . . $-55°C$ to $+110°C$

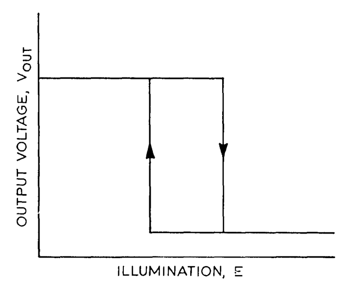
TYPICAL TRANSFER CHARACTERISTICS

SERIES ULN-3330 AND ULN-3360



Dwg No. A-11,128

SERIES ULN-3363

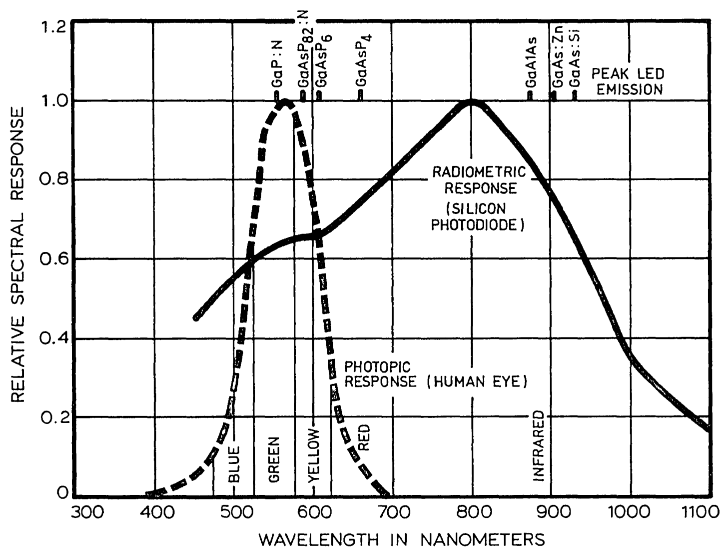


Dwg No A-13,265

ELECTRICAL CHARACTERISTICS at $T_A = +25°C$, $V_{CC} = 6.0$ V, $\lambda = 880$ nm

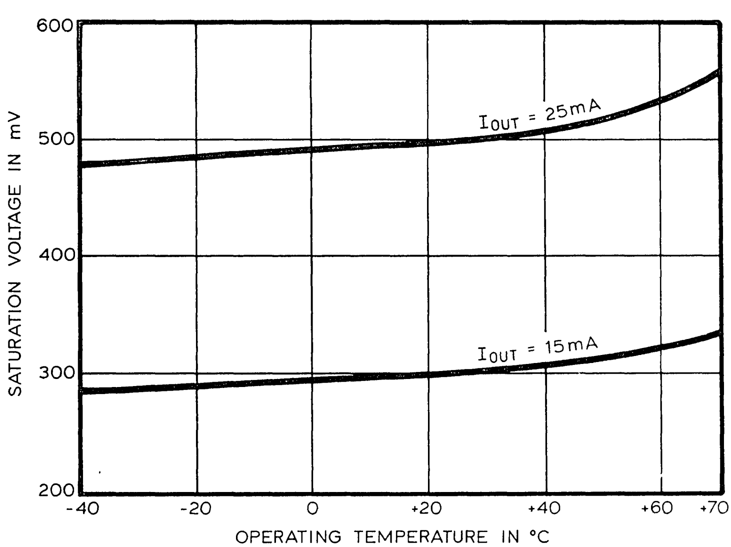
Characteristic	Symbol	Test Conditions	Limits Min.	Limits Typ.	Limits Max.	Units
Supply Voltage Range	V_{CC}		4.0	6.0	15	V
Supply Current	I_{CC}		—	4.0	8.0	mA
Light Threshold Level	E_{ON}	Output ON	45	55	65	$\mu W/cm^2$
	E_{OFF}	Output OFF	—	62	—	$\mu W/cm^2$
Hysteresis	ΔE	$(E_{OFF} - E_{ON})/E_{OFF}$	10	13	16	%
Output ON Voltage	V_{OUT}	$I_{OUT} = 15$ mA	—	300	500	mV
		$I_{OUT} = 25$ mA	—	500	800	mV
Output OFF Current	I_{OUT}	$V_{OUT} = 15$ V	—	—	1.0	μA
Output Fall Time	t_f	90% to 10%	—	200	500	ns
Output Rise Time	t_r	10% to 90%	—	200	500	ns

RELATIVE SPECTRAL RESPONSE AT T_A = +25°C AS A FUNCTION OF WAVELENGTH OF LIGHT



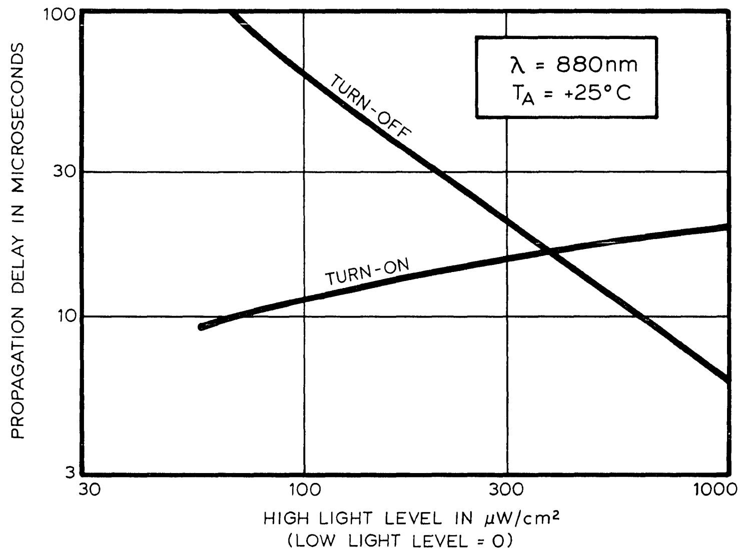
Dwg. No. A-12,135A

OUTPUT SATURATION VOLTAGE AS A FUNCTION OF OPERATING TEMPERATURE



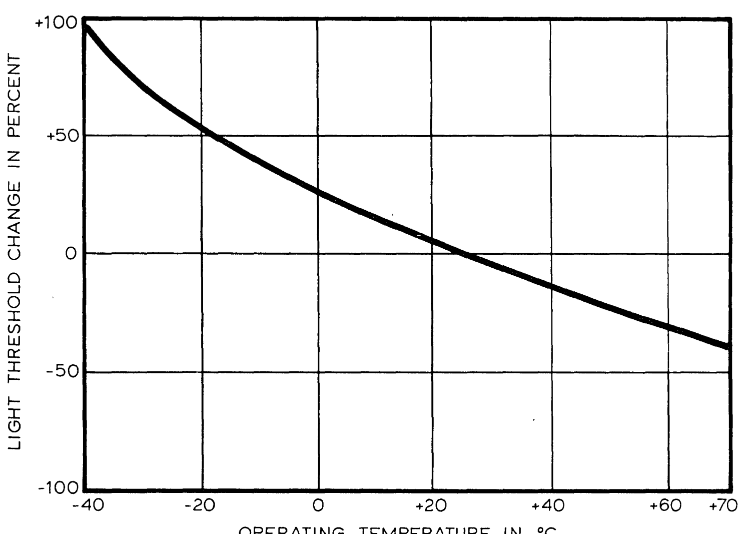
Dwg. No. A-12,307

**PROPAGATION DELAY
AS A FUNCTION OF LIGHT LEVEL**



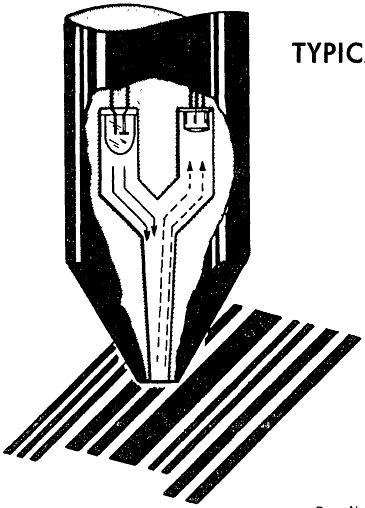
Dwg. No. A-12,308

**LIGHT-THRESHOLD CHANGE
AS A FUNCTION OF OPERATING TEMPERATURE**



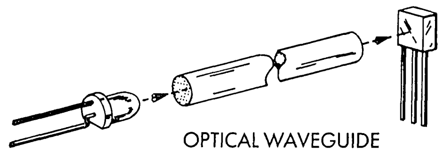
Dwg No A-12,309

TYPICAL APPLICATIONS*



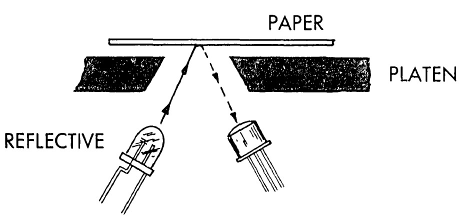
Dwg. No A-13,266

BAR CODE READER

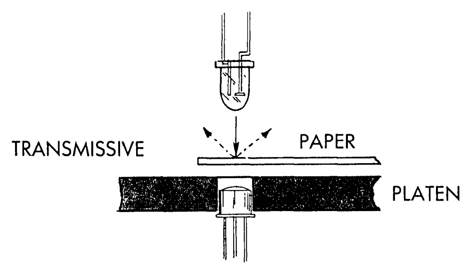


Dwg. No. A-13,267

OPTICAL ISOLATOR



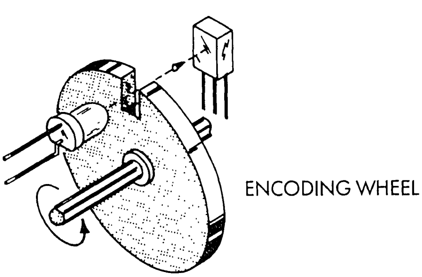
Dwg. No. A-13,268



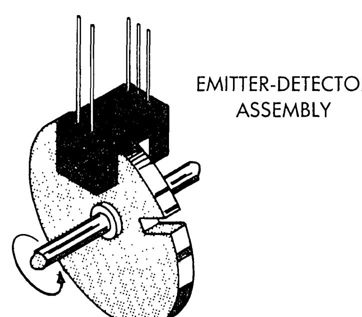
Dwg. No A-13,269

SHEET DETECTOR

5



Dwg. No A-13,270



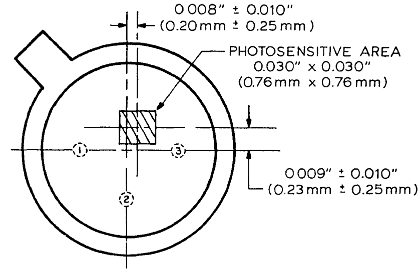
Dwg No. A-13,271

OPTICAL ENCODER

*Optics and ambient light shields omitted for clarity.

'D' PACKAGE

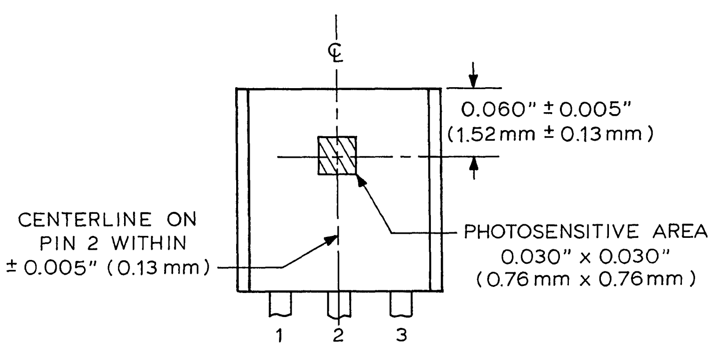
SENSOR-CENTER LOCATION



Dwg. No A-13,302

'T' PACKAGE

SENSOR-CENTER LOCATION



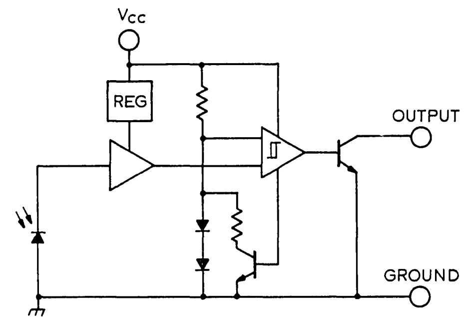
Dwg. No. A-13,301 A

ULN-3332M AND ULN-3333M MULTICHANNEL OPTOELECTRONIC SWITCHES

FEATURES (Each Channel)

- Photodiode with
  On-Chip Amplifier
  On-Chip Comparator with Hysteresis
  On-Chip Output Driver
  ON-Chip Voltage Regulator
- Sensitive Switch Points
- Accurate Element Placement
- Operation to 30 kHz

FUNCTIONAL BLOCK DIAGRAM
(EACH CHANNEL)



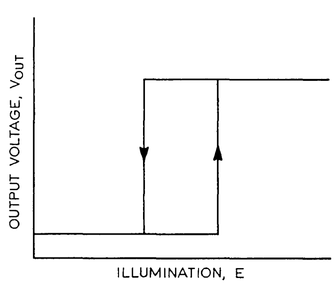
Dwg. No. A-13,264

Sprague ULN-3332M and ULN-3333M optoelectronic switches provide multichannel light detection and low-level signal processing in a single eight-lead package. These monolithic integrated circuits, requiring no external components, meet the need for accurate cost-effective light-sensing devices. Their high sensitivities and narrow switch point ranges make them ideal devices for use in optical encoding applications.

Each optoelectronic IC includes a 30-mil by 30-mil photodiode, a high-gain current amplifier, a comparator with 13 percent hysteresis, an output driver stage, and a voltage regulator. Each channel turns ON as the illumination of the photodiode falls below 55 μW/cm^2 at 880 nm. An internal latch provides hysteresis. The output turns OFF when the illumination surpasses the turn-ON threshold by typically 13 percent. The ULN-3332M has two channels, while the ULN-3333M offers three channels. These devices also have a low-power analog output per channel for phase detection.

Each channel in the ULN-3332M and the ULN-3333M have buffered open-collector outputs for current-sink applications. Typical loads include incandescent lamps, LED's sensitive relays, and microprocessor inputs. Both devices are supplied in a miniature, clear plastic, eight-lead dual in-line package.

TYPICAL TRANSFER CHARACTERISTICS



Dwg. No A-11,128

ABSOLUTE MAXIMUM RATINGS

Supply Voltage, V_{CC}	15 V
Output Voltage, V_{OUT}	15 V
Output Current, I_{OUT}	25 mA
Operating Temperature Range, T_A	−40°C to +70°C
Storage Temperature Range, T_S	−55°C to +110°C

5

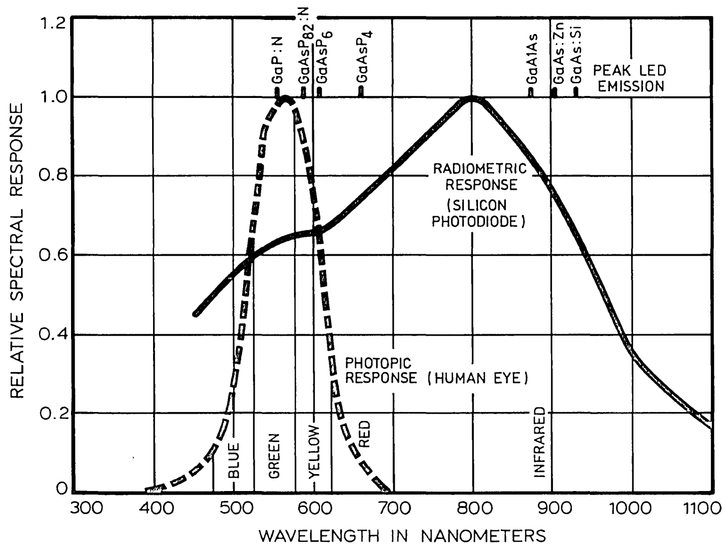
ELECTRICAL CHARACTERISTICS at T_A = +25°C, V_{CC} = 6.0 V, λ = 880 nm (Each Channel)

			Limits			
Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Supply Voltage Range	V_{CC}		4.0	6.0	15	V
Supply Current	I_{CC}		—	4.0	8.0	mA
Light Threshold Level	E_{ON}	Output ON	45	55	65	μW/cm²
	E_{OFF}	Output OFF	—	62	—	μW/cm²
Hysteresis	ΔE	$(E_{OFF} - E_{ON})/E_{OFF}$	10	13	16	%
Analog Output	V_{ON}	$E \leq E_{OFF}$	—	22	—	μV/μW/cm²
Analog Output Voltage Range	V_{ON}		0	—	2.1	V
Output ON Voltage	V_{OUT}	I_{OUT} = 15 mA	—	300	500	mV
		I_{OUT} = 25 mA	—	500	800	mV
Output OFF Current	I_{OUT}	V_{OUT} = 15 V	—	—	1.0	μA
Output Fall Time	t_f	90% to 10%	—	200	500	ns
Output Rise Time	t_f	10% to 90%	—	200	500	ns

PINOUT

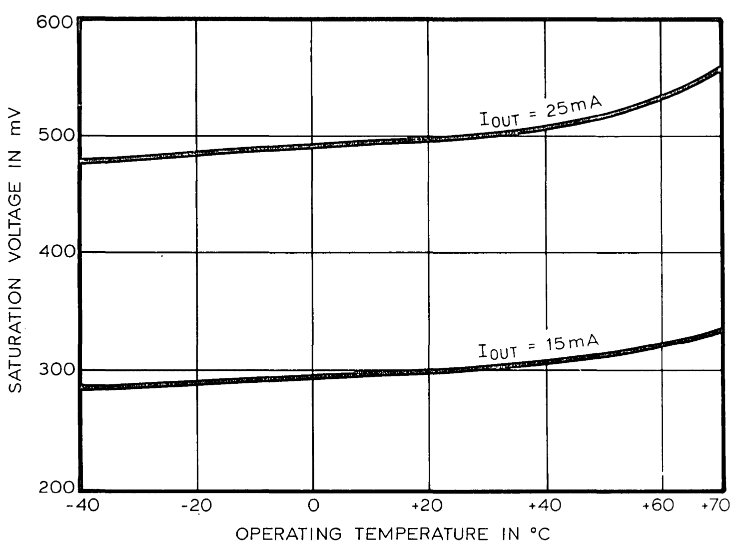
	Device Type	
Pin #	ULN-3332M	ULN-3333M
1	Analog Out 1	Digital Out 1
2	Digital Out 1	Analog Out 2
3	GND 2	Digital Out 2
4	Analog Out 2	Analog Out 3
5	Digital Out 2	Digital Out 3
6	No Connection	V_{CC}
7	V_{CC}	GND
8	GND 1	Analog Out 1

RELATIVE SPECTRAL REPSONSE AT T_A = +25°C
AS A FUNCTION OF WAVELENGTH OF LIGHT



Dwg No A-12,135A

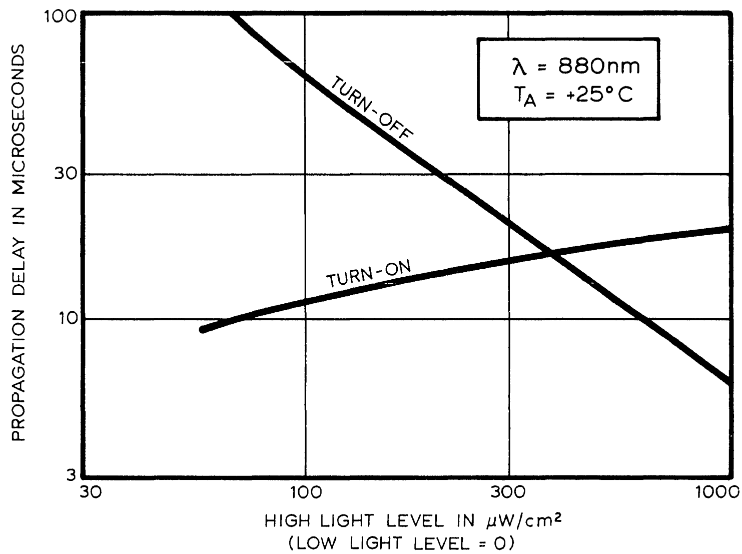
OUTPUT SATURATION VOLTAGE
AS A FUNCTION OF OPERATING TEMPERATURE
(EACH CHANNEL)



Dwg. No. A-12,307

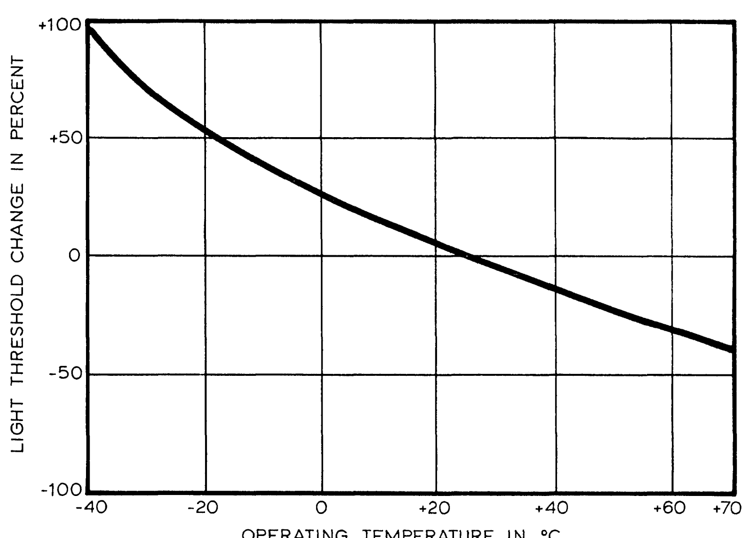
5

**PROPAGATION DELAY
AS A FUNCTION OF LIGHT LEVEL**



Dwg. No. A-12,308

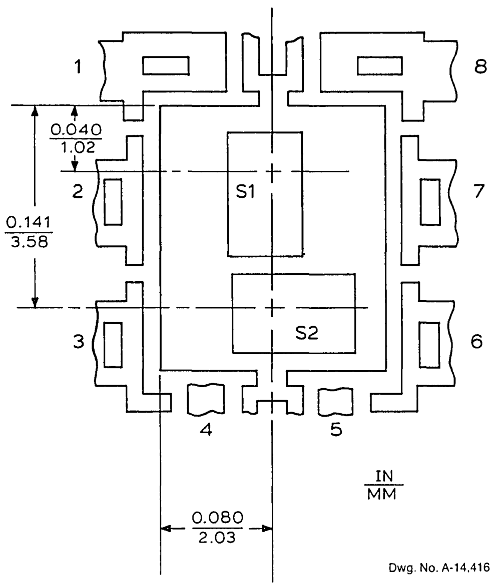
**LIGHT-THRESHOLD CHANGE
AS A FUNCTION OF OPERATING TEMPERATURE**



Dwg. No. A-12,309

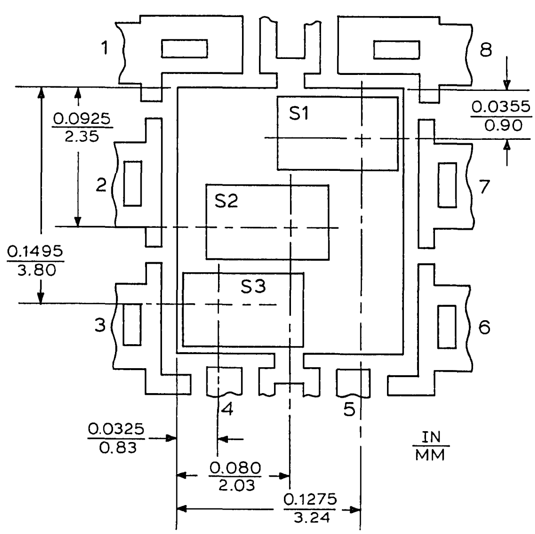
SENSOR CENTER LOCATIONS

ULN-3332M



Dwg. No. A-14,416

ULN-3333M



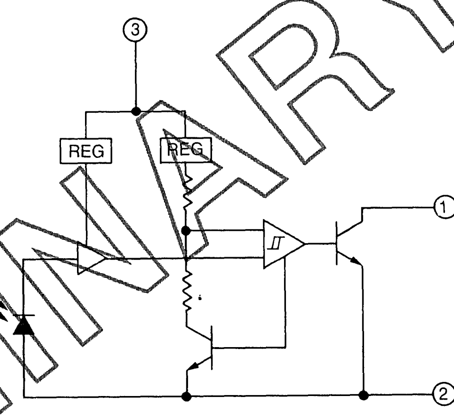
Dwg. No A-14,417

5

ULN-3390D AND ULN-3390T OPTOELECTRONIC SWITCHES—TWILIGHT SENSORS

FEATURES
- Photodiode with On-Chip
  Amplifier
  Comparator
  Output Driver
  Voltage Regulator
- 20 μW/cm² and 10 μW/cm² Trip Points
- 50% Hysteresis
- Temperature Compensation
- Operation to 30 kHz
- Plastic or Hermetic Package

FUNCTIONAL BLOCK DIAGRAM



Dwg No. W-154

Designed for use in twilight sensing applications and in emergency and outdoor lighting, the Type 3390 optoelectronic switch is a monolithic integrated circuit containing a photodiode, low-level amplifier, comparator, voltage regulator, and output driver. The comparator is fabricated to give the sensor a built-in typical hysteresis value of 50 percent.

With temperature-compensated trip points, protection against damage by bright light, and increased hysteresis values, the ULN-3390 represents a significant design improvement over previous opto-electronic switches. The integrated sensors are more stable over time and temperature than cadmium sulfide cell assemblies, require fewer components, and have calibrated switching characteristics.

The ULN-3390D and ULN-3390T switches typically turn ON as illumination falls below 10 μW/cm² at 880 nm. Internal hysteresis prevents deactivation until illumination exceeds 20 μW/cm². The switching points can be factory-adjusted to customer specifications.

The ULN-3390D is furnished in a hermetically sealed metal package with a glass end cap. The "D" package conforms to JEDEC outline TO-52 (TO-206AC). ULN-3390T is supplied in a three-lead clear plastic package 0.080" (2.03 mm) thick.

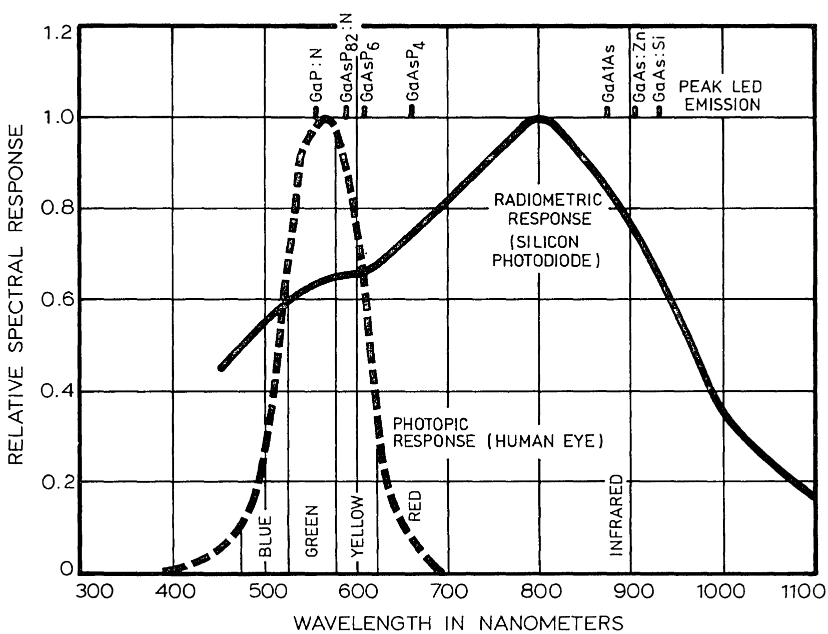
ABSOLUTE MAXIMUM RATINGS

Supply Voltage, V_{CC}	25 V
Output Voltage, V_{OUT}	25 V
Output Current I_{OUT}	25 mA
Operating Temperature Range, T_A	−40°C to +85°C
Storage Temperature Range, T_S	
(ULN-3390D)	−55°C to +125°C
(ULN-3390T)	−55°C to +110°C

ELECTRICAL CHARACTERISTICS at $T_A = +25°C$ (unless otherwise noted)

Characteristic	Symbol	Test Conditions	Limits Min.	Typ.	Max.	Unit
Supply Voltage Range	V_{CC}	$-40°C < T_A < +85°C$	4.0	—	16	V
Supply Current	I_{CC}	$-40°C < T_A < +85°C$, $V_{CC} = 5V$, $E > 20\mu W/cm^2$	—	3.0	10	mA
Output Saturation Voltage	$V_{CE(sat)}$	$I_{OUT} = 15$ mA, $E \leq 6\mu W/cm^2$, $-40°C < T_A < +85°C$	—	300	400	mV
Output Leakage Current	I_{OUT}	$V_{OUT} = 15$ V, $E > 20\mu W/cm^2$, $-40°C < T_A < +85°C$	—	0.1	10	µA
Output Rise Time	t_r	10% to 90%	—	200	500	ns
Output Fall Time	t_f	90% to 10%	—	200	500	ns
Light Threshold Level	E_{ON}	Output On, $V_{CC} = 5V$, $\lambda = 880$ nm	6.0	10	14	$\mu W/cm^2$
	E_{OFF}	Output Off, $V_{CC} = 5V$, $\lambda = 880$ nm	—	20	—	$\mu W/cm^2$
Hysteresis	ΔE	$(E_{OFF}-E_{ON})/E_{OFF}$	45	50	55	%

RELATIVE SPECTRAL RESPONSE AT $T_A = +25°C$ AS A FUNCTION OF WAVELENGTH OF LIGHT

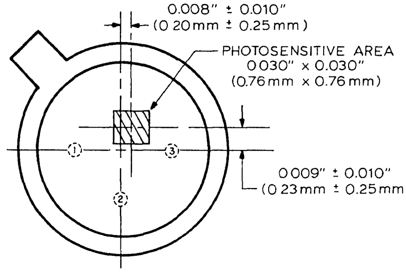


Dwg No A-12, 135A

ULN-3390D

SENSOR-CENTER LOCATION

'D'

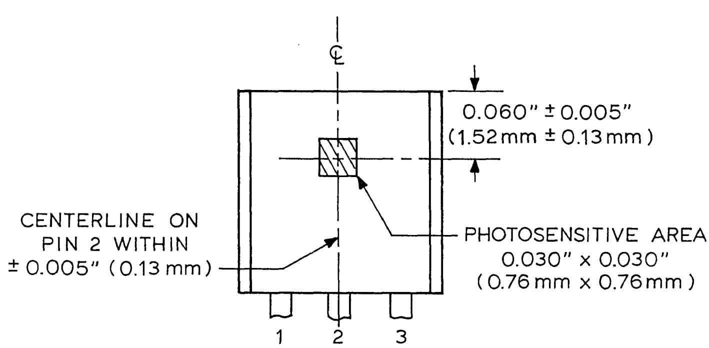


Dwg No. A-13,302

ULN-3390T

SENSOR-CENTER LOCATION

'T'



Dwg No. A-13,301 A

ULN-3395D AND ULN-3395T OPTOELECTRONIC SWITCHES

FEATURES

- Light Sensing Switch
- Photodiode with On-Chip
  Wide Bandwidth Amplifier
  Comparator with Hysteresis
  Voltage Regulator
- Propagation Delay $< 5\ \mu$sec
- Hysteresis Minimizes Switch Bounce
- 4.5 V to 16 V Operation
- Digital Compatible Output
- Plastic or Hermetic Package

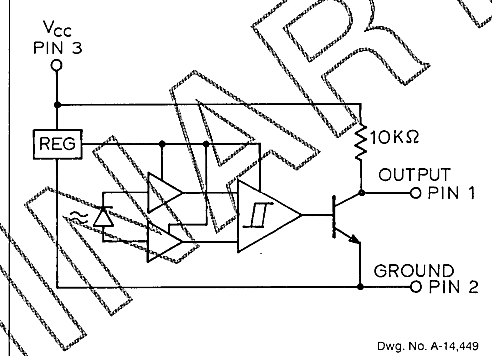
The Sprague Type ULN-3395 optoelectronic switches provide light detection and high speed signal processing in a single three leaded package. This monolithic integrated circuit requires no external components and provides a low cost solution for optical encoder/isolator applications.

Each sensor IC includes a light sensing photodiode, dual transimpedance amplifiers, Schmitt trigger, a bandgap voltage regulator, and a bipolar output stage capable of sinking up to 25 mA. The bandgap regulator allows use of this IC with supply voltages of 4.5 V to 16 V. On-chip temperature compensation circuitry allows the optical switch points to track AlGaAs LED emission at various ambient temperatures.

The ULN-3395 IC turns ON when the illumination at the photodiode is greater than 350 μW/cm². An internal latch provides hysteresis, disabling turn OFF until the light falls below 280 μW/cm². In both cases, the light source is assumed to be an AlGaAs LED. The output stage includes an internal 10 kΩ pull-up resistor that allows direct use with microprocessor and TTL logic.

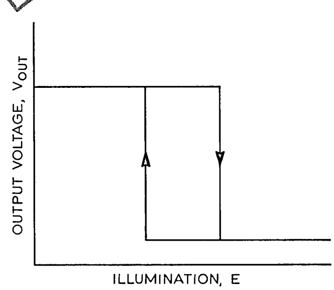
Type ULN-3395T and Type ULN-3395D are rated in operation over the temperature range of −40°C to +70°C. The ULN-3395T is supplied in a miniature three leaded plastic SIP only 0.080" (2.03 mm) thick. The ULN-3395D is supplied in a hermetically sealed, three pin 'D' package with a glass endcap which conforms to JEDEC outline TO-52 (TO-206AC).

FUNCTIONAL BLOCK DIAGRAM



Dwg. No. A-14,449

TYPICAL TRANSFER CHARACTERISTICS



Dwg. No. A-13,265

ABSOLUTE MAXIMUM RATINGS

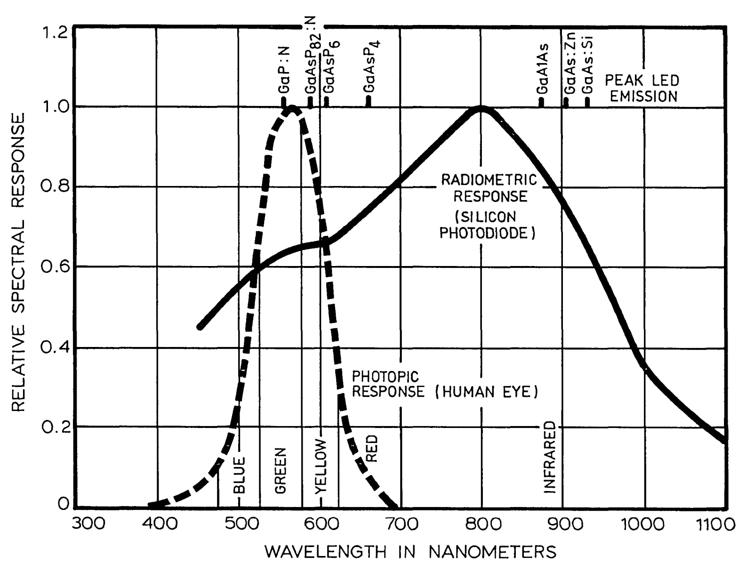
Supply Voltage, V_{CC}	25 V
Output Voltage, V_{OUT}	25 V
Output Current, I_{OUT}	30 mA
Operating Temperature Range	−40°C to +70°C
Storage Temperature Range	
Suffix 'D'	−55°C to +150°C
Suffix 'T'	−40°C to +110°C

5

ELECTRICAL CHARACTERISTICS at T_A = +25°C, V_{CC} = 6.0 V, λ = 880 nm

Characteristic	Symbol	Test Conditions	Limits Min.	Limits Typ.	Limits Max.	Units
Supply Voltage Range	V_{CC}		4.5	—	16	V
Supply Current	I_{CC}		—	5.0	8.0	mA
Light Threshold Level	E_{ON}	Output ON	—	350	—	μW/cm²
	E_{OFF}	Output OFF	—	280	—	μW/cm²
Hysteresis	ΔE	$(E_{OFF} - E_{ON})/E_{OFF}$	—	20	—	%
Output ON Voltage	V_{SAT}	I_{OUT} = 25 mA	—	400	600	mV
Output OFF Current	I_{OFF}	V_{OUT} = 16 V	—	—	1.0	μA
Propagation Delay	T_{PLH}	Output Low to High	—	3.0	5.0	μs
	T_{PHL}	Output High to Low	—	3.0	5.0	μs
Output Fall Time	t_f	90% to 10%	—	200	500	ns
Output Rise Time	t_r	10% to 90%	—	200	500	ns

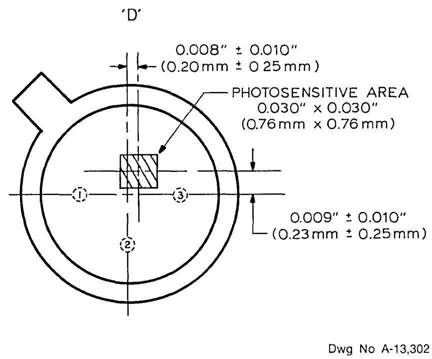
RELATIVE SPECTRAL RESPONSE AT T_A = +25°C
AS A FUNCTION OF WAVELENGTH OF LIGHT



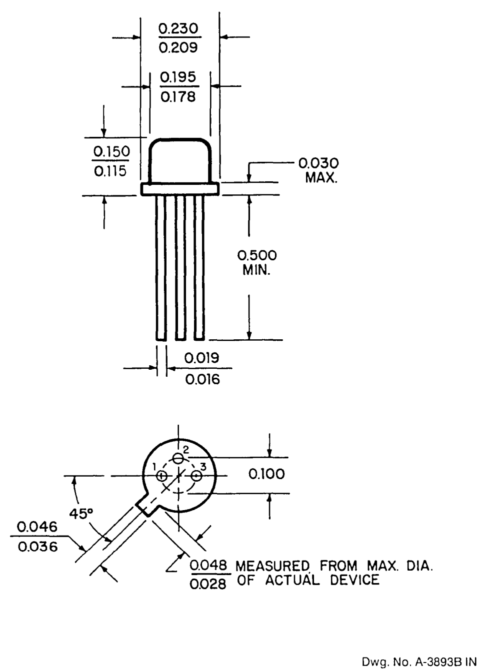
Dwg. No. A-12,135A

'D' PACKAGE

SENSOR-CENTER LOCATION



DIMENSIONS IN INCHES

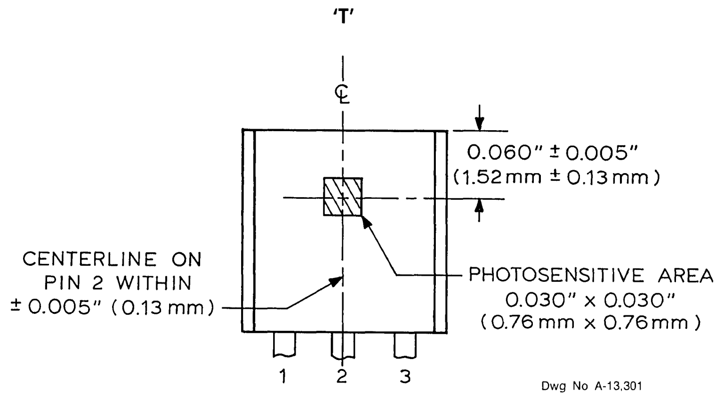


NOTE: Lead diameter is controlled in the zone between 0.050" (0.13 mm) and 0.250" (6.35 mm) from the seating plane. Between 0.250" (6.35 mm) and 0.500" (12.7 mm) from the seating plane, a maximum lead diameter of 0.021" (0.53 mm) is specified. Outside of these zones the lead diameter is not controlled.

5

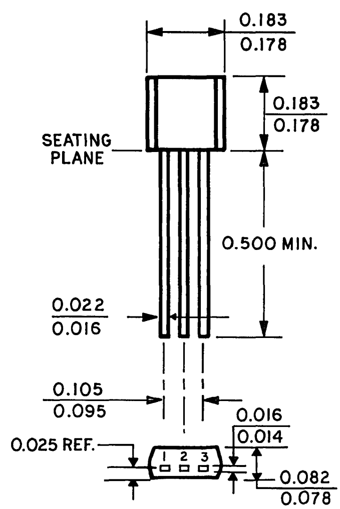
'T' PACKAGE

SENSOR-CENTER LOCATION



Dwg No A-13,301

DIMENSIONS IN INCHES



Dwg No. A-12,139 IN

NOTE: Lead dimensions are controlled in the zone between 0.050" (0.13 mm) and 0.250" (6.35 mm) from the seating plane. Between 0.250" (6.35 mm) and 0.500" (12.7 mm) from the seating plane, a maximum lead diameter (diagonal dimension) of 0.021" (0.53 mm) is specified. Outside of these zones the lead dimensions are not controlled.

NOTES

NOTES

SECTION 6—SPECIAL-PURPOSE SENSORS

6

APPLICATION-SPECIFIC SENSORS

The Sensor Division of Sprague has developed, through an extensive research and development program, the most advanced Hall Effect sensors. The design of these sensors offers the end-user the most simplified means of installation and a cost-effective approach to contactless switching and sensing. In this section, you will find sensors that detect the presence or absence of ferrous metal; ferrous metal gear teeth, and notches in ferrous metal. PowerHall™ latches that have the capabilities of driving inductive and resistive load of up to 300 mA are available and PowerHall™ switches are planned. A revolutionary dual output switch is available for sensing of both the North and South poles of a ring magnet. All of these sensors have incorporated the latest in sensor design technology and the highest standards of reliability.

Calibrated Linear Magnetic Sensors

Calibrated magnetic sensors are available from the factory for use in precision designs. The UGN-3503U is a low temperature calibrated linear supplied with a calibration sheet. Its primary use is in low-cost prototyping situations where accurate magnetic measurements are essential. The UGN-3604K is a calibrated Hall element based on the UGN-3605K family, which may also be used in prototyping applications.

Gear Tooth Sensor

Our new gear tooth sensor product line capitalizes on the superior characteristics of our high-quality Hall Effect switches. In situations which require sensing of a moving ferrous target down to 0 rpm at temperatures ranging from −40°C to +150°C, the Sprague gear tooth sensor is the sensor of choice.

The gear tooth sensor uses an amplified output derived from Hall Effect IC magnetic sensors to trip an onboard Schmitt trigger. The trigger points are trimmed at the factory to provide consistent circuit operating parameters.

Sensor performance is based on the target's magnetic properties, geometry and temperature. Target design assistance is available at the factory.

Dual Output Hall Effect Switch

Brushless dc motor commutation is electronically controlled by magnetic sensing Hall Effect switches (see UGN-3075U, UGN-3275K). A major issue in reliability and efficiency is crossover distortion caused by a lack of delay between energizing of the coils. The UGN-3235 senses both North and South poles and provides two outputs, each of which may be used to control the energizing of a motor winding. This results in a guaranteed delay in the switching of coils and windings.

This unique dual output sensor is temperature compensated to operate over a wide range of temperatures and is available in a miniature 4-lead package. Contact the factory for more information or applications support.

PowerHall™ Switches and Latches

Selected Hall Effect ICs are available with high current sink capabilities. The UGN-5275K is a dual output latch with 300 mA typical sink capabilities designed for use in brushless motor applications. In addition to this device, high power switches are also being designed for all switch families. For more information contact the factory.

SELECTION GUIDE

(In Order of Device Function)

Function	Output	Max. I_{SINK}	Device Type	Page
Digital Gear Tooth Sensor	Open-Collector	25 mA	UGN/S-3056U	6-3
Dual Output Hall Effect Switch	Dual Open-Collector	25 mA	UGN-3235K	6-7
Dual Output PowerHall™ Latch	Dual Open-Collector	.5 A	UGN-5275 UGN-5276 UGN-5277	6-9

UGN-3056U AND UGS-3056U BIPOLAR DUAL HALL ELEMENT DIGITAL GEAR TOOTH SENSOR

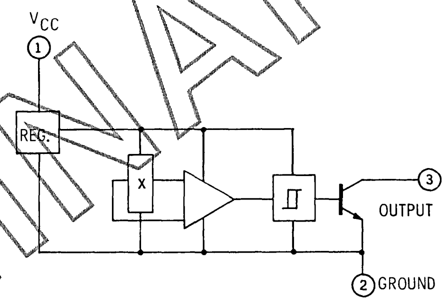
FEATURES

- Senses Ferrous Targets down to 0 rpm.
- Wide Operating Temperature Range (− 40°C to + 150°C).
- Wide Range of Effective Air Gaps.
- 4.5 V to 18 V Supply Voltage Range.
- Fast Operating Speed (100 kHz).
- Output Compatible with all Digital Logic Families.

APPLICATIONS

- Rotational Position Sensor
  Gear Tooth Sensor
  Slot Sensor
  Crankshaft Sensor
  Tachometer Sensor
  Counter
- Linear Position Sensor
  Fluid Level Sensor
  Slot Sensor

FUNCTIONAL BLOCK DIAGRAM



Dwg. No. A-11,002A

The digital Hall Effect gear tooth sensor is an extremely sensitive device made possible by Sprague breakthroughs in Hall-sensor design and technology. The sensors have superior magnetic characteristics, operate over a wide range of air gaps, and are very stable over a wide temperature range (− 40°C to + 150°C). On-chip temperature compensation circuitry minimizes shifts in effective working air gap, and switch points over temperature.

Each Hall Effect digital gear tooth sensor IC includes a voltage regulator, quadratic Hall voltage generator, temperature stability circuit, signal amplifier, Schmitt trigger, and open collector output on a single silicon chip. The on-board regulator permits operation with supply voltages of 4.5 V to 18 V. The switches' output can sink up to 20 mA at a conservatively-rated repetition rate of 100 kHz. These devices can be used with bipolar or MOS logic circuits.

Optimum gear tooth sensor performance is dependent on careful design and implementation of the magnetic circuit in which the sensor is one component. The magnetic circuit consists of the gear tooth sensor IC, magnet, ferrous metal target and immediate surrounding environment. Careful attention to magnet selection and target design results in larger functional air gaps and lower magnet costs.

The gear tooth sensor switches on and off in response to flux density gradients of sufficient magnitude. (The appropriate switch points for your application should be determined in consultation with applications engineers at the factory. Circuit switch points are also adjusted there.) Large flux density gradients are developed across ferrous metal —air interfaces such as a gear tooth, gear slot boundary. Proper target design and magnet selection maximizes these flux density gradients and thereby optimizes the effect working air gap of the overall gear tooth assembly.

The gear tooth sensor IC is offered in a three-pin plastic package—the 60 mil (1.54 mm) thin, 178 mil square magnetically optimized "U" package (see Section 8 for the package dimensions).

ABSOLUTE MAXIMUM RATINGS

Power Supply V_{CC} .... 18 V
Magnetic Flux Density .... Unlimited
Output OFF Voltage .... 18 V
Output ON Current, I_{SINK} .... 25 mA
Operating Temperature Range, T_A .... $-40°C$ to $+150°C$
Storage Temperature Range, T_S .... $-65°C$ to $+170°C$*

*Devices can be stored at $+200°C$ for short periods of time.

ELECTRICAL CHARACTERISTICS at $T_A = +25°C$, $V_{CC} = 4.5$ V to 18 V (unless otherwise noted)

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Supply Voltage	V_{CC}		4.5	—	18	V
Output Saturation Voltage	$V_{CE(sat)}$	$\triangle B > 100G$, $V_{CC} = 18$ V, $I_{SINK} = 20$ mA	—	—	400	mV
Output Leakage Currrent	I_{OFF}	$\triangle B < -100G$, $V_{CC} = V_{OUT} = 18$ V	—	—	10	μA
Supply Current	I_{CC}	$\triangle B < -100G$, $V_{CC} = 18$ V, Output Open	—	—	9.0	mA
Output Rise Time	t_r	$V_{CC} = 12$ V, $R_L = 820$, $C_L = 20$ pF	—	—	2.0	μs
Output Fall Time	t_f	$V_{CC} = 12$ V, $R_L = 820$, $C_L = 20$ pF	—	—	2.0	μs

MAGNETIC CHARACTERISTICS

	$T_A = +25°C$		$T_A = 40°C$ to $+150°C$		
Characteristic	Min.	Max.	Min.	Max.	Units
Operate Point, B_{OP}	-200	50	-200	50	G
Release Point, B_{RP}	-250	0	-250	0	G
Hysteresis, B_H	40	70	40	70	G

APPLICATION NOTES

Optimum gear tooth sensor performance is dependent on careful design and implementation of the magnetic circuit in which the sensor is one component. The magnetic circuit consists of the gear tooth sensor IC, magnet, ferrous metal target and the immediate surrounding environment. Careful attention to magnet selection and target design results in larger functional air gaps and lower magnet costs.

Target Material and Geometry

The best ferrous target materials are cold rolled steels (1010 to 1070 grades). Sintered metal compounds are also usable but care must be taken to insure uniform composition and density of the target. Heat treatment to mechanically harden targets may deteriorate their magnetic goodness. Such treatments should be minimized.

Figures 1 through 3 can be used to determine the tooth width, height and window spacing needed to operate at a particular effective air gap at 25°C. These figures are based on factory measurements using a particular magnet and gear tooth sensor IC assembly. (Contact the factory for details.) If the target is a gear with a known diametral pitch, consult Figure 4.

Magnet Material and Geometry

The rare earth magnetic materials are the magnetic materials of choice in gear tooth sensing applications. They are more expensive than Alnico and ceramic magnets, but their ten fold higher maximum energy products and small thermal coefficients make larger effective working air gaps possible. For additional information on magnets and a list of magnet vendors, see Section 7, Applications.

The pole face of the magnet must be at least twice the size of the device package. The length of the magnet will determine the "reach out" of the magnet and hence the effective working air gap of the overall assembly. The longer the magnet, the greater will be the effective working air gap.

The flux density across the pole face of a magnet is not uniform. It is higher in the center and falls off toward the sides. Because the gear tooth sensor IC senses flux density gradients, it is necessary to position the IC on the magnet pole face such that the flux density gradient is minimized across the IC surface. Positioning the IC in the center of the magnet pole face usually insures this. Additional steps can be taken to linearize the pole face flux density gradient. This includes the addition of a pole piece to the pole face of the magnet.

Gear Tooth Sensor Assembly Operating Parameters

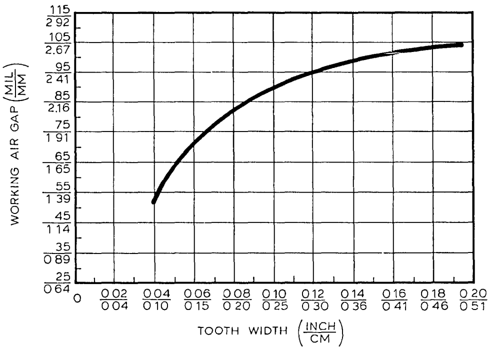
The operating characteristics of the *gear tooth sensor IC* are specified in terms of operate and release points and hysteresis over the desired temperature range. On-chip temperature compensation circuitry minimizes shifts in operate and release points and hysteresis. On the higher functional level, these parameters translate into minimal shifts in effective working air gap and switch point variability over temperature.

The operating characteristics of the *gear tooth sensor assembly* are most often specified in terms of effective working air gap, switch point variability and pulse width. Each of these assembly specifications depends on the target and magnet materials and geometries as well as on the IC operate and release points. Consult Figures 1 and 3 to select the necessary target dimensions in order to obtain a reasonable working air gap and pulse width for the intended application. Once the target is available, obtain a flux density map of the target, determine the flux density gradient and the operate and release points necessary to obtain the desired pulse width. Before the latter steps are taken, consult the factory to insure the most cost-effective choices.

Guide to Installation

All Hall Effect integrated circuits are susceptible to mechanical stress effects. Caution should be exercised to minimize the application of stress to the leads or the epoxy package. Glues and potting compounds shrink while curing and can shift the operating parameters of a Hall Effect device.

To prevent permanent damage to the Hall cell, heat-sink the leads during hand-soldering. Recommended maximum conditions for wave soldering are provided in Section 8, Packages.



Dwg No. A-14,446

Figure 1
Working Air Gap vs Tooth Width

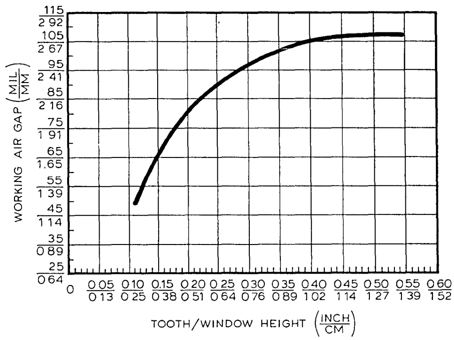


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Figure 2
Working Air Gap vs Tooth/Window Height

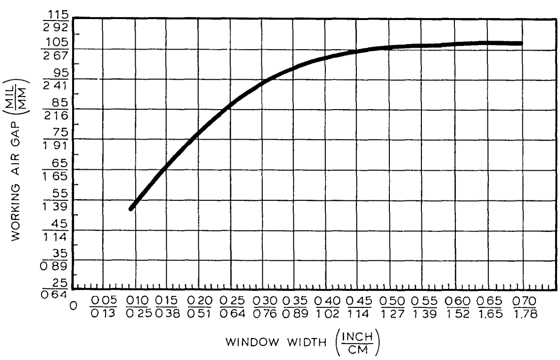

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Figure 3
Working Air Gap vs Window Width

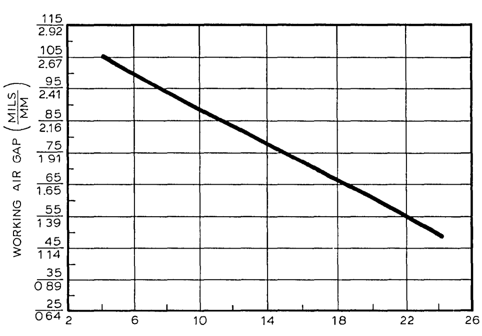

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Figure 4
Effective Working Air Gap vs Diametral Pitch
Temperature = 25°C

UGN-3235K
HALL EFFECT DIGITAL DUAL OUTPUT SWITCH

FEATURES

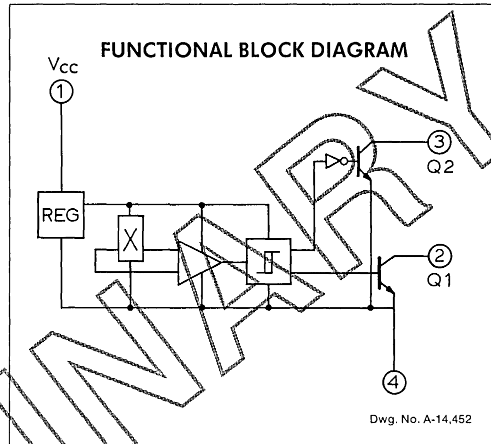
- Magnetic Sensing Switch
- Dual outputs independently activated by North and South Pole Fields
- Independent actuation of outputs eliminates motor switching transients
- Hysteresis minimizes stray field effects
- 4.5 V to 24 V operation
- Digital compatible outputs

The Sprague Type UGN-3235K switching Hall Effect sensor is a bipolar integrated circuit designed for electronic commutation in brushless DC motors. The device features dual independently activated outputs. These devices are typically used to sense multi-pole, rotating ring magnets and to generate timing pulses for use in brushless DC motor and other multi-pole sensing applications.

Each sensor IC includes a Hall voltage generator, operational amplifier, two Schmitt triggers, a voltage regulator, and dual bipolar output transistors. The regulator allows use of this IC with supply voltages of 4.5 V to 24 V. On-chip temperature compensation minimizes switch point drifts with changing ambient temperature.

Each open collector output is independently activated by the incident magnetic flux. Output Q1 is activated and deactivated by changing South pole flux while output Q2 responds to changing North pole flux. This action is illustrated in the Output Switching Characteristics figure. The indepenent actuation of the two outputs causes a built in switching delay that is dependent on the rate of change of the magnetic field. The delay ensures that the two outputs are never ON at the same time, hence eliminating crossover distortion in motor coil drivers. An added benefit of this switching scheme is the ability to sense each pole of a ring magnet, which doubles the resolution of rotary position magnetic encoders.

Type UGN-3235K is rated in operation over the temperature range of $-20°C$ to $+85°C$. Higher temperature ranges may be obtained from the factory. The dual output sensors are supplied in a four-pin plastic SIP, .0200″ (5.08 mm) wide, 0.130″ (3.3 mm) high, and 0.060″ (1.54 mm) thick.



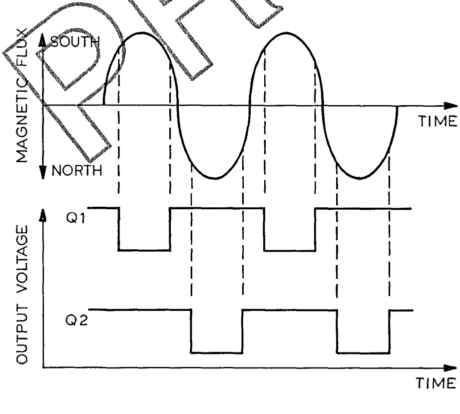


Figure 1
Output Switching Characteristics

ABSOLUTE MAXIMUM RATINGS

Power Supply V_{CC}	25 V
Magnetic Flux Density, B	Unlimited
Output OFF Voltage	25 V
Output ON Current, I_{SINK}	50 mA
Operating Temperature Range, T_A	$-20°C$ to $+85°C$
Storage Temperature Range, T_S	$-65°C$ to $+150°C$

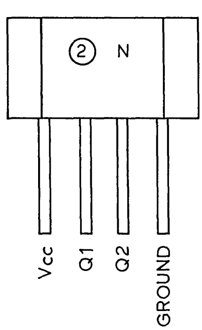
6

ELECTRICAL CHARACTERISTICS at T_A = +25°C, V_{CC} = 4.5 V to 24 V (unless otherwise noted)

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Supply Voltage	V_{CC}		4.5	—	24	V
Output Saturation Voltage	$V_{CE(sat)}$	V_{CC} = 24 V, I_{SINK} = 20 mA	—	—	400	mV
Output Leakage Currrent	I_{OFF}	V_{OUT} = 24 V, V_{CC} = 24 V	—	—	10	μA
Supply Current	I_{CC}	V_{CC} = 24 V, Output Open	—	—	7.0	mA
Output Rise Time	t_r	V_{CC} = 14 V, R_L = 820Ω, C_L = 20 pF	—	0.04	0.4	μs
Output Fall Time	t_f	V_{CC} = 14 V, R_L = 820Ω, C_L = 20 pF	—	0.18	0.4	μs

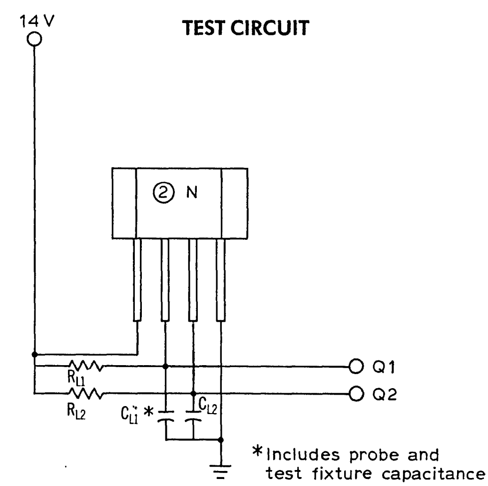
MAGNETIC CHARACTERISTICS

		T_A = +25°C			
Characteristic	Output	Min.	Typ.	Max.	Units
Operate Point, B_{OP}	Q1	—	150	—	G
	Q2	—	−150	—	G
Release Point, B_{RP}	Q1	—	125	—	G
	Q2	—	−125	—	G
Hysteresis, B_H	Q1	—	25	—	G
	Q2	—	−25	—	G



Dwg. No. A-14,453

TEST CIRCUIT



Dwg. No. A-14,451

UGN-5275K THROUGH UGN-5277K DUAL COMPLEMENTARY OUTPUT POWERHALL™ LATCHES

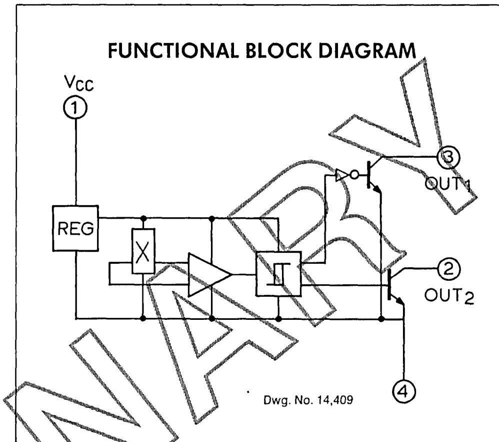
FEATURES

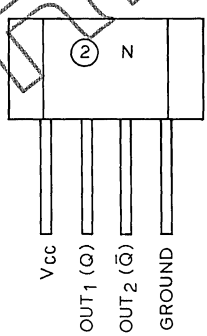
- Magnetic sensing, dual output latch
- On-chip Schmitt trigger with hysteresis
- Temperature compensated switch points
- High current sink capability
- Low profile SIP

Sprague Type UGN-5275, UGN-5276, and UGN-5277 latching Hall Effect sensors are bipolar integrated circuits designed for electronic commutation in brushless DC motors. All three types feature dual complementary power outputs that are capable of sinking up to 300 mA. The latches are typically used to sense matched magnetic flux densities of alternating polarity from multi-pole ring magnets.

Each sensor IC includes a Hall voltage generator, operational amplifier, Schmitt trigger, voltage regulator, and dual bipolar output transistors. The regulator allows use of the integrated circuit with supply voltages of 4.5 V to 14 V. On-chip compensation circuitry enhances switch point performance over temperature. Large bipolar output transistors are fed by a unique driver stage that minimizes power dissipation in the IC. The magnetic operation of this IC is similar to that of the UGN-3275K dual output Hall Effect latch.

The open collector output Q of the IC switches low when the sensor is exposed to a magnetic field greater than its rated operate point. Output Q̄bar switches high at approximately the same instant. When the sensor is exposed to a negative polarity magnetic field less than its release point, output Q switches high while Q̄bar switches low. The outputs, in their low state, are capable of sinking up to 300 mA. This feature enables the direct driving of high current loads, relays, and motor coils.





Dwg No. A-14,407A

Types UGN-5275K, UGN-5276K and UGN-5277K are rated for operation over the temperature range of −20°C to +85°C. The dual output Hall Effect latches are supplied in a four-pin plastic SIP, 0.200″ (5.08 mm) wide, 0.130″ (3.3 mm) high, and 0.060″ (1.54 mm) thick.

ABSOLUTE MAXIMUM RATINGS

Power Supply V_{CC}	14 V
Magnetic Flux Density, B	Unlimited
Output OFF Voltage	30 V
Output ON Current, I_{SINK}	.5 A
Operating Temperature Range, T_A	−20°C to +85°C
Storage Temperature Range, T_S	−65°C to +150°C

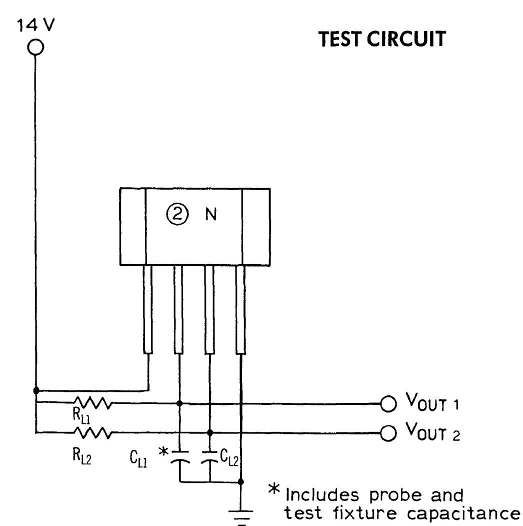
ELECTRICAL CHARACTERISTICS at T_A = +25°C, V_{CC} = 4.5 V to 14 V (unless otherwise noted)

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Supply Voltage	V_{CC}		4.5	—	14	V
Output Saturation Voltage	$V_{CE(sat)}$	V_{CC} = 14 V, I_{SINK} = 300 mA	—	400	—	mV
Output Leakage Currrent	I_{OFF}	V_{OUT} = 14 V, V_{CC} = 14 V	—	—	10	μA
Supply Current	I_{CC}	V_{CC} = 14 V, Output Open	—	—	30	mA
Output Rise Time	t_r	V_{CC} = 14 V, R_L = 45Ω, C_L = 20 pF	—	1.0	—	μs
Output Fall Time	t_f	V_{CC} = 14 V, R_L = 45Ω, C_L = 20 pF	—	1.0	—	μs
Switch Time Differential	Δt	V_{CC} = 14 V, R_L = 45Ω, C_L = 20 pF	—	1.0	—	μs

MAGNETIC CHARACTERISTICS

Characteristic	Device Type	T_A = +25°C		T_A = −20°C to +85°C		Units
		Min.	Max.	Min.	Max.	
Operate Point, B_{OP}	5275	50	250	50	250	G
	5276	50	350	50	350	G
	5277	25	150	15	200	G
Release Point, B_{RP}	5275	−250	−50	−250	−50	G
	5276	−350	−50	−350	−50	G
	5277	−150	−25	−200	−15	G
Hysteresis, B_H	All	100	—	100	—	G

TEST CIRCUIT



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NOTES

NOTES

SECTION 7—APPLICATIONS

7

HALL EFFECT IC APPLICATIONS GUIDE

Sprague Electric Company uses the latest bipolar integrated circuit technology in combination with the century-old Hall Effect to produce Hall Effect ICs. These are contactless, magnetically activated switches and sensors with the potential to simplify and improve systems.

Low-Cost Simplified Switching

Simplified switching is a Hall sensor's strong point. Sprague Hall Effect IC switches combine Hall voltage generators, signal amplifiers, Schmitt trigger circuits, and transistor output circuits on single integrated circuit chips. Output is clean, fast, and switched without bounce—an inherent problem with mechanical contact switches. A Sprague Hall Effect switch typically operates at up to a 100 kHz repetition rate, and costs less than many common electromechanical switches.

Efficient, Effective, Low-Cost Linear Sensors

The Sprague linear Hall Effect sensor detects the motion, position, or change in field strength of an electromagnet, a permanent magnet, or a ferromagnetic material with an applied magnetic bias. Energy consumption is very low. The output is linear and temperature-stable. The sensor's frequency response is flat up to approximately 25 kHz.

A Sprague Hall Effect sensor is more efficient and effective than inductive or optoelectronic sensors, and at a lower cost.

Sensitive Circuits For Rugged Service

The Hall Effect sensor is virtually immune to environmental contaminants and is suitable for use under severe service conditions. The circuit is very sensitive and provides reliable, repetitive operation in close tolerance applications. The Hall Effect sensor can see precisely through dirt and darkness.

Current Applications

Current applications for Sprague Hall Effect ICs include use in ignition systems, speed controls, security systems, alignment controls, micrometers, mechanical limit switches, computers, printers, disk drives, keyboards, machine tools, keyswitches, and pushbutton switches. They are also used as tachometer pickups, current limit switches, position detectors, selector switches, current sensors, linear potentiometers and brushless dc motor commutators.

THE HALL EFFECT SENSOR: HOW DOES IT WORK?

The basic Hall sensor is a small sheet of semiconductor material represented by **Figure 1.**

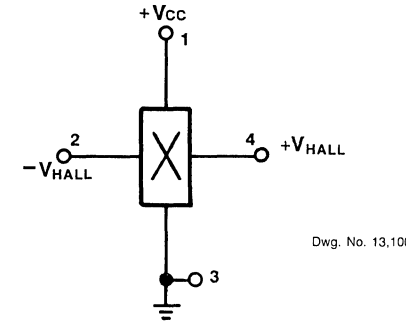

Figure 1

A constant voltage source, as shown in **Figure 2,** will force a constant bias current to flow in the semiconductor sheet. The output will take the form of a voltage measured across the width of the sheet that will have negligible value in the absence of a magnetic field.

If the biased Hall sensor is placed in a magnetic field with flux lines at right angles to the Hall current (**Figure 3**), the voltage output is directly proportional to the strength of the magnetic field. This is the Hall Effect, discovered by E. F. Hall in 1879.

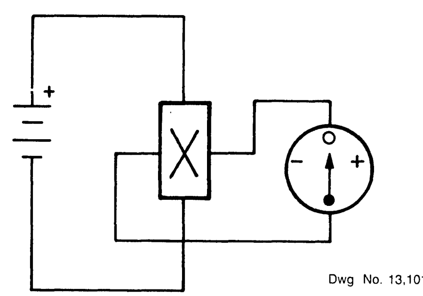

Figure 2

Linear Output Hall Effect Devices

The Sprague UGN-3605 integrated circuit is a Hall sensor in its simplest form. It is simply a Hall element that will give an output voltage response to applied magnetic field changes. Electrical connections for the UGN-3605 are shown in **Figure 1.** Sprague also provides a calibrated version of UGN-3605 with a calibration chart for engineering purposes.

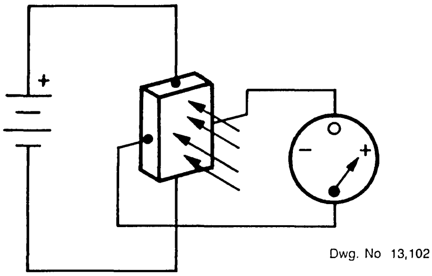

Figure 3

The output voltage of the UGN-3605 is quite small. This can present problems, especially in an electrically noisy environment. Addition of a stable high-quality dc amplifier and voltage regulator to the circuit (**Figures 4 and 5**) improves the transducer's output and allows it to operate over a wide range of supply voltages. The modified device provides an easy-to-use analog output that is linear and proportional to the applied magnetic flux density.

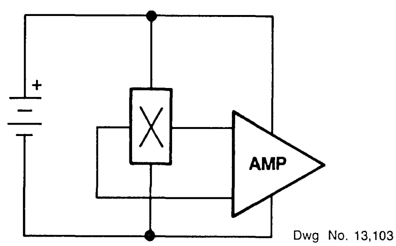

Figure 4

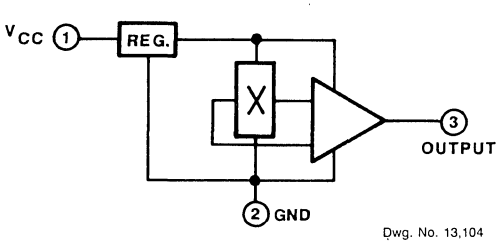

Figure 5

The Sprague UGN-3501 is this type of linear output device. In the three-lead "T" and "U" packages, the UGN-3501 is almost exactly the circuit described above. The UGN-3501 is also furnished in the "K" and "LI" package. In that case, it has a differential output and a pinout that can be used to establish an offset voltage null.

The UGN-3503 and UGS-3503 have improved sensitivity and temperature-stable characteristics. The output of Type 3503 is ratiometric; that is, its output is proportional to its supply voltage.

Digital Output Hall Effect Switches

The addition of a Schmitt trigger threshold detector with built-in hysteresis, as shown in **Figure 6,** gives the Hall Effect circuit digital output capabilities. When the applied magnetic flux density exceeds a certain limit, the trigger provides a clean transition from OFF to ON without contact bounce. Built-in hysteresis eliminates oscillation (spurious switching of the output) by introducing a magnetic dead zone in which switch action is disabled after the threshold value is passed.

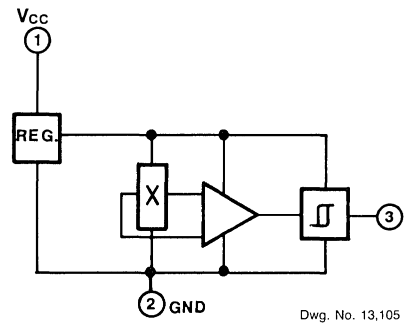

Figure 6

An open-collector NPN output transistor added to the circuit (**Figure 7**) gives the switch digital logic compatibility. The transistor is a saturated switch that shorts the output terminal to ground wherever the applied flux density is higher than the ON trip point of the device. The switch is compatible with all digital families. The output transistor can sink enough current to directly drive many loads, including relays, triacs, SCRs, LEDs, and lamps.

The circuit elements in **Figure 7,** fabricated on a monolithic silicon chip and encapsulated in a small epoxy or ceramic package, are common to all Sprague Hall Effect digital switches. Differences between device types are generally found in specifications such as magnetic parameters, operating temperature ranges, and temperature coefficients.

Operation

All Hall Effect devices are activated by a magnetic field. A mount for the the devices, and electrical connections, must be provided. Parameters such as load current, environmental conditions, and supply voltage must fall within the specific limits shown in the appropriate Sprague documentation.

Magnetic fields have two important characteristics—flux density and polarity (or orientation). In the absence of any magnetic field, most Sprague Hall Effect digital switches are designed to be OFF (open circuit at output). They will turn ON only if subjected to a magnetic field that has both sufficient density and the correct orientation.

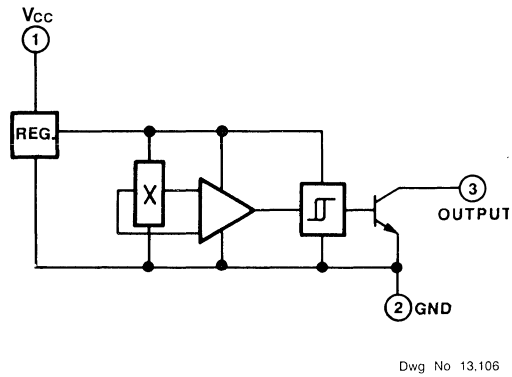

Figure 7

Sprague Hall switches have an active area that is closer to one face of the package (the face with the lettering, the branded face). To operate the switch, the magnetic flux lines must be perpendicular to this face of the package, and must have the correct polarity. If an approaching south pole would cause switching action, a north pole would have no effect. In practice, a close approach to the branded face of a Sprague Hall switch by the south pole of a small permanent magnet will cause the output transistor to turn ON (**Figure 8**).

A Transfer Characteristics Graph (**Figures 10 and 11**) plots this information. It is a graph of output as a function of magnetic flux density (measured in gauss) presented to the Hall cell. The magnetic flux density is shown on the horizontal axis. The digital output of the Hall switch is shown along the vertical axis.

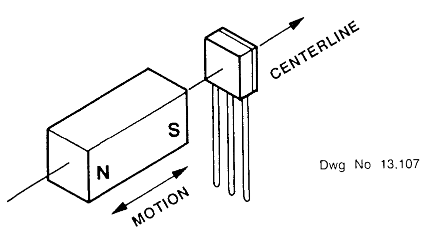

Figure 8

To acquire data for this graph, add a power supply and a pull-up resistor that will limit current through the output transistor and enable the value of the output voltage to approach zero (**Figure 9**).

In the absence of an applied magnetic field (0 G), the switch is OFF, and the output voltage equals the power supply (12 V). A permanent magnet's south pole is then moved perpendicularly toward the active area of the device. As the magnet's south pole approaches the branded face of the switch, the Hall cell is exposed to increasing magnetic flux density. At some point (240 G in this case), the output transistor turns ON and the output voltage goes to zero **(Figure 10)**. That value of flux density is called the operate point. If we continue to increase the field's strength, say to 600 G, nothing more happens. The switch turns ON once and stays ON.

To turn the switch OFF, the magnetic flux density must fall to a value far lower than the 240 G operate point because of the built-in hysteresis. For this example we use 90 G hysteresis, which means the device turns OFF when flux density decreases to 150 G (**Figure 11**). That value of flux density is called the release point.

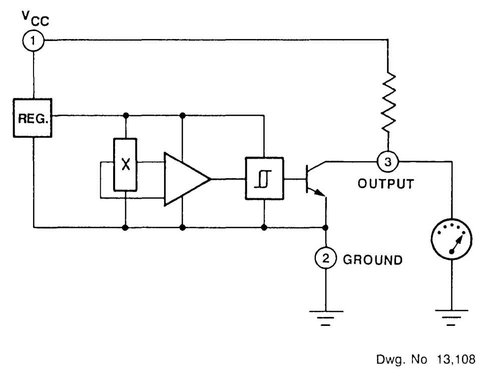

Figure 9

Characteristics and Tolerances

The exact magnetic flux density values required to turn Hall switches ON and OFF differ for several reasons, including design criteria and manufacturing tolerances. Extremes in temperature will also somewhat affect the operate and release points.

For each device type, Sprague provides worst-case magnetic characteristics for the operate value, the release value, and hysteresis. Maximum and minimum values for the magnetic parameters at the temperature extremes are shown in Table 1.

All Sprague switches are guaranteed to turn ON at or below the maximum operate point flux density. When the magnetic field is reduced, all devices will turn OFF before the flux density drops below the minimum release point value. Each device is guaranteed to have at least the minimum amount of hysteresis to ensure clean switching action. This hysteresis ensures that, even if mechanical vibration or electrical noise is present, the switch output is fast, clean, and occurs only once per threshold crossing.

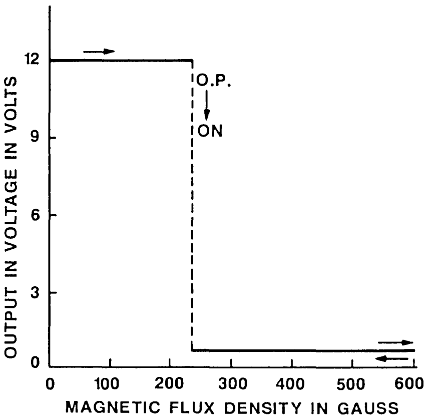

Figure 10

Dwg. No. 13,109

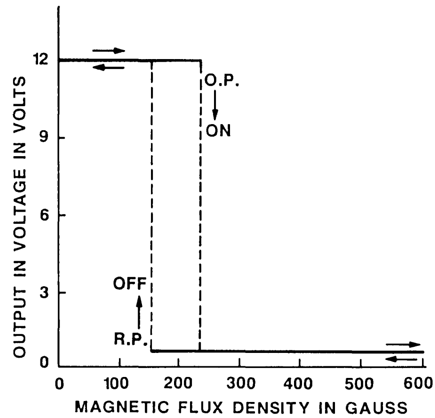

Figure 11

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TABLE 1

Characteristics of Hall Effect Switches

Sprague Type	Package	Description	Operating* Temperature Range*	Operate† Point Min. (G)	Operate† Point Max. (G)	Release† Point Min. (G)	Release† Point Max. (G)	Supply Voltage Min. (V)	Supply Voltage Max. (V)	Supply Current Typ. (mA)	Supply Current Max. (mA)	Typ. $V_{CE(sat)}$ (mV)	Leakage Current Typ. (μA)	Leakage Current Max. (μA)	Typ. Rise Time (ns)	Typ. Fall Time (ns)
3013	HH,LT,LL,T,U, UA	Switch	UGN	—	450	25	—	4.5	24	3.0	5.0	85	0.05	10	150	400
3019	HH,LT,LL,T,U, UA	Switch	UGN UGS	—	500	125	—	4.5	24	3.0	5.0	85	0.05	10	150	400
3020	HH,LT,LL,T,U, UA	Switch	UGN UGS	—	350	50	—	4.5	24	3.0	5.0	85	0.05	10	150	400
3030	HH,LT,LL,T,U, UA	Bipolar Switch	UGN UGS	—	250	−250	—	4.5	24	3.0	5.0	85	0.05	10	150	400
3035	U	Biased Latch	UGN	—	50	50	—	4.5	24	3.0	5.0	85	0.05	10	150	400
3040	HH,LT,LL,T,U, UA	Switch	UGN UGS	—	200	50	—	4.5	24	3.0	5.0	85	0.05	10	150	400
3075	HH,LT,LL,T,U, UA	Latch	UGN UGS	50	250	−250	−50	4.5	24	3.0	7.0	85	0.2	1.0	100	200
3076	HH,LT,LL,T,U, UA	Latch	UGN UGS	50	350	−350	−50	4.5	24	3.0	7.0	85	0.2	1.0	100	200
3077	HH,T,U,LT,LL, UA	Bipolar Latch	UGN UGS	50	150	−150	-50	4.5	24	3.0	7.0	85	0.02	1.0	100	200
3120	HH,T,U, UA	Switch	UGN UGS	—	350	50	—	4.5	24	4.7	8.0	85	0.05	10	40	180
3131	HH,T,U, UA	Bipolar Switch	UGN UGS	−75	95	−95	75	4.5*	24	—	7.0	85	—	10	40	180
3140	HH,T,U, UA	Switch	UGN UGS	70	200	50	180	4.5	24	4.7	8.0	85	0.05	10	40	180
3201	K	Dual Output Switch	UGN	—	750	100	—	5.0	16	20	25	400 (Max.)	—	100	—	—
3203	K	Dual Output Switch	UGN	—	350	25	—	5.0	16	20	25	400 (Max.)	—	100	—	—
3220	K	Dual Output Switch	UGN	—	350	50	—	4.5	16	3.5	9.0	110	0.1	20	—	—
3275	K	Dual Output Latch	UGN UGS	50	250	−250	−50	4.5	24	—	7.0	85	—	10	40	180
3276	K	Dual Output Latch	UGN UGS	50	350	−350	−50	4.5	24	—	7.0	85	—	10	40	180
3277	K	Dual Output Latch	UGN UGS	50	150	−150	−50	4.5	24	—	7.0	85	—	10	40	180

*UGN = −20°C to +85°C.
UGS = −40°C to +125°C.
†@ 25°C

GETTING STARTED

Since the electrical interface is usually straightforward, the design of a Hall Effect system should begin with the physical aspects. In position-sensing or motion-sensing applications, the following questions should be answered:

How much and what type of motion is there?

What angular or positional accuracy is required?

How much space is available for mounting the sensing device and activating magnet?

How much play is there in the moving assembly?

How much mechanical wear can be expected over the lifetime of the machine?

Will the product be a mass-produced assembly, or a limited number of machines that can be individually adjusted and calibrated?

What temperature extremes are expected?

A careful analysis will pay big dividends in the long term.

The Analysis

The field strength of the magnet should be investigated. The strength of the field will be the greatest at the pole face, and will decrease with increasing distance from the magnet. The strength of the magnetic field can be measured with a gaussmeter or a calibrated linear Hall sensor, such as a Sprague UGN-3503U (see Appendix II).

A plot of field strength (magnetic flux density) is a function of distance along the intended line of travel of the magnet. Hall device specifications (sensitivity in mV/G for a linear device, or operate and release points in gauss for a digital device) can be used to determine the critical distances for a particular magnet and type of motion. Note that these field strength plots are not linear, and that the shape of the flux density curve depends greatly upon magnet shape, the magnetic circuit, and the path traveled by the magnet.

Total Effective Air Gap (TEAG)

Hall Effect switches are offered in two packages, "T" and "U." The "U" package is about 0.020" (0.05 mm) thinner than the "T" package. The difference is found in the distance from the branded face of the package to the surface of the Hall cell: The active area depth. The "T" pack's active area depth is 0.036" (0.9 mm); the "U" pack's is 0.016" (0.4 mm)

Total effective air gap, or TEAG, is the sum of active area depth and the distance between the package's surface and the magnet's surface. The graph of flux density as a function of total effective air gap (**Figure 12A**) illustrates the considerable increase in flux density at the sensor provided by the thinner package. The actual gain depends on the characteristic slope of flux density for a particular magnet.

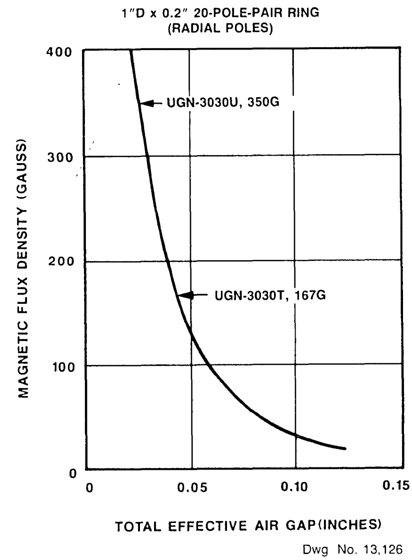

Figure 12A

Modes of Operation

Even with a simple bar or rod magnet, there are several possible paths for motion. The magnetic pole could move perpendicularly straight at the active face of the Hall device. This is called the head-on mode of operation. The curve of **Figure 12B** illustrates typical flux density (in gauss) as a function of TEAG for a cylindrical magnet.

The head-on mode is simple, works well, and is relatively insensitive to lateral motion. The designer should be aware that overextension of the mechanism could cause physical damage to the epoxy package of the Hall device.

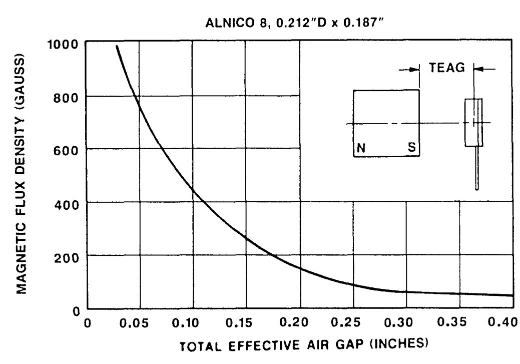

Figure 12B

A second possibility would be to move the magnet in from the side of the Hall device in the slide-by mode of operation, as illustrated in **Figure 13.** Note that now the distance plotted is not total effective air gap, but rather the perpendicular distance

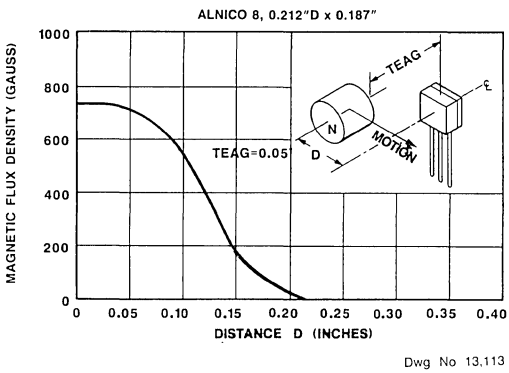

Figure 13

from the centerline of the magnet to the centerline of the package. Air gap is specified because of its obvious mechanical importance, but bear in mind that to do any calculations involving flux density, the "package contribution" must be added and the TEAG used, as before. The slide-by mode is commonly used to avoid contact if overextension of the mechanism is likely. The use of strong magnets and/or ferrous flux concentrators in well-designed slide-by magnetic circuits will allow better sensing precision with smaller magnet travel than the head-on mode.

Magnet manufacturers generally can provide head-on flux density curves for their magnets, but they often do not characterize them for slide-by operation, possibly because different air gap choices lead to an infinite number of these curves; however, once an air gap is chosen, the readily available head-on magnet curves can be used to find the peak flux density (a single point) in the slide-by application by noting the value at the total effective air gap.

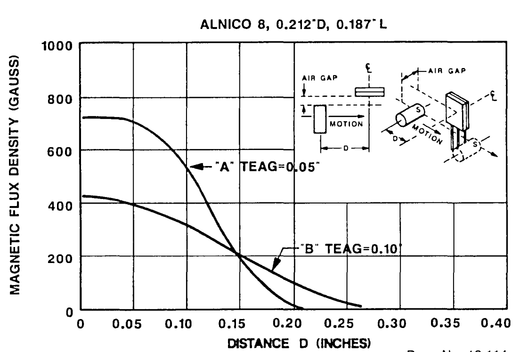

Figure 14

Steep Slopes—High Flux Densities

For linear Hall devices, greater flux changes for a given displacement give greater outputs, clearly an advantage. The same property is desirable for digital Hall devices, but for more subtle reasons. To achieve consistent switching action in a given application, the Hall device must switch ON and OFF at the same positions relative to the magnet.

To illustrate this concept, consider the flux density curves from two different magnet configurations in **Figure 14.** With an operate point flux density of 200 G, a digital Hall effect device would turn ON at a distance of approximately 0.14 inches in either case. If manufacturing tolerances or temperature effects shifted the operate point to 300 G, notice that for curve A (steep slope) there is very little change in the distance at which switching occurs. In the case of curve B, the change is considerable. The release point (not shown) would be affected in much the same way. The basic principles illustrated in this example can be modified to include mechanism and device specification tolerances and can be used for worse-case design analysis. Examples of this procedure are shown in later sections.

Vane Interrupter Switching

In this mode, the activating magnet and the Hall device are mounted on a single rigid assembly with a small air gap between them. In this position, the Hall device is held in the ON state by the activating magnet. If a ferromagnetic plate, or vane is placed between the magnet and the Hall device, as shown in **Figure 15**, the vane forms a magnetic shunt that distorts the flux field away from the Hall device.

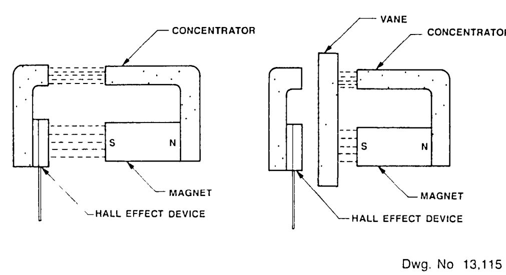

Figure 15

Use of a movable vane is a practical way to switch a Hall device. The Hall device and magnet can be molded together as a unit, thereby eliminating alignment problems, to produce an extremely rugged switching assembly. The ferrous vane or vanes that interrupt the flux could have linear motion, or rotational motion, as in an automotive distributor. Ferrous vane assemblies, due to the steep flux density/distance curves that can be achieved, are often used where precision switching over a large temperature range is required.

7

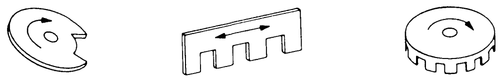

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Figure 16

The ferrous vane can be made in many configurations, as shown in **Figure 16**. With a linear vane similar to that of **Figure 16B**, it is possible to repeatedly sense position within 0.002" over a 125°C temperature range.

ELECTRICAL INTERFACE FOR DIGITAL HALL DEVICES

The output stage of a digital Hall switch is simply an open-collector NPN transistor. The rules for use are the same as those for any similar switching transistor.

When the transistor is OFF, there is a small output leakage current (typically a few nanoamps) that usually can be ignored, and a maximum (breakdown) output voltage (usually 24 V), which must not be exceeded.

When the transistor is ON, the output is shorted to the circuit common. The current flowing through the switch must be externally limited to less than a maximum value (usually 20 mA) to prevent damage. The voltage drop across the switch ($V_{CE(sat)}$) will increase for higher values of output current. You must make certain this voltage is compatible with the OFF, or "logic zero," voltage of the circuit you wish to control.

Hall devices switch very rapidly, with typical rise and fall times in the 400 ns range. This is rarely significant, since switching times are almost universally controlled by much slower mechanical parts.

Common Interface Circuits

Figure 17 illustrates a simplified schematic symbol for Hall digital switches (Sprague Types 3013, 3019, 3020, 3030, 3040). It will make further explanation easier to follow.

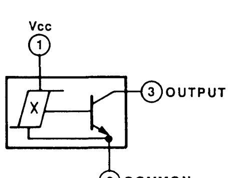

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Figure 17

Interface for digital logic integrated circuits usually requires only an appropriate power supply and pull-up resistor.

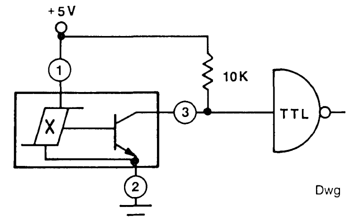

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Figure 18A

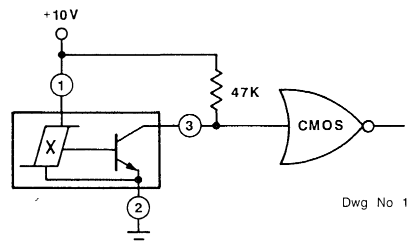

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Figure 18B

With current-sinking logic families, such as DTL or the popular 7400 TTL series (**Figure 18A**), the Hall switch has only to sink one unit-load of current to the circuit common when it turns ON (1.6 mA maximum for TTL). In the case of CMOS gates (**Figure 18B**), with the exception of switching transients, the only current that flows is through the pull-up resistor (about 0.2 mA in this case).

Loads that require sinking currents up to 20 mA can be driven directly by the Hall switch.

A good example is a Light Emitting Diode (LED) indicator that requires only a resistor to limit current to an appropriate value. If the LED drops 1.4 V at a current of 20 mA, the resistor required for use with a 12 V power supply can be calculated as:

$$\frac{12V - 1.4\ V}{0.02A} = 530\ \Omega$$

The nearest standard value is 560 Ω, resulting in the circuit of **Figure 19**.

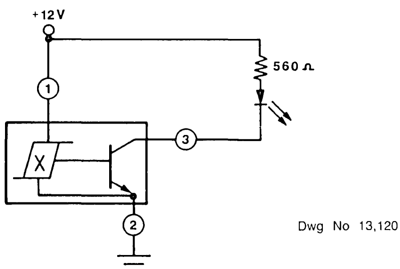

Figure 19

Sinking more current than 20 mA requires a current amplifier. For example, if a certain load to be switched requires 4 A and must turn ON when the activating magnet approaches, the circuit shown in **Figure 20** could be used.

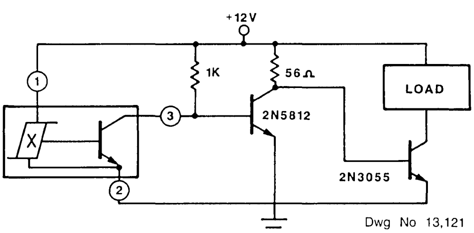

Figure 20

When the Hall switch is OFF (insufficient magnetic flux to operate), about 12 mA of base current flows through the 100 Ω resistor to the 2N5812 transistor, thereby saturating it and shorting the base of the 2N3055 to ground, which keeps the load OFF. When a magnet is brought near the Hall switch, it turns ON, shorting the base of the 2N5812 to ground and turning it OFF. This allows:

$$\frac{12\ \text{V}}{56\ \Omega} = 210\ \text{mA}$$

of base current to flow to the 2N3055, which is enough to saturate it for any load current of 4 A or less.

The Hall switch cannot source current to a load in its OFF state, but it is no problem to add a transistor that can. For example, consider using a 40669 triac to turn ON a 115 V or 230 V ac load. This triac would require about 80 mA of gate current to trigger it to the ON condition. This could be done with a 2N5811 PNP transistor, as shown below in **Figure 21**.

When the Hall switch is turned ON, 9 mA of base current flows into the 2N5811, thereby saturating it and allowing it to supply 80 mA of current to trigger the triac. When the Hall switch is OFF, no base current flows in the 2N5811, which turns it OFF and allows no gate current to pass to the triac. The 4.7 kΩ and the 1 kΩ resistors were added as a safeguard against accidental turn-on by leakage currents, particularly at elevated temperatures. Note that the +12 V supply common is connected to the low side of the ac line, and in the event of a mixup, the Hall switch and associated low-voltage circuitry would be 115 V above ground. *Be careful!*

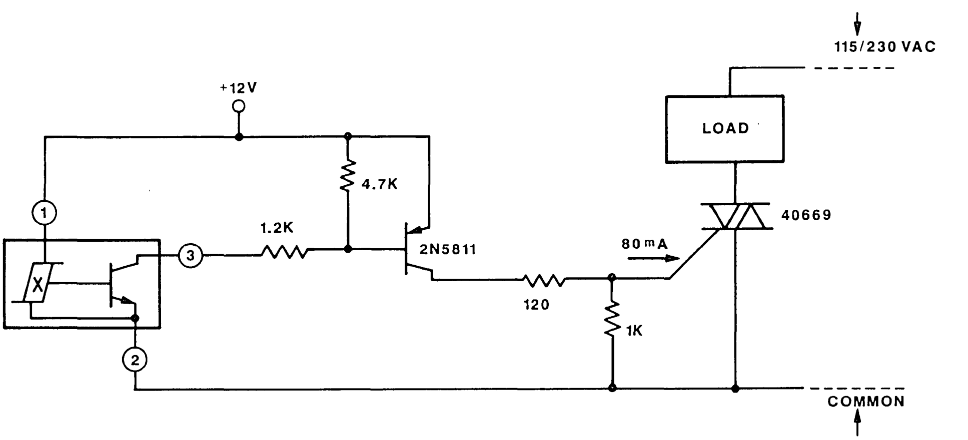

Figure 21

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7

ROTARY ACTIVATORS FOR HALL SWITCHES

A frequent application involves the use of Hall switches to generate a digital output proportional to velocity, displacement, or position of a rotating shaft. The activating magnetic field for rotary applications can be supplied in either of two ways:

Magnetic Rotor Assembly

The activating magnet(s) are fixed on the shaft and the stationary Hall switch is activated with each pass of a magnetic south pole (**Figure 22A**). If several activations per revolution are required, rotors can sometimes be made inexpensively by molding or cutting plastic or rubber magnetic material. Ring magnets can also be used. Ring magnets are commercially available disc-shaped magnets with poles spaced around the circumference. They will operate Hall switches dependably and at reasonable costs.

A. MAGNETIC ROTOR

B. FERROUS VANE ROTOR

Dwg. No. 13,123

Figure 22

Ring magnets do have limitations:

The accuracy of pole placement (usually within 2 or 3 degrees).

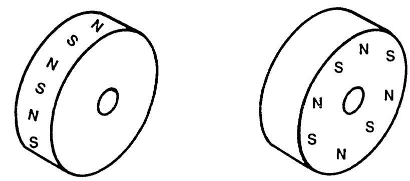
Uniformity of pole strength (±5%, or worse).

These limitations must be considered in applications requiring precision switching.

Ferrous Vane Rotor Assembly

Both the Hall switch and the magnet are stationary (**Figure 22B**); the rotor interrupts and shunts the flux with the passing of each ferrous vane.

Vane switches tend to be a little more expensive than ring magnets, but because the dimensions and configuration of the ferrous vanes can be carefully controlled, they are often used in applications requiring precise switching or duty cycle control.



A. RADIAL

B. AXIAL

Dwg. No 13,124

Figure 23

Properly designed vane switches can have very steep flux density curves, yielding precise and stable switching action over a wide temperature range.

Ring Magnets for Hall Switch Applications

Ring magnets suitable for use with Hall switches are readily available from magnet vendors in a variety of different materials and configurations. The poles may be oriented either radially (**Figure 23A**) or axially (**Figure 23B**) with up to 20 pole-pairs on a one-inch diameter ring. For a given size and pole count, rings with axial poles have somewhat higher flux densities.

Materials most commonly used are various Alnicos, Ceramic 1, and barium ferrite in a rubber or plastic matrix material. Manufacturers usually have stock sizes with a choice of the number of pole pairs. Custom configurations are also available at a higher cost.

Alnico is a name given to a number of aluminum-nickel-cobalt alloys that have a fairly wide range of magnetic properties. In general, Alnico ring magnets have the highest flux densities, the smallest changes in field strength with changes in temperature, and the highest cost. They are generally too hard to shape except by grinding and are fairly brittle, which complicates the mounting of bearings or arbor.

Ceramic 1 ring magnets (trade names Indox, Lodex) have somewhat lower flux densities (field strength) than the Alnicos, and their field strength changes more with temperature; however, they are considerably lower in cost and are highly resistant to demagnetization by external magnetic fields. The ceramic material is resistant to most chemicals and has high electrical resistivity. Like Alnico, they can withstand temperatures well above that of Hall switches and other semiconductors, and must be ground if reshaping or trimming is necessary. They may require a support arbor to reduce mechanical stress.

The rubber and plastic barium ferrite ring magnets are roughly comparable to Ceramic 1 in cost, flux density, and temperature coefficient, but are soft enough to shape using conventional methods. It is also possible to mold or press them onto a shaft for some applications. They do have temperature limitations ranging from 70°C to 150°C, depending on the particular material, and their field strength changes more with temperature than Alnico or Ceramic 1.

Regardless of material, ring magnets have limitations on the accuracy of pole placement and uniformity of pole strength which, in turn, limit the precision of the output waveform. Evaluations have shown that pole placement in rubber, plastic, and ceramic magnets usually falls within 2° or 3° of target, but 5° errors have been measured. Variations of flux density from pole to pole will commonly be ±5%, although variations of up to ±30% have been observed.

Figure 24 is a graph of magnetic flux density as a function of angular position for a typical 4 pole-pair ceramic ring magnet, one inch in diameter, with a total effective air gap of 0.066" (0.030" clearance plus 0.036" package contribution). It shows quite clearly both the errors in pole placement and variations of strength from pole to pole.

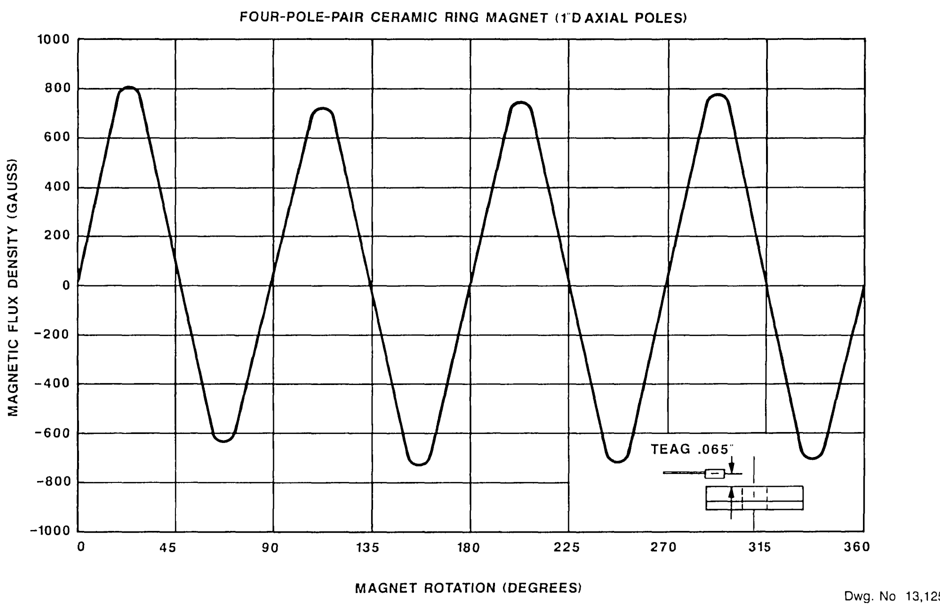


Figure 24

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A frequent concern with ring magnets is ensuring sufficient flux density for reliable switching. There is a trade-off between the number of pole-pairs and the flux density for rings of a given size. Thus, rings with large numbers of poles have lower flux densities. It is important that the Total Effective Air Gap (TEAG) is kept to a minimum, since flux density at the Hall active area decreases by 5 G or 6 G per 0.001" for many common rings. This is clearly shown in **Figure 25**, a graph of flux density at a pole as a function of TEAG for a typical 20-pole-pair plastic ring magnet. Also shown in **Figure 25** is the effect of "package contribution" to the TEAG. The standard Sprague "T" package contributes about 0.036", while the thin "U" package contributes only about 0.016". The other factor contributing to TEAG is mechanical clearance, which should be as small as possible consistent with dimensional tolerances of the magnet, bearing tolerances, bearing wear, and temperature effects on the Hall switch mounting bracket.

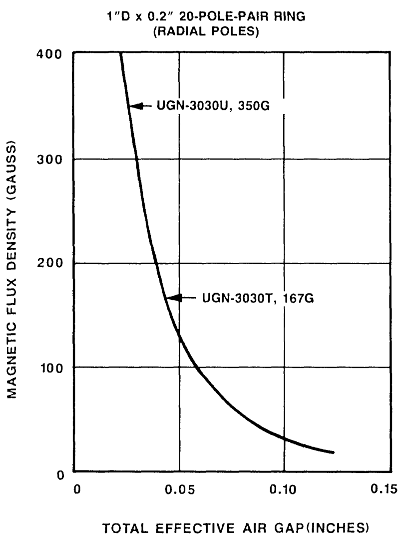

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Figure 25

What is a Bipolar Switch?

A bipolar switch, the Sprague Type 3030, has a maximum operate point of +250 G, a minimum release point of −250 G, and a minimum hysteresis of 20 G at +25°C; however, the operate point could be as low as −230 G (−250 G minimum release, + 20 G minimum hysteresis) and the release could be as high as +230 G (250 G maximum operate, −20 G minimum hysteresis). **Figure 26A** shows two cases of operate and release with one device operating at the maximum operate and release points, and the other with minimum operate and release points.

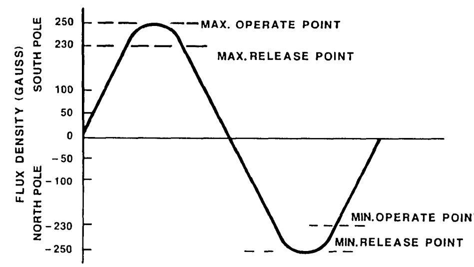

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Figure 26A

In applications previously discussed, the Hall switch was operated (turned ON) by the approach of a magnetic south pole (positive flux). When the south pole was removed (flux approaches zero), the Hall switch had to release (turn OFF). On ring magnets, both south and north poles are present in an alternating pattern. The release point flux density becomes less important, for if the Hall switch has not turned OFF when the flux density goes to zero (south pole has passed), it will certainly turn OFF when the following north pole causes flux density to go negative. Bipolar Hall switches take advantage of this extra margin in release point flux values to achieve lower operate point flux densities, a definite advantage in ring magnet applications.

The Bipolar Latch

Unlike the Type 3030 bipolar switch, which may operate and release with a south pole or north pole, the Sprague bipolar latch offers a more precise control of the operate and release parameters. This Hall integrated circuit has been designed to operate (turn ON) with a south pole only; it will then remain ON when the south pole has been removed. In order to have the bipolar latch release (turn OFF), it must be presented with a north magnetic pole. This alternating south pole-north pole operation, when properly designed, will produce a duty cycle approaching 50%.

The Sprague Type 3075 was designed specifically for applications requiring a tightly controlled duty cycle, such as in brushless dc motor commutation. This was accomplished with the introduction of the bipolar latch in 1982. The 3075 has become very popular as a brushless dc motor commutator, shaft encoder, speedometer element, and tachometer sensor.

Duty cycle is controlled with an alternating magnetic field, as shown in **Figure 26B**.

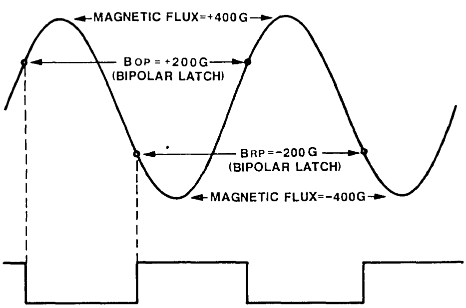

Figure 26B

Design Example

Given:

Operating temperature range of $-20°$ to $+85°C$.

Bipolar Hall switch UGN-3030U in standard "U" package:

Maximum operate point +250 G from −20° to +85°C.

Minimum release point −250 G from −20°C to +85°C.

Air gap package contribution 0.016".

Necessary mechanical clearance 0.030".

First, find the Total Effective Air Gap:

TEAG = clearance + package contribution

TEAG = 0.030" + 0.016" = 0.046"

Now, determine the necessary flux density sufficient to operate the Hall switch, plus 40%.

To operate the Hall switch, the magnet must supply a minimum of ±250 G at a distance of 0.046" over the entire temperature range. Good design practice requires the addition of extra flux to provide some margin for aging, mechanical wear, and other imponderables. If we add a pad of 100 G, a reasonable number, the magnet required must supply ±350 G at a distance of 0.046" over the temperature range.

Temperature Effects

Unfortunately, magnet strength is affected by temperature to some degree. Temperature coefficients of some common magnetic materials are given below:

Material	Temperature Coefficient
Rubber/Plastic	−0.2% to −0.3% per °C
Ceramic 1	−0.15% to −0.2% per °C
Alnico 2, 5	−0.02% to −0.03% per °C
Alnico 8	±0.01% per °C

If we are considering a ceramic ring magnet with a worst-case temperature coefficient of −0.2%/°C, we must add some extra flux density to the requirement at room temperature to ensure that we still have +350 G per south pole at +85°C. This amount is:

$[(85°C - 25°C) \times 0.2\%/°C]\ 350\ G = +42\ G$

Thus, the flux density that will ensure that the Hall switch will operate over temperature is 350 G + 42 G = 392 G per south pole at +25°C.

Follow the same procedure for the north pole requirements. If the magnet will supply +350 G per south pole and −350 G per north pole at +85°C, it will supply even more flux density per north pole at −20°C because of the negative temperature coefficient.

In applications where temperature conditions are more severe, Alnico magnets are considerably better than the ceramic magnets we considered. It is also possible to order custom Hall switches from Sprague with specifications tailored to your application. For example, you can specify operate and release points at a particular temperature, with temperature coefficients for operate and release points, if that is better suited to your application. On a custom basis, Sprague Hall switches are available with operate and release point temperature coefficients of less than 0.3 G/°C, and with operate flux densities of less than 100 G.

If you intend to use a low-cost, low flux density ring magnet, then the Sprague UGN-3030U device in the 0.060" package would be the best choice. The thin package costs no more, and the package contribution is reduced from 0.036" to 0.016", which results in a significant improvement in peak flux density from a magnet, as shown previously in **Figure 25**.

If the rotor drive can withstand an increased torque requirement, consider a ferrous flux concentrator. Flux density can be increased by 10% to 40% in this manner. A concentrator of 0.03125" mild steel having the same dimensions as, and cemented to, the back surface of the Hall switch, will increase flux density by about 10%. A return path of mild steel from the back side of the device to the adjacent poles can add even more. Often the functions of mounting bracket and flux concentrator can be combined. Additional information can be found in the section on flux concentrators.

RING MAGNETS —DETAILED DISCUSSION

An Inexpensive Alternative

Innovative design can produce surprisingly good results. Rubber and plastic magnet stock comes in sheets. One side of the sheet is magnetic north; the other side is south. This material is relatively inexpensive and can easily be stamped or die-cut into various shapes.

These properties prompted one designer to fabricate an inexpensive magnetic rotor assembly that worked very well. The rubber magnet stock was die-cut into a star-shaped rotor form, as shown in **Figure 27**. A nylon bushing formed a bearing, as shown in **Figure 28**.

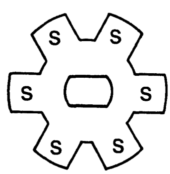

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Figure 27

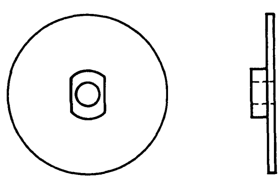

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Figure 28

Finally, a thin mild steel backing plate was mounted to the back of the assembly to give mechanical strength and to help conduct the flux back from the north poles on the opposite side. This actually served to form apparent north poles between the teeth; the measured flux between south pole teeth is negative. **Figure 29** shows the completed magnetic rotor assembly, essentially a ring magnet with axial poles.

The Hall switch was mounted with its active surface close to the top of the rotor assembly, facing the marked poles. There is some versatility in this approach, as asymmetrical poles can be used to fabricate a rotor that will allow trimmable ON time and, thus, work as a timing cam. **Figure 30** illustrates a cam timer adjusted to 180° ON and 180° OFF.

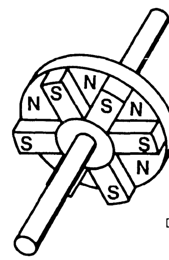

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Figure 29

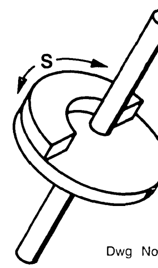

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Figure 30

Ring Magnet Selection

When you discuss your application with a magnet vendor, the following items should be considered:

Mechanical Factors
- —Dimensions and tolerances.
- —Mounting hole type and maximum eccentricity.
- —Rotational speed.
- —Mechanical support required.
- —Coefficient of expansion.

Magnetic Factors
- —Poles: number, orientation, and placement accuracy.
- —Flux density at a given TEAG (remember to add the Hall switch package contribution to the clearance figure).
- —Magnetic temperature coefficient.

Environmental Factors
- —Tolerance of the material to the working environment (temperature, chemical solvents, electric potentials).

Flux density curves from several typical ring magnets are included to present an idea of what can be expected from various sizes and materials. **Figure 31** shows the curve for a ring similar in size and material to that of **Figure 25**, but with 10 pole-pairs instead of 20 (note increased flux density values). **Figure 32** shows the curve from a one-pole-pair Alnico 8 ring. **Figure 33** shows the curve from a three-pole-pair Ceramic 1 ring. **Figure 34** shows the curves from a four-pole-pair Ceramic 1 ring, with and without a ferrous flux concentrator.

Incoming inspection of ring magnets is always advisable. You can ensure the magnets are within the agreed upon magnetic specifications by making measurements with a commercial gaussmeter, or a calibrated linear Hall device mounted in a convenient test fixture. Calibrated UGN-3504U Hall devices and technical assistance are available from Customer Service, Sprague Sensor Division, Concord, NH (603) 224-2755 or 224-1961.

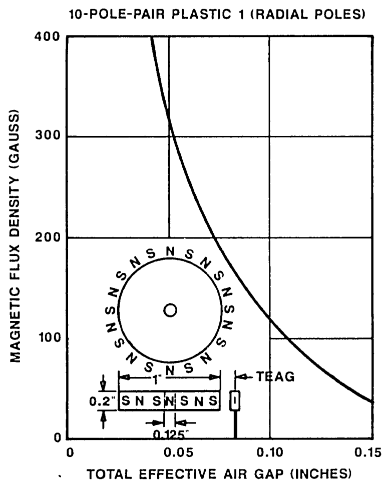

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Figure 31

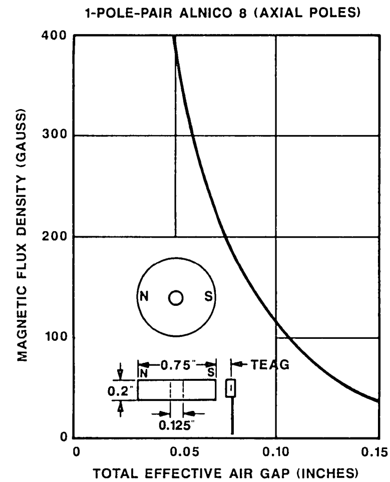

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Figure 32

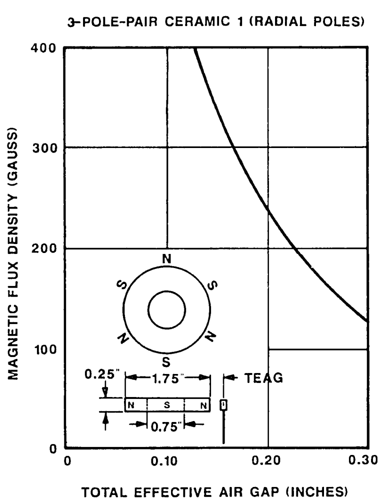

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Figure 33

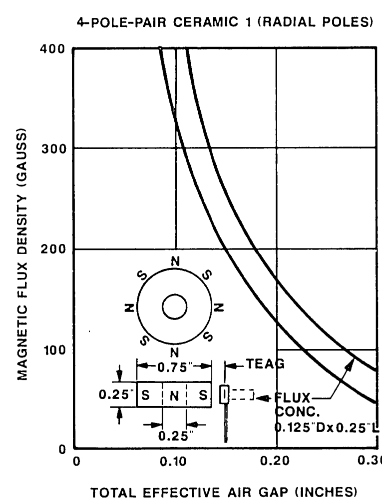

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Figure 34

FERROUS VANE ROTARY ACTIVATORS

A ferrous vane rotor assembly is the alternative to magnetic rotors for rotary Hall switch applications. As shown previously, a single magnet will hold a Hall switch ON except when one of the rotor vanes interrupts the flux path and shunts the flux path away from the Hall switch. The use of a single stationary magnet allows very precise switching by eliminating ring magnet variations, placement, and strength. Unlike the evenly spaced poles on ring magnets, the width of rotor vanes can easily be varied. It is possible to vary the Hall switch OFF and ON times, which gives the designer control over the duty cycle of the output waveform. Ferrous vane rotors are a good choice where precise switching is desired over a wide range of temperatures. As the vane passes between magnet and Hall switch, progressively more flux will be blocked or shunted. Small variations in lateral position have a very small effect on the transition point.

A Ferrous Vane In Operation

Figure 35 combines top and front views of a ferrous vane magnet/Hall switch system with the graph of flux density as a function of vane travel produced by this system. Note that the drawings and the graph are vertically aligned along the horizontal axis. Position is measured from the leading edge of the vane to the centerline of the magnet/ Hall device.

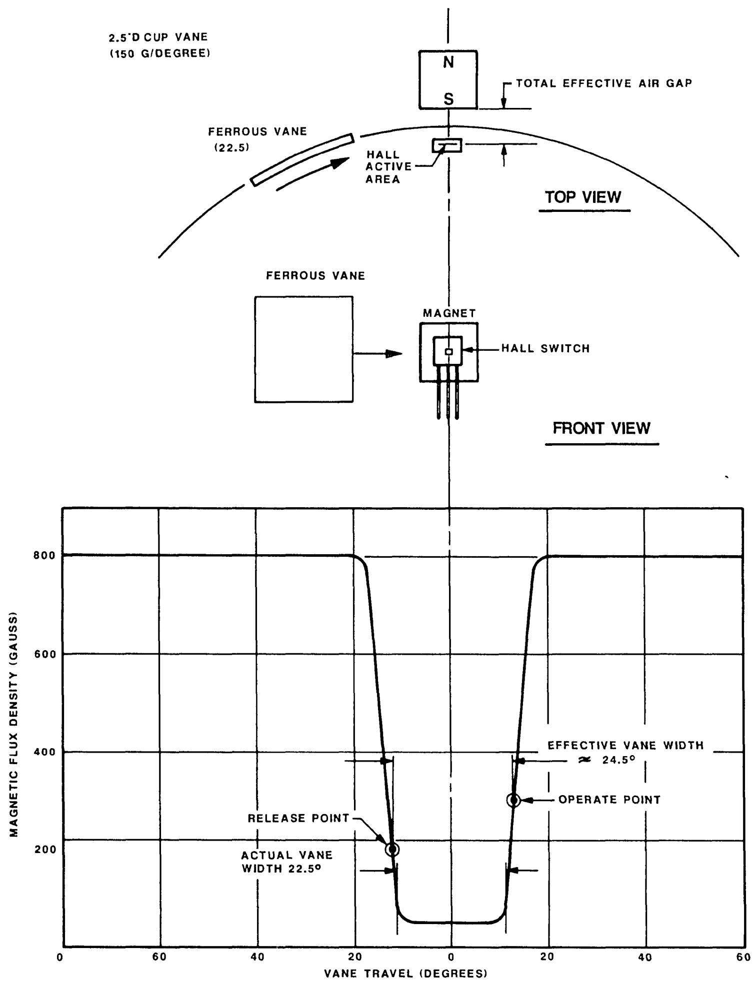

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Figure 35

Initially, when the vane is located entirely to the left of the magnet, the vane has no effect and the flux density at the sensor is at a maximum of 800 G. As the leading edge of the vane nears the magnet, the shunting effect of the vane causes the flux density to decrease in a nearly linear fashion. There, the magnet is covered by the vane and flux density is at a minimum. As the vane travels on it starts to uncover the magnet. This allows the flux to increase to its original value. After that, additional vane travel has no further influence on flux density at the sensor.

A Hall switch located in the position of the sensor would initially be ON because of the presence of the magnetic field. Somewhere in the linearly decreasing region, the flux would fall below the release point, and the Hall switch would turn OFF. It would remain OFF until the increasing flux reaches the operate point for that particular Hall switch. Recall that the operate point flux density is greater than the release point flux density by the amount of hysteresis for that particular Hall switch.

The interval during which the Hall switch remains OFF is determined by the actual width of the vane and the steepness of the magnetic slope, as well as by the operate and release point flux density values for the Hall switch. This interval is called the effective vane width, and it is always somewhat greater than the physical vane width.

Rotor Design

Two commonly used rotor configurations are the disk and the cup, as shown in **Figure 36**.

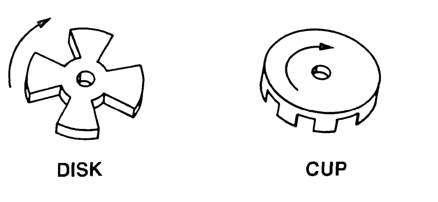


Figure 36

The disk is easily fabricated and, hence, is often used for low-volume applications such as machine control. Axial movement of the rotor must be considered. Vane activated switches tolerate this quite well, but the rotor must not hit the magnet or the Hall switch.

Cup rotors are somewhat more difficult to fabricate and so are more expensive, but dealing with a single radial distance simplifies calculations and allows precise control of the output waveforms. For cup rotors, radial bearing wear or play is the significant factor in determining the clearances, while axial play is relatively unimportant. Cup rotors have been used very sucessfully in automotive ignition systems. The dwell range is determined by the ratio of the vane-to-window widths when the rotor is designed. Firing point stability may be held to ±0.005 distributor degrees per degree Celsius in a well-designed system.

Material

Vanes are made of a low carbon steel to minimize the residual magnetism and to give good shunting action. The vane thickness is chosen to avoid magnetic saturation for the value of flux density it must shunt. Vanes usually are between 0.03″ and 0.06″ thick.

Vane/Window Widths, Rotor Size

Generally, the smallest vanes and window on a rotor should be at least one and one-half times the width of the magnet pole to provide adequate shunting action and to maintain sufficient differential between the OFF and ON values of flux density.

In Table 2, the maximum flux density (obtained with window centered over the magnet, the minimum flux density (vane centered over the magnet), and the difference between the two values are tabulated for three cases:

1. Vane and window width the same as magnet pole width.
2. Vane and window width one and one-half times magnet pole width.
3. Vane and window width two times the magnet pole width.

In each case the magnet is 0.25″ × 0.25″ × 0.125″ samarium cobalt; the air gap is 0.1″; the rotor vanes are made of 0.04″ mild steel stock.

TABLE 2

Window Vane Width Factor	1.0	1.5	2.0
Flux Density with Window Centered	630 G	713 G	726 G
Flux Density with Vane Centered	180 G	100 G	80 G
Flux Change Density	450 G	613 G	646 G

If a small rotor with many windows and vanes is required, a miniature rare earth magnet must be used to ensure sufficient flux density for reliable operation. For example, a 0.1″ cubical samarium cobalt magnet makes it practical to fabricate a 1.25″ diameter rotor with as many as 10 windows and vanes. With fewer vanes, even further size reduction is possible.

Steep Magnetic Slopes for Consistent Switching

The flux density vane travel graph for most common vane configurations (**Figure 35**), is very nearly linear in the transition regions. The Hall switch operate and release points fall in these linear transition regions, and it is easily seen that if these values change, the position of the vane which causes the switching must change also. **Figure 37** shows the flux density as a function of vane position for two different magnetic circuits. In one case the magnetic slope is 2.5 G/mil. In the second case, it is 5.0 G/mil.

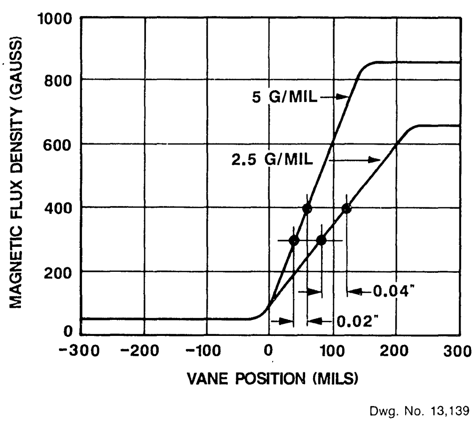


Figure 37

If the 2.5 G/mil system is used with a Hall switch known to have an operate point flux density of 300 G at +25°C, the device would switch ON when the vane is 85 mils past the center of the window at this temperature. If the Hall switch operate point went up to 400 G at a temperature of +125°C (this represents Hall switch temperature coefficient of 1 G/°C), the vane must move to 120 mils past center, a change in switching position of 45 mils. If the same Hall switch is used in the second system having the 5 mil/G slope, the operate point would shift only 20 mils, or half as much, since the slope is twice as steep.

Slopes in typical vane systems range from 1 G/mil to 15 G/mil, and are affected by magnet type and size, the magnetic circuit, and the total effective air gap. It is interesting to note that, although slide-by operation can give very steep slopes, the transition point is much affected by lateral motion (change in air gap); therefore, vanes are often preferred for applications involving play or bearing wear.

Small Air Gaps for Steep Slopes

The air gap should be as small as the mehanical system allows. Factors to be considered are:

Vane material thickness and vane radius.

Maximum eccentricity for cup vanes.

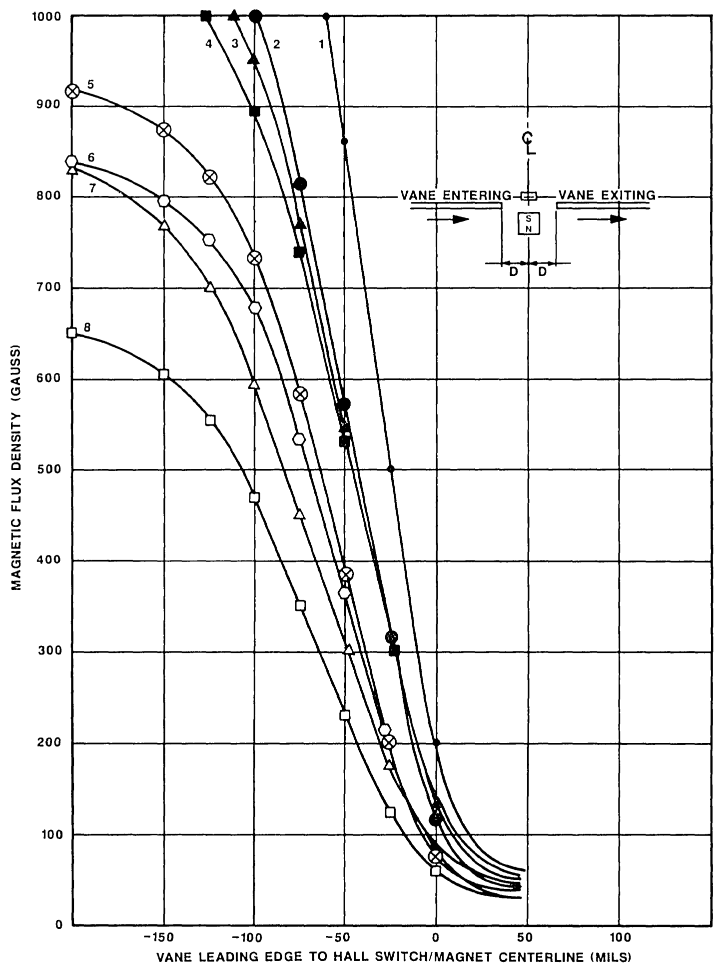
Bearing tolerance and wear.

Change in air gap with temperature due to mounting considerations.

TABLE 3

Curve	Magnet	Air Gap	Slope G/mil	*Concentrator
A	0.25"D, 0.25"LSamarium Cobalt	0.1"	14	Yes
B	0.25"D, 0.25"L Samarium Cobalt	0.1"	9.85	No
C	0.25"D, 0.125"L Samarium Cobalt	0.1"	9.0	Yes
D	0.25"D, 0.125"L Samarium Cobalt	0.125"	8.7	Yes
E	0.25"D, 0.125"L Samarium Cobalt	0.1"	7.8	No
F	0.25"D, 0.125"L Samarium Cobalt	0.125"	6.3	No
G	0.25"D, 0.125"L Samarium Cobalt	0.125"	5.6	Yes
H	0.25"D, 0.125"L Samarium Cobalt	0.125"	4.5	No

Note: The "U" package is used for all measurements.*



SYMBOL	MAGNET	AIR GAP	SLOPE(G/MIL)	*CONC.
1 ●	0.25"D,0.25"L SAM.CO.	0.1"	14	YES
2 ⬤	0.25"D,0.25"L SAM.CO.	0.1"	9.85	NO
3 ▲	0.25"D,0.125"L SAM.CO.	0.1"	9.0	YES
4 ■	0.25"D,0.25"L SAM.CO.	0.125"	8.7	YES
5 ⊗	0.25"D,0.125"L SAM.CO.	0.1"	7.8	NO
6 ⬡	0.25"D,0.25"L SAM.CO.	0.125"	6.3	NO
7 △	0.25"D,0.125"L SAM.CO.	0.125"	5.6	YES
8 □	0.25"D,0.125"L SAM.CO.	0.125"	4.5	NO

NOTE - THE "U" PACKAGE IS USED FOR ALL MEASUREMENTS

N S *0.125"D,0.25"L MILD STEEL

Dwg. No. 13,140

Figure 38

In **Figure 38** two different samarium cobalt magnets are used in a vane system to illustrate the effects of changes in air gap and magnet size. Note that only the falling transition region is shown (transition regions are symmetrical). The distances on the horizontal axis have been measured from the leading edge of the vane.

The term "air gap" as used in **Figure 38** is not the total effective air gap, but is simply the distance from the face of the magnet to the surface of the

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Hall switch. It does not include the package contribution. The "U" package is often used in ferrous vane applications because it has a shallow active area depth.

Flux Concentrators Pay Dividends

What if economic or size considerations dictated the smaller magnet used in **Figure 38,** and mechanical considerations dictated the larger (0.125") air gap, but the resulting flux density and slope (Curve 8) were not good enough? Curve 7 in **Figure 38** shows the very substantial improvement that can be achieved by adding simple flux concentrators. Those used in the example were 0.125" in diameter by 0.250" long, and were fastened behind the Hall switch.

Design Example

The magnet/concentrator configuration we just considered (Curve 7, **Figure 38**) seems to offer a high performance/cost ratio. Following is an evaluation of its use in an automotive ignition system using a 2.5" diameter cup rotor.

The initial timing and wide operating temperature range requirements for this application have generally led designers to specify custom Hall switches in terms of the minimum and maximum operate or release point at +25°C, plus a maximum temperature cofficient on these parameters over the operating temperature range. Representative specifications might be:

+25°C Operate Point, Minimum .... 300 G
+25°C Operate Point, Maximum .... 450 G
+25°C Release Point, Minimum .... 200 G

Temperature Coefficients:
Δ O.P./ Δ T, maximum = +0.7 G/°C
Δ R.P./ Δ T, maximum = +1.0 G/°C

Solid-state Hall effect ignition systems can be designed to fire either on operate or release of the Hall switch. We have arbitrarily chosen to have the system in this example fire when the switch operates and, thus, the operate point specifications of the Hall switch (between 300 and 450 G at +125°C) will determine the amount of uncertainty in the initial timing of the spark. It is possible that the mechanical system would also make a contribution, but that is not considered here.

Figure 39 shows the measured flux density at the position of the sensor as a function of the vane travel. The shape of the curve requires explanation: Because the flat minimum and maximum flux regions are irrelevant, it is convenient to measure from the vane's leading edge to the magnet centerline while plotting the falling transition, skip the low flux region where the vane is shunting most of the flux, and measure distance from the trailing

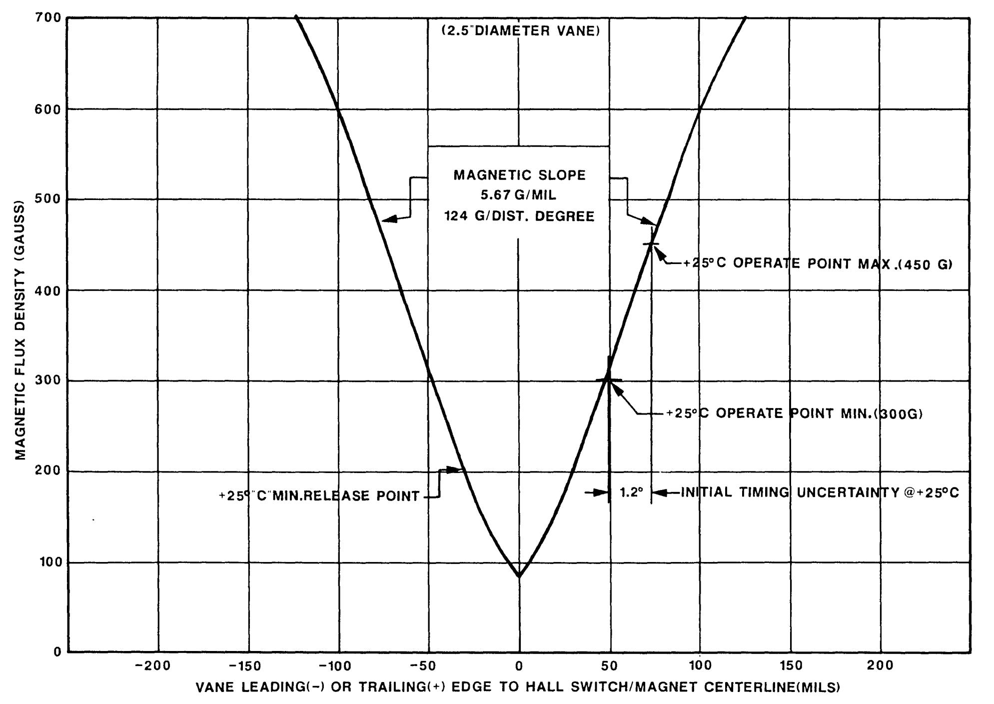

Figure 39

edge of the vane to the magnet centerline while plotting data for the rising transition. (The same presentation would result if all data were plotted while a vane passed the magnet, the center low flux areas were snipped out, and the ends containing the linear transitions were pulled together.) From this graph, we can identify the magnetic slope of the transition regions for our system—approximately 5.67 G per 0.001" of vane travel.

Calculations based on the rotor diameter (2.5") show we have 22 mils of vane travel per distributor degree. The 5.67 G/mil slope obtained from **Figure 39** is equivalent to 125 G per distributor degree. From the specifications it is known that the Hall switch will operate when flux is between 300 and 450 G, leaving a 150 G window of uncertainty. At +25°C, this will be:

$$150\text{G} \times \frac{\text{Distributor Degree}}{125\text{ G}} =$$

$$1.2\text{ Distributor Degrees}$$

Additional contributions to the initial timing uncertainty will result if the Total Effective Air Gap is changed, as that would affect the shape or slopes of the magnetic flux density/vane travel curve of **Figure 39**. Factors to be considered are the magnet peak energy product tolerances, as well as manufacturing tolerances in the final Hall switch/magnet assembly.

Temperature Stability of Operate Point

The Hall switch operate point temperature coefficient is 0.7 G/°C in the 3000 series parts. To translate this into distributor degrees per degree Celius, we take:

$$\frac{0.7\text{ G}}{1°\text{C}} \times \frac{\text{Distributor Degrees}}{125\text{ G}} =$$

$$0.0056\text{ Distributor Degrees/°C}$$

The distributor timing would, therefore, change 0.56 degrees for a temperature change of 100°C.

A typical samarium cobalt magnet temperature coefficient is −0.04%/°C. A magnetic field of 375 G at +25°C would decrease to 360 G at +125°C. For **Figure 40,** our system has a magnetic slope of 5.67 G/mil, giving an additional vane travel requirement at +125°C of:

$$(375\text{ G-}360\text{ G}) \times \frac{1\text{ mil}}{5.67\text{ G}} = 2.7\text{ mils}$$

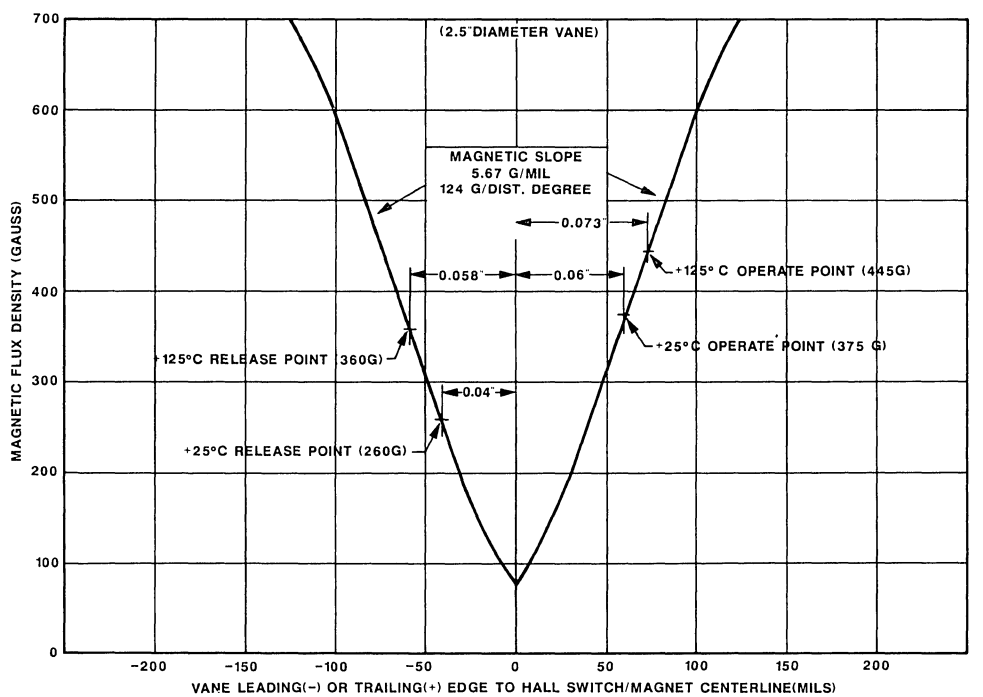

Figure 40

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This translates to timing change of:

$$2.7 \text{ mils} \times \frac{\text{Distributor Degrees}}{22 \text{ mils}} =$$

$$0.12 \text{ Distributor Degrees}$$

for a temperature change of 100°C.

Calculating Dwell Angle and Duty Cycle Variations

The dwell angle in a conventional system is the number of distributor degrees during which the points are closed, which corresponds to the amount of time current can flow in the coil's primary winding. In our example, current flows in the coil primary from the time the Hall switch releases until it operates, which is called the effective vane width. For nostalgic reasons we will assume an eight-cylinder engine, which requires a distributor rotor with eight windows and eight vanes of equal size. One window-vane segment thus occupies 45 distributor degrees and will fire one cylinder. Let us further assume a typical Hall switch operate point of 375 G at +25°C (A), and a +25°C release point of 260 G (B). From **Figure 40** we find that the points will close 40 mils before the vane's leading edge passes the magnet centerline; they open 60 mils after the vane's trailing edge passes the magnet centerline. The effective vane width is greater than the mechanical vane width by an amount:

$$(60 \text{ mils} + 40 \text{ mils}) \times \frac{\text{Distributor Degrees}}{22 \text{ mils}} =$$

$$4.54 \text{ Distributor Degrees}$$

This gives a dwell angle of (45° + 4.54°) = 49.54 distributor degrees at +25°C. The duty cycle is:

$$\frac{49.4°}{90°} = 55.0\% \text{ at } +25°\text{C}.$$

Using the specified worst-case temperature coefficients, we calculate the new operate and release points at +125°C to be 445 G (C) and 360 G (D), also shown in **Figure 40**. The dwell angle at +125°C would then be:

$$45° + \left[(73 \text{ mils} + 58 \text{ mils}) \times \frac{\text{Distributor Degrees}}{22 \text{ mils}}\right] =$$

$$50.9 \text{ Distributor Degrees}$$

The duty cycle is then:

$$\frac{50.9°}{90°} = 56.6\%.$$

Effects of Bearing Wear

A ±10-mil radial movement of the vane, with its position adjusted to the approximate operate point of the Hall switch, gave a measured change of ±6 G. This translates into a change of:

$$6 \text{ G} \times \frac{\text{Distributor Degrees}}{124 \text{ G}} =$$

$$0.048 \text{ Distributor Degrees,}$$

which is equivalent to 0.097 crankshaft degrees.

Mounting Also Affects Stability

In the example above, it was assumed that the physical relationship between the Hall switch and the magnet was abolutely stable. In practice it is necessary to design the mountings with some care if this is to be true. It has been found that supporting the magnet or Hall switch with formed brackets of aluminum or brass will often contribute a significant temperature-related error to the system. Use of molded plastic housings has proven to be one of the better mounting techniques.

Individual Calibration Techniques

In some applications, it may be desirable to have the vane switch assemblies operate within a narrower range of vane edge positions than is possible with a practical operate point specification for the Hall switch; for example, if it were necessary to reduce the initial timing window in the previous case. One solution would be individual calibation. Possible techniques include:

1) Adjusting the air gap by changing the magnet position.
2) Adjusting the position of a flux concentrator behind the Hall switch.
3) Adjusting the position of a small bias magnet mounted behind the Hall switch.
4) Demagnetizing the magnet in small increments that would decrease the magnetic slope and, thus, increase the temperature effects.
5) Adjusting the position of the Hall switch-magnet assembly relative to the rotor in a manner similar to rotating an automotive distributor to change the timing.

OPERATING MODES

Head-on and Slide-By Modes

The most common operating modes are head-on and slide-by. The head-on mode is simple and relatively insensitive to lateral motion, but cannot be used where overextension of the mechanism might damage the Hall switch. The flux density plot for a typical head-on operation (**Figure 41**) shows that the magnetic slope is quite shallow for low values of flux density, a disadvantage that generally requires extreme mechanism travel and extreme sensitivity to flux changes in operate and release points of the Hall switch. This problem can be overcome by selecting Hall switches with higher operate and release properties.

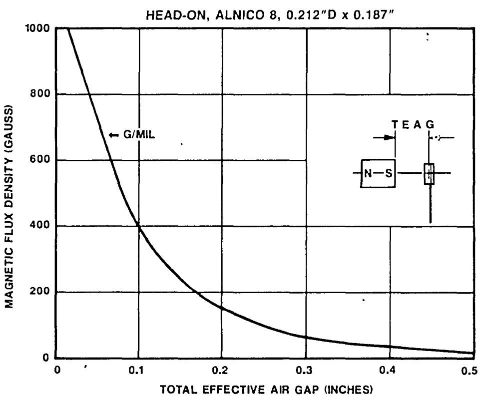

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Figure 41

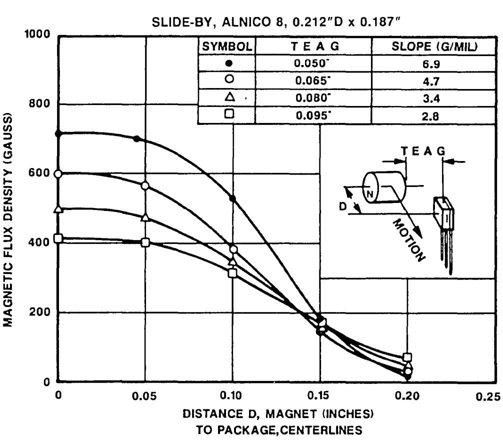

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Figure 42

The slide-by mode is also simple, can have reasonably steep slopes (to about 10 G/mil) and has no problem with mechanism over-travel. It is, however, very sensitive to lateral play, as the flux density varies dramatically with changes in the air gap. This can be seen clearly in the curves of **Figure 42**, in which the flux density curves are plotted for actual slide-by operation with various air gaps. It is apparent that the operating mechanism can have little side play if precise switching is required.

OPERATING MODE ENHANCEMENTS —COMPOUND MAGNETS

Push-Pull

Because the active area of a Hall switch is close to the branded face of the package, it is usually operated by approaching this face with a magnetic south pole. It is also possible to operate a Hall switch by applying a magnetic north pole to the back side of the package. While a north pole alone is seldom used, the push-pull configuration (simultaneous application of a south pole to the branded side and a north pole to the back side) can give much greater field strengths than are possible with any single magnet (**Figure 43**). Perhaps more important, push-pull arrangements are quite insensitive to lateral motion and are worth considering if a loosely fitting mechanism is involved.

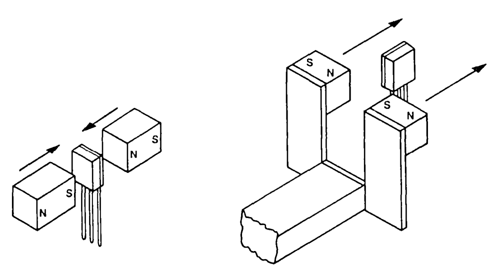

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Figure 43

Figure 44 shows the flux density curve for an actual push-pull slide-by configuration that achieves a magnetic slope of about 8 G/mil.

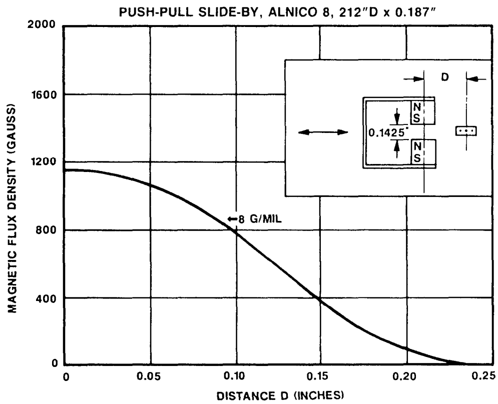

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Figure 44

Push-Push

Another possibility, a bipolar field with a fairly steep slope (which is also linear), can be created by using a push-push configuration in the head-on mode (**Figure 45**)

In the push-push mode, head-on configuration as shown in **Figure 45**, the magnetic fields cancel each other when the mechanism is centered, giving zero flux density at that position. **Figure 46** shows the flux density plot of such a configuration. The curve is linear and moderately steep at better than 8 G/mil. The mechanism is fairly insensitive to lateral motion.

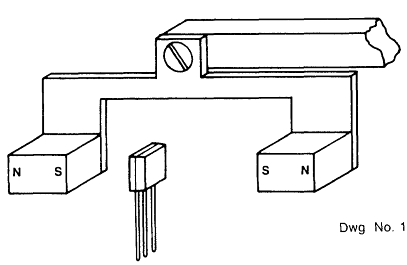

Figure 45

Biased Operation

It is also possible to bias the Hall switch by placing a stationary north or south pole behind it to alter the operate and release points. For example, a north pole attached to the reverse face would turn the device normally ON until a north pole providing a stronger field in the opposite direction approached the opposite face. (**Figure 47**)

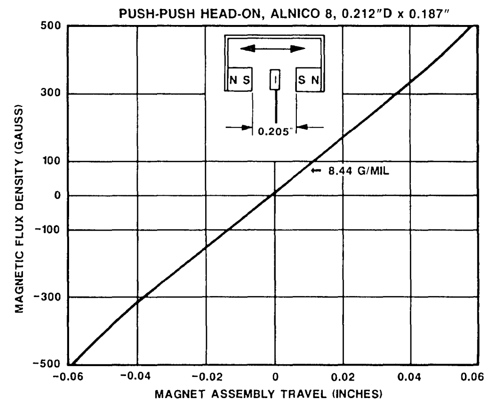

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Figure 46

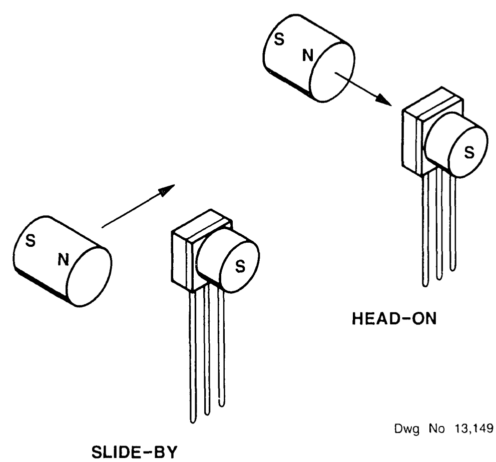


Figure 47

Figures 48-51 demonstrate four additional slide-by techniques. Compound magnets are used in push-pull, slide-by, edgewise configurations to achieve a magnetc slope of 17.4 G/mil. Rare earth magnets may be used to obtain substantially steeper slopes. A flux density curve of up to 100 G/mil is obtainable.

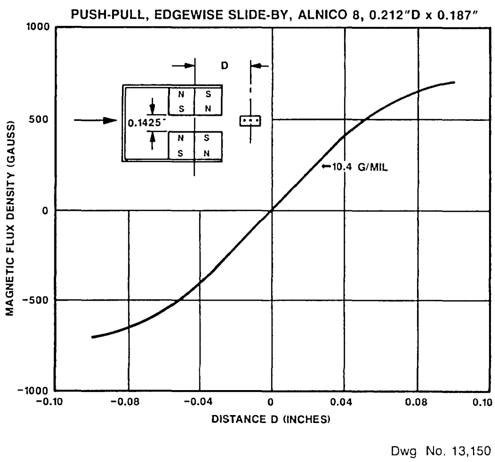


Figure 48

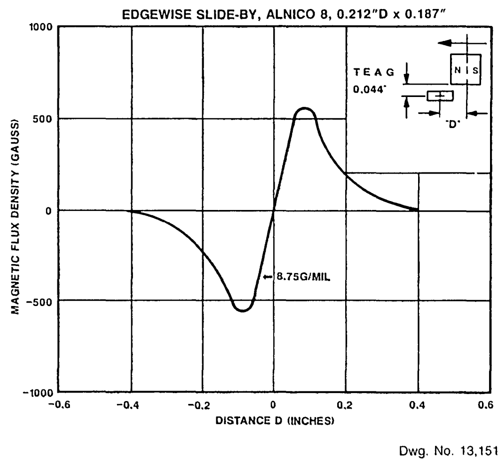


Figure 49

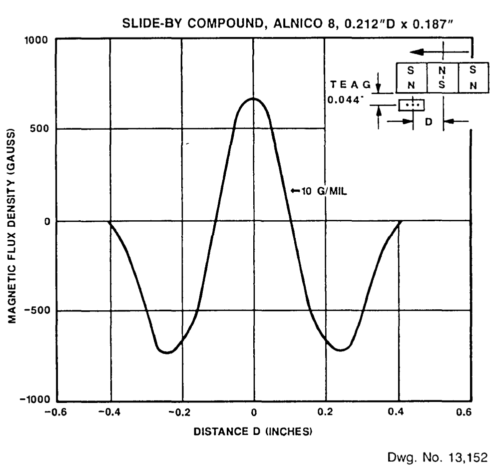


Figure 50

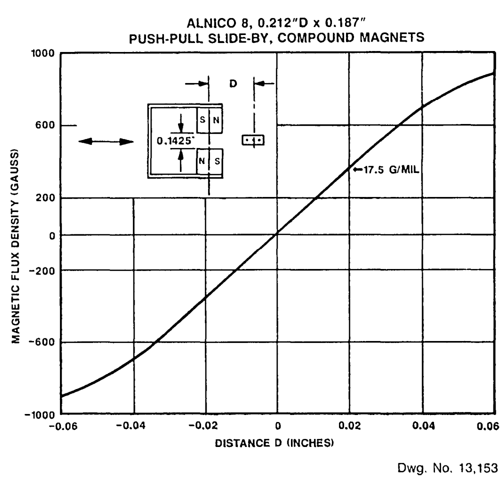


Figure 51

7

INCREASING FLUX DENSITY BY IMPROVING THE MAGNETIC CIRCUIT

Magnetic flux can travel through air, plastic, and most other materials only with great difficulty. Since there is no incentive for flux from the activating magnet to flow through the (plastic and silicon) Hall device, only a portion of it actually does. The balance flows around the device and back to the other pole by whatever path offers the least resistance. (**Figure 52**)

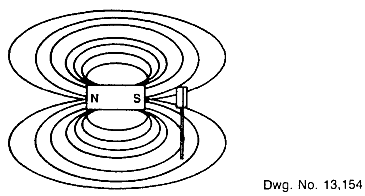


Figure 52

However, magnetic flux easily flows through a ferromagnetic material such as mild steel. The reluctance of air is greater by a factor of several thousand than that of mild steel.

In a Hall device application, the goal is to minimize the reluctance of the flux path from the magnetic south pole, through the Hall device, and back to the north pole. The best possible magnetic circuit for a Hall device would provide a ferrous path for the flux, as shown in **Figure 53**, with the only "air gap" being the Hall device itself.

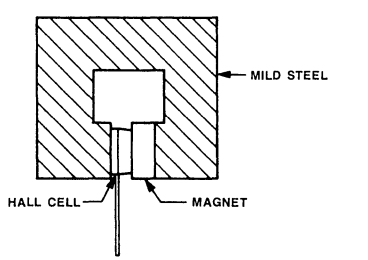


Figure 53

While a complete ferrous flux path is usually impractical, unnecessary, and even impossible in applications requiring an undistorted or undisturbed flux field, it is a useful concept that points the way to a number of very practical compromises for improving flux density.

Flux Concentrators

Flux concentrators are low carbon (cold-rolled) steel magnetic conductors. They are used to provide a low reluctance path from a magnet's south pole, through the Hall sensor, and back to the north pole. Flux concentrators can take many forms and will often allow use of smaller or less expensive magnets (or less expensive, less sensitive Hall devices) in applications where small size or economy are important. They are of value whenever it is necessary or desirable to increase flux density at the Hall device. Increases of up to 100% are possible.

An example of the effectiveness of a concentrator is illustrated in **Figures 54(A)** and **54(B)**.

(A) The south pole of a samarium cobalt magnet 0.25" square and 0.125" long, is spaced 0.25" from the Hall switch. There is a flux density of 187 G at the active area.

(B) With a concentrator 0.125" in diameter and 0.5" long, the flux density increases to 291 G.

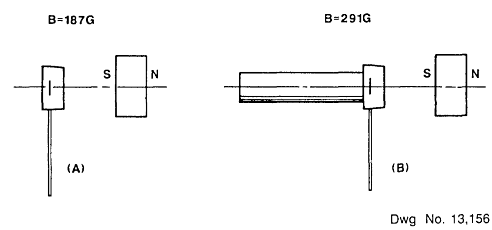


Figure 54

Size of the Concentrator

The active area of the Hall device is typically 0.01" square. Best results are obtained by tapering the end of the concentrator to approximately the same dimensions. With the "U" package, however, there is 0.044" from the active area to the rear surface of the package. Due to this 0.044" distance, a slightly larger end to the concentrator results in higher values of flux density at the active area. If the end is too large, the flux is insufficiently concentrated. **Figure 55(A), (B),** and **(C)** illustrates these effects using cylindrical flux concentrators and a 0.25" gap.

The length of the concentrator also has an effect on the flux density. This is illustrated in **Figure 56.**

Cylindrical concentrators were used here for convenience, but the body of the concentrator has little effect. The important factors are the shape, position, and surface area of the magnet end nearest the Hall sensor.

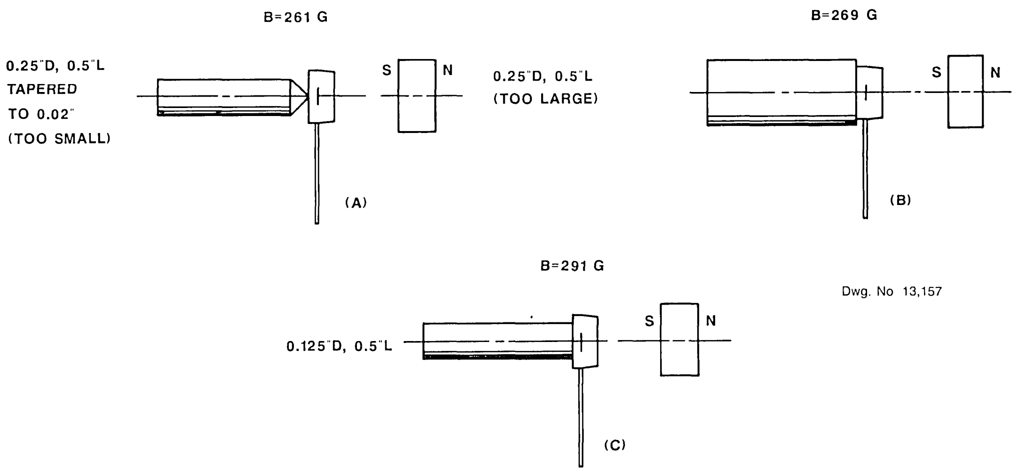


Figure 55

The effectiveness of other concentrator configurations can be measured easily by using a calibrated linear Hall device, such as the Sprague UGN-3503U, or a commercial gaussmeter.

Mounting the Magnet To a Ferrous Plate

Mounting the magnet to a ferrous plate will give an additional increase in flux density at the Hall element. Using the same configuration as in **Figure 55(C)**, which produced 291 G, note the available flux attained in **Figure 57(A)** and **(B)** with the addition of the ferrous plate.

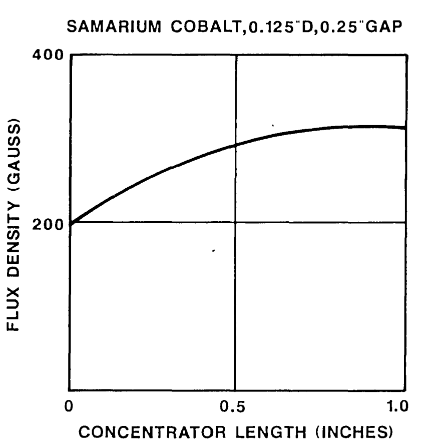
Figure 58 shows a possible concentrator for a ring magnet application. Using a flux concentrator that extends to both of the adjacent north poles, flux density increases from 265 G to 400 G (0.015" air gap). Note that the concentrator has a dimple, or mesa, centered on the Hall device. In most applications, the mesa will give a significant increase in flux density over a flat mounting surface.

Attractive Force and Distorted Flux Field

Whenever a flux concentrator is used, an attractive force exists between magnet and concentrator. That may be undesirable.

Feed-Throughs

An example of the use of a magnetic conductor to feed flux through a nonferrous housing is shown in **Figure 59.** A small electric motor has a 0.125" cube samarium cobalt magnet mounted in the end of its rotor, as shown. A 0.125" cube ferrous conductor extends through the alloy case with a 0.031" air gap between it and the magnet's south pole. The Hall switch is mounted at the other end with a flux concentrator behind it.



Dwg No 13,158

Figure 56

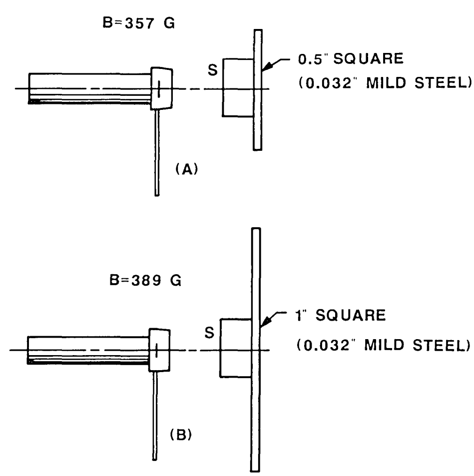


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Figure 57

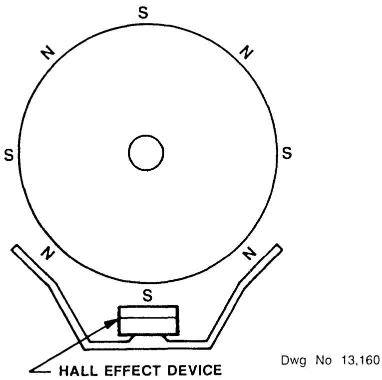


Figure 58

In general, the feed-through should be of approximately the same cross-sectional area and shape as is the magnet pole.

This concept can be used to feed flux through any non-ferrous material, such as a pump case, pipe, or panel.

The two curves of **Figure 60** illustrate the effects on flux density of increasing the length of the feed-through, as well as the contribution by the flux concentrator behind the Hall switch. Values for curve A were obtained with the flux concentrator in place, those for curve B without it. In both cases, the highest flux densities were achieved with the shortest feed-through dimension L, which was 0.125". Peak flux density was 350 G with flux concentrator in place, 240 G without it.

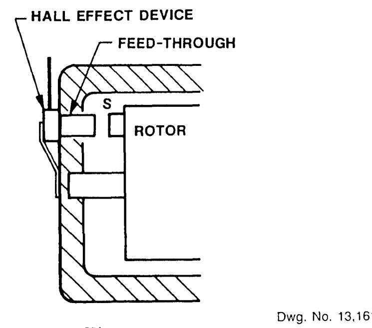


Figure 59

MAGNET SELECTION

A magnet must operate reliably with the total effective air gap in the working environment. It must fit the available space. It must be mountable, affordable, and available.

Figures Of Merit

The figures of merit commonly applied to magnetic materials are:

Residual Induction (B_r) in gauss: How strong is the magnetic field?

Coercive Force (H_c) in oersteds: How well will the magnet resist external demagnetizing forces?

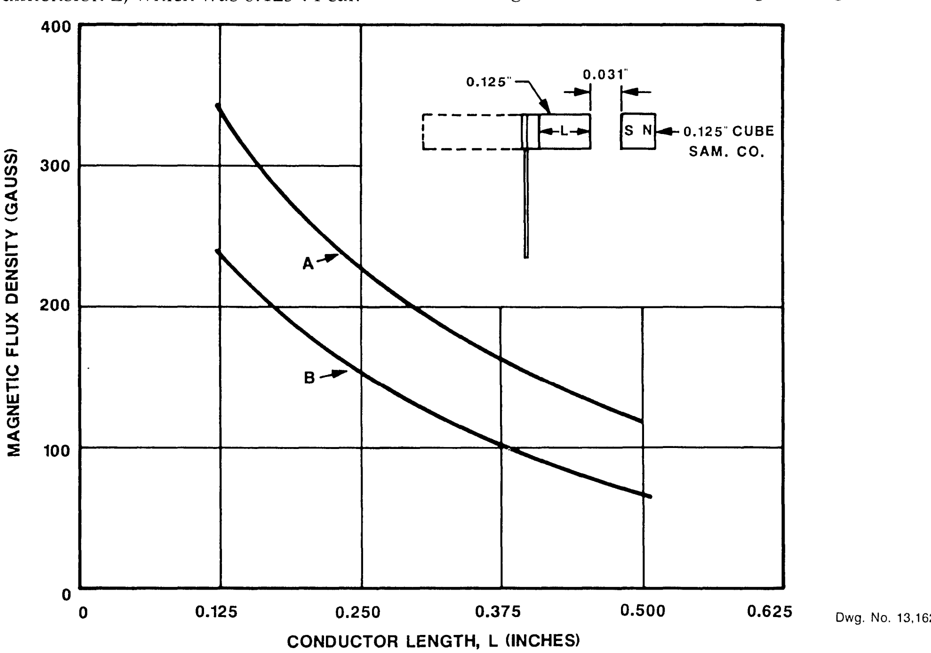


Figure 60

Maximum Energy Product (BH_{max}) in gauss-oersteds times 10^{-6}. A strong magnet that is also very resistant to demagnetizing forces has a high Maximum Energy Product. Generally, the larger the energy product, the better, stronger, and more expensive the magnet.

Temperature Coefficient in percent per degree Celsius: How much will the strength of the magnet change as temperature changes?

Magnetic Materials

Neodymium (Ne-Fe B)—The new neodymium-iron-boron alloys fill the need for a high maximum-energy product, moderately priced magnet material. The magnets are produced by either a powdered-metal technique called orient-press-sinter or a new process incorporating jet casting and conventional forming techniques. Current work is being directed toward reducing production costs, increasing operating temperature ranges and decreasing temperature coefficients. Problems relating to oxidation of the material can be overcome through the use of modern coatings technology. Maximum energy products range from 7.0 to 15.0 MGOe depending on the process used to produce the material.

Rare Earth—Cobalt is an alloy of a rare earth metal, such as samarium, with cobalt (abbreviated RE cobalt). These magnets are the best in all categories, but are also the most expensive by about the same margins. Too hard for machining, they must be ground if shaping is necessary. Maximum energy product, perhaps the best single measure of magnet quality, is approximately 16×10^6.

Alnico is a class of alloys containing aluminum, nickel, cobalt, iron, and additives that can be varied to give a wide range of properties. These magnets are strong and fairly expensive, but less so than RE cobalt. Alnico magnets can be cast, or sintered by pressing metal powders in a die and heating them. Sintered Alnico is well suited to mass production of small, intricately shaped magnets. It has more uniform flux density, and is mechanically superior. Cast Alnico magnets are generally somewhat stronger. The non-oriented or isotropic Alnico alloys (1, 2, 3, 4) are less expensive and magnetically weaker than the oriented alloys (5, 6, 5-7, 8, 9). Alnico is too hard and brittle to be shaped except by grinding. Maximum energy product ranges from 1.3×10^6 to 10×10^6.

Ceramic magnets contain barium or strontium ferrite (or another element from that group) in a matrix of ceramic material that is compacted and sintered. They are poor conductors of heat and electricity,

TABLE 4
Properties of Magnetic Materials

Material	Maximum Energy Product (Gauss-Oersted)	Residual Induction (Gauss)	Coercive Force (Oersteds)	Temperature Coefficient	Cost	Comments
R.E. Cobalt	16×10^6	8.1×10^3	7.9×10^3	−0.05%/°C	Highest	Strongest, smallest, resists demagnetizating best
Alnico 1, 2, 3, 4	$1.3\text{-}1.7 \times 10^6$	$5.5\text{-}7.5 \times 10^3$	$0.42\text{-}0.72 \times 10^3$	−0.02%/°C to −0.03%/°C	Medium	Non-oriented
Alnico, 5, 6, 5-7	$4.0\text{-}7.5 \times 10^6$	$10.5\text{-}13.5 \times 10^3$	$0.64\text{-}0.78 \times 10^3$	−0.02%/°C to −0.03%	Medium-High	Oriented
Alnico 8	$5.0\text{-}6.0 \times 10^6$	$7\text{-}9.2 \times 10^3$	$1.5\text{-}1.9 \times 10^3$	−0.01%/°C to +0.01%/°C	Medium-High	Oriented, high coercive force, best temperature coefficient.
Alnico 9	10×10^6	10.5×10^3	1.6×10^3	−0.02%/°C	High	Oriented, highest energy product.
Ceramic 1	1.0×10^6	2.2×10^3	1.8×10^3	−0.2%/°C	Low	Non-oriented, high coercive force, hard, brittle, non-conductor
Ceramic 2, 3, 4, 6	$1.8\text{-}2.6 \times 10^6$	$2.9\text{-}3.3 \times 10^3$	$2.3\text{-}2.8 \times 10^3$	−0.2%/°C	Low-Medium	Partially oriented, very high coercive force, hard, brittle, non-conductor
Ceramic 5, 7, 8	$2.8\text{-}3.5 \times 10^6$	$3.5\text{-}3.8 \times 10^3$	$2.5\text{-}3.3 \times 10^3$	−0.2%/°C	Medium	Fully oriented, very high coercive force, hard, brittle, non-conductor
Cunife	1.4×10^6	5.5×10^3	0.53×10^3	—	Medium	Ductile, can cold form and machine
Fe-Cr	5.25×10^6	13.5×10^3	0.60×10^3	—	Medium-High	Can machine prior to final aging treatment
Plastic	$0.2\text{-}1.2 \times 10^6$	$1.4.3 \times 10^3$	$0.45\text{-}1.4 \times 10^3$	−0.2%/°C	Lowest	Can be molded, stamped, machined
Rubber	$0.35\text{-}1.1 \times 10^6$	$1.3\text{-}2.3 \times 10^3$	$1\text{-}1.8 \times 10^3$	−0.2%/°C	Lowest	Flexible
Neodymium	$7\text{-}15 \times 10^6$	$6.4\text{-}11.75 \times 10^3$	$5.3\text{-}6.5 \times 10^3$	−.157%/°C to −.192/°C	Medium-High	Non-oriented

are chemically inert, and have high values of coercive force. As with Alnico, ceramic magnets can be fabricated with partial or complete orientation for additional magnetic strength. Less expensive than Alnico, they also are too hard and brittle to shape except by grinding. Maximum energy product ranges from 1×10^6 to 3.5×10^6.

Cunife is a ductile copper base alloy with nickel and iron. It can be stamped, swaged, drawn, or rolled into final shape. Maximum energy product is approximately 1.4×10^6.

Iron-Chromium magnets have magnetic properties similar to Alnico 5, but are soft enough to undergo machining operations before the final aging treatment hardens them. Maximum energy product is approximately 5.25×10^6.

Plastic and rubber magnets consist of barium or strontium ferrite in a plastic matrix material. They are very inexpensive and can be formed in numerous ways including stamping, molding, and machining, depending upon the particular matrix material. Since the rubber used is synthetic, and synthetic rubber is also plastic, the distinction between the two materials is imprecise. In common practice, if a plastic magnet is flexible, it is called a rubber magnet. Maximum energy product ranges from 0.2×10^6 to 1.2×10^6.

Choosing Magnet Strength

A magnet must have sufficient flux density to reach the Hall switch maximum operate point specification at the required air gap. Good design practice suggests the addition of another 50 G to 100 G for insurance and a check for sufficient flux at the expected temperature extremes.

The data sheet on the Sprague UGN-3020U Hall switch specifies a 350 G maximum operate point at +25°C. After adding a pad of 100 G, we have 450 G at +25°C. If operation to +70°C is needed, the requirement is 450 G + 45 G = 495 G. (For calculations, we use ±0.7°C operate point coefficient and ±1.0/°C release point coefficient.) Since the temperature coefficient of most magnets is negative, this factor would also require some extra flux at room temperature to guarantee high-temperature operation.

Coercive Force

Coercive force becomes important if the operating environment will subject the magnet to a strong demagnetizing field, such as that encountered near the rotor of an ac motor. For such applications a permanent magnet with high coercive force (ceramic, Alnico 8, or, best of all, RE cobalt) is clearly indicated.

Price and Peak Energy Product

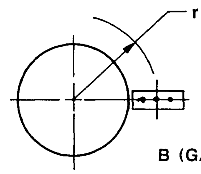
The common permanent magnet materials and their magnetic properties are summarized in Table 4. The cost column shows the relationship between the price paid for a magnet and its peak energy product.

CURRENT LIMITING AND MEASURING

Current Sensors

Hall Effect devices are excellent current-limiting or measuring sensors. Their response ranges from dc to the kHz region. The conductor need not be interrupted in high-current applications.

The magnetic field about a conductor is normally not intense enough to operate a Hall effect device **(Figure 61).**



$$B\ (\text{GAUSS}) \approx \frac{I\ (\text{AMPS})}{4\pi r\ (\text{INCHES})}$$

Dwg. No. 13,163

Figure 61

The radius, r, is measured from the center of the conductor to the active area of the Hall device. With a radius of 0.5″ and a current of 1,000 A, there would be a magnetic flux density of 159 G at the Hall device. At lower current, use a toroid or closed magnetic circuit to increase the flux density, as illustrated in **Figure 62(A)** and **(B)**.

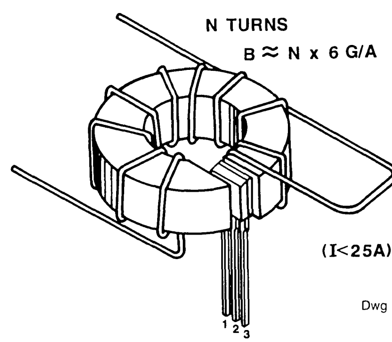


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Figure 62(A)

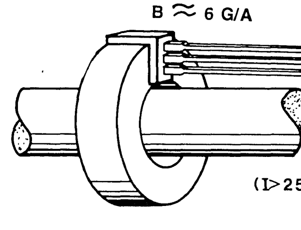

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Figure 62(B)

With an 0.08" air gap for the "T" or "M" packages, there would be 6G/A per turn for **Figure 62(A),** and 6G/A for **Figure 62(B).**

The core material can be of either ferrite or mild steel (C-1010) for low-frequency applications, and ferrite for high-frequency measurements.

The main concerns are:

—That the core retains minimal field when the current is reduced to zero.

—That the flux density in the air gap is a linear function of the current.

—And that the air gap is stable over the operating temperature range.

The cross-sectional dimensions of the core are at least twice the air gap dimension to ensure a reasonably homogeneous field in the gap. For example, a toroid with an 0.08" gap would have at least a 0.16" × 0.16" cross-section.

Another simple and inexpensive application is illustrated in **Figure 63.** A toroid of the appropriate diameter is formed from mild steel stock, 0.0625" thick and 0.1875" wide. The ends are formed to fit on each side of the central portion of the Hall device. One advantage of this technique is that the toroid can be placed around a conductor without disconnecting the conductor.

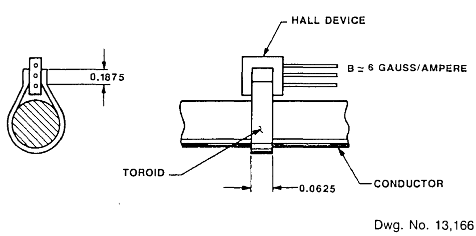


Figure 63

Multi-Turn Applications

There are several considerations in selecting the number of turns for a toroid such as the one in **Figure 62(A):**

Hall Switches

Keep the flux density in the 200 G to 300 G range for a trip point. Sprague can supply parts with a narrow distribution of magnetic parameters within this range. If, for example, you want the Hall switch to turn ON at 10 A:

$$N = \frac{300\text{ G}}{6\text{ G/A} \times 10\text{ A}} = 5\text{ turns}$$

It is possible to supply parts having a ±20% operating point window in this range. (Contact Sprague Customer Service, Concord, New Hampshire 603/224-1961.)

Hall Linears

It is desirable to have flux density in the 200 G to 300 G range to maximize the output signal/zero drift ratio. In using the Sprague UGN-3501LI, for example, the zero drift is typically 0.15 mV/°C, so from 0°C to +70°C there would be typically a ±7 mV zero drift. A sensitivity of 1.4 mV/G and a 300 G field would give a 420 mV output signal.

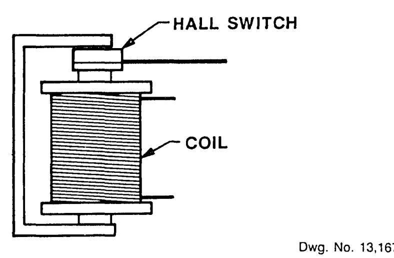


Figure 64

TABLE 5

Characteristics of Hall Effect Linear Devices

Sprague Type	Package	Description	Operating Temperature Range*	Supply Voltage Min. (V)	Supply Voltage Max. (V)	Supply Current Typ. (mA)	Supply Current Max. (mA)	Quiescent Output Min. (V)	Quiescent Output Max. (V)	Typ. Sensitivity (mV/G)
3501	LI	Differential Output, Emitter Follower	UGN	8.0	16	10	18	—	0.4	1.3
3501	HH,LT,LL,T,U	Single Output, Emitter Follower	UGN	8.0	12	10	20	2.5	5.0	0.7
3503	HH,LT,LL,T,U	Single Output, Emitter Follower	UGN UGS	4.5	6.0	9.0	14	2.25	2.75	1.3
3605	K	Differential Output	UGN	—	5.0†	—	5.0†	—	—	0.4§

*UGN = −20°C to +85°C.
UGS = −40°C to +125°C.
†Typical value.
§Increases as I_{CC} increases.

7

The Type 3501LI also has a −0.3%/°C sensitivity coefficient. For example, a 420 mV output signal at 0°C would drop to 330 mV at +70°C.

The sensitivity of Type 3501LI can be calibrated by adding matched resistors to each leg of the zero control. They give an added bonus of a reduced sensitivity coefficient of about −0.15%/°C as they approach 50 Ω values.

For low-current applications in which many turns are required, one can wind a bobbin, slip it over a core, and complete the magnetic circuit through the Hall device with a bracket-shaped pole piece, as shown in **Figure 64.**

With this bobbin-bracket configuration it is possible to measure currents in the low milliampere range or to replace a relay using a Hall switch. To activate a Hall switch at 10 mA (±20%), using a device with a 200 G (±40 G) operate point, bobbin windings require:

$$N = \frac{200\ \text{G}}{6\ \text{G/A} \times 0.01\ \text{A}} = 3333\ \text{turns}$$

It would be practical to tweak the air gap for final, more precise calibration. In all cases, *be careful not to stress the package.*

Other Applications For Linear Sensors

Electrical and magnetic characteristics of Sprague linear Hall Effect ICs are shown in Table 5.

Type UGN-3503U and UGS-3503U Hall Effect linear sensors are used primarily to sense relatively small changes in magnetic field—changes too small to operate a Hall Effect switching device. They are customarily capacitively coupled to an amplifier, which boosts the output to a higher level.

As motion detectors, gear tooth sensors, and proximity detectors (**Figure 65**), they are magnetically driven mirrors of mechanical events. As sensitive monitors of electromagnets, they can effectively measure a system's performance with negligible system loading while providing isolation from contaminated and electrically noisy environments.

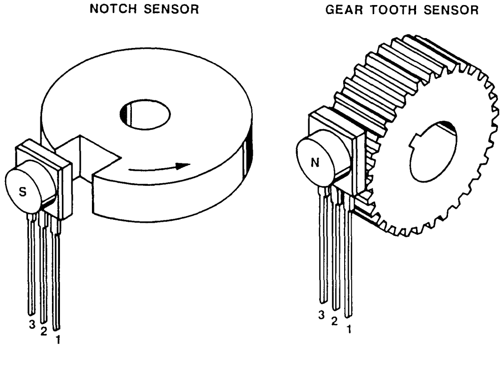


Figure 65

Each Hall Effect integrated circuit includes a Hall sensing element, linear amplifier, and emitter-follower output stage. Problems associated with handling tiny analog signals are minimized by having the Hall cell and amplifier on a single chip.

The output null voltage of Type 3503 is nominally one-half the supply voltage. A south magnetic pole presented to the branded face of the Hall effect sensor will drive the output higher than the null voltage level. A north magnetic pole will drive the output below the null level.

In operation, instantaneous and proportional output-voltage levels are dependent on magnetic flux density at the most sensitive area of the device. Greatest sensitivity is obtained with a supply voltage of 6 V, but at the cost of increased supply current and a slight loss of output symmetry. The sensor's output is usually capacitively coupled to an amplifier that boosts the output above the millivolt level.

In the two applications shown in **Figures 66** and **67**, permanent bias magnets are attached with epoxy glue to the back of the epoxy packages. The presence of ferrous material at the face of the package then acts as a flux concentrator.

The south pole of a magnet is attached to the back of the package if the Hall Effect IC is to sense the presence of ferrous material. The north pole of a magnet is attached to the back surface if the integrated circuit is to sense the absence of ferrous material.

Calibrated linear Hall devices, which can be used to determine the actual flux density presented to the Type 3503 sensor in a particular application, are available from the Sensor Division, Sprague Electric Company, Concord, NH 03301.

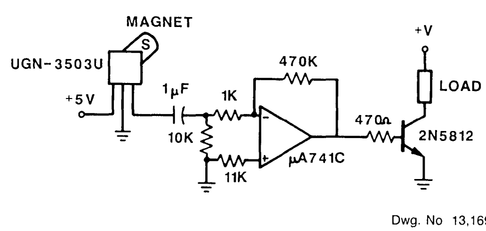


Figure 66

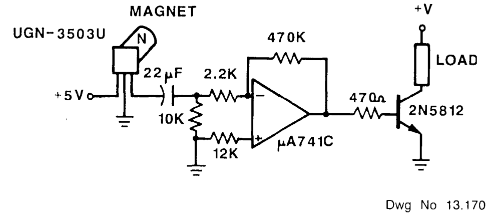


Figure 67

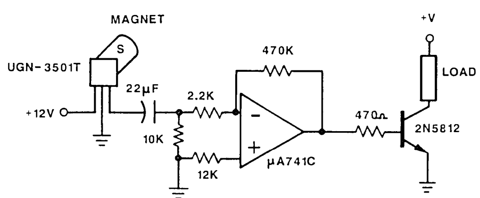
Ferrous Metal Detectors

Two similar detector designs are illustrated in **Figures 68** and **69.** The first senses the presence of a ferrous metal; the other senses an absence of the metal. The two sensing modes are accomplished simply by reversing the magnet poles relative to the Sprague UGN-3501T. The pole of the magnet is affixed to the unbranded side of the UGN-3501T in both cases.

Frequency response characteristics of this circuit are easily controlled by changing the value of the input decoupling capacitor for the low-frequency break-point. If high-frequency attenuation is desired, a capacitor can be used to shunt the feedback resistor.

Metal Sensor

The north pole of the magnet is affixed to the back side of a UGN-3501T. The sensor is in contact with the bottom of a 0.09375" epoxy board. A 20 mV output change (decrease) is produced as a 1" steel ball rolls over the sensor. This signal is amplified and inverted by the µA 741C operational amplifier and drives the 2N8512 ON.



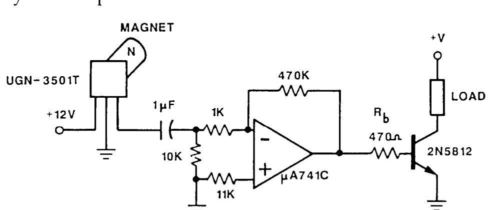
Dwg No. 13,171

Figure 68

Notch Sensor

The south pole of the magnet is fixed to the backside of a UGN-3501T. The sensor is 0.03125" from the edge of a steel rotor. A 0.0625" wide by 0.125" deep slot in the rotor edge passing the sensor causes a 10 mV peak output change (decrease). This signal is amplified and inverted by the µA 741C op amp and drives the 2N5812 ON.

Note that, in both examples, the branded side of the UGN-3501T faces the material (or lack of material) to be sensed. In both cases, the presence (or absence) of the ferrous metal changes the flux density at the Hall Effect sensor so as to produce a negative going output pulse. The pulse is inverted by the amplifier to drive the transistor ON.

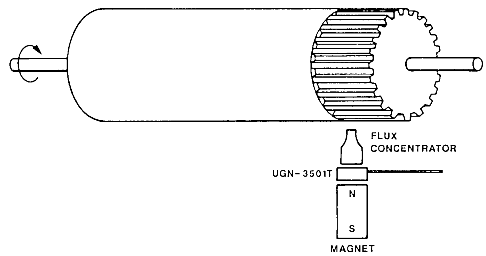


Dwg No 13,172

Figure 69

Printer Application

The device in **Figure 70** senses lobes on a character drum. Lobes are spaces 0.1875" apart around the circumference, are 0.25" long and rise 10 to 15 mils from the surface of the drum.



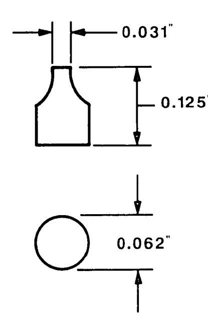
Dwg No. 13,173

Figure 70

A UGN-3501T Hall Effect linear IC sensor is used with an Indiana General Magnet Products Company SR8522 magnet. The north pole is affixed to the reverse side of the "T" pack. A flux concentrator is affixed to the branded face of the "T" pack. Though it does not provide a flux return path, a concentrator will focus the magnetic field through the switch.

The concentrator blade, shown in **Figure 71,** is aligned with the drum lobe at an air gap distance of 0.01". The output change is 10 mV peak, amplified as shown to develop a +3 V output from the operational amplifier, driving the transistor ON, as illustrated in **Figure 72.**

Sensitivity is so great in this configuration that the UGN-3501T output signal's baseline quite closely tracks eccentricities in the drum. This affects lobe resolution, but lobe position can still be measured.



Dwg No 13,174

Figure 71

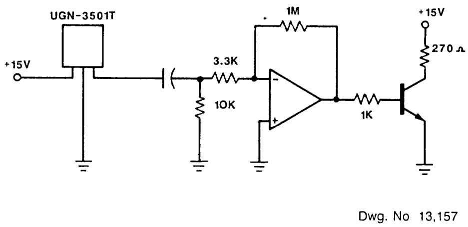


Figure 72

Differential Output Device

The Type UGN-3501LI is well-suited to accurate measurement and control of position, weight, thickness, velocity, and current. The device provides a linear differential output that is a function of magnetic field intensity, with a typical sensitivity of 1.4 V/1000 G.

Either magnetic pole can be used. Pins 1 and 8 are current-sinking and sourcing terminals for the differential output. Changing poles inverts the output. Connections may be reversed to account for this change.

Figure 73 shows a 20 Ω potentiometer used to establish an output offset null. Pins 5, 6 and 7 can be shorted if an output offset voltage of up to ± 400 mV can be tolerated.

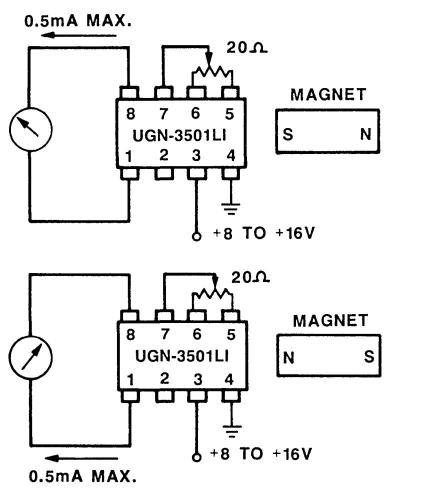


Figure 73

UGN-3501LI Output Design

The output-current capability of the UGN-3501LI is 0.5 mA. In the differential connection, one output pin sources load current, the other must sink it. A simple method for increasing drive capability is illustrated in **Figure 74.**

A 4.3 Ω resistor is connected from each output pin to ground. The quiescent bias current of the output stage is increased, and the sinking capability is increased to 1 mA.

If higher current-drive capability is required, the simplest solution is the addition of a pair of emitter-followers, shown in **Figure 75.**

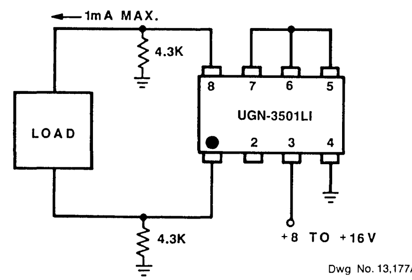


Figure 74

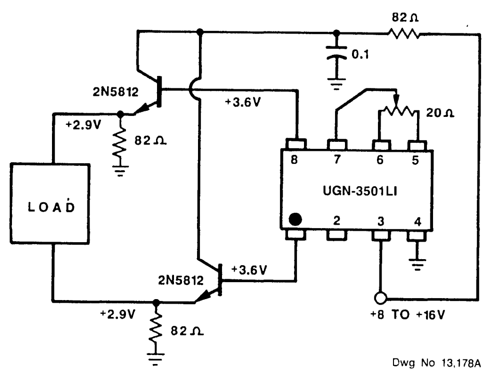
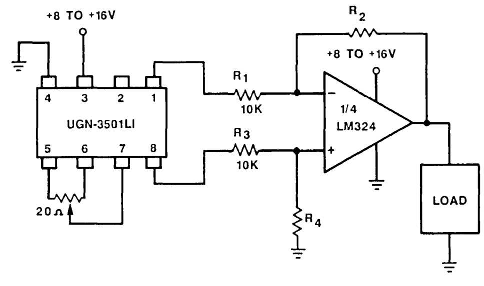


Figure 75

Up to 30 mA of load current can be sourced by the circuit as shown. This can be increased considerably by using Darlington power transistors and lower resistance in the emitter circuits. Note that the emitter-followers have no voltage gain. The output-voltage differential is essentially the same as that of the UGN-3501LI.

An operational amplifier will supply a voltage gain and a current gain, and transform the differential output of the UGN-3501LI to a single-ended output, as illustrated in **Figure 76.** (The circuit will drive a load that has one side grounded.)



Dwg No 13,179A

Figure 76

The LM324 quad operational amplifier will operate from a single power supply if the output does not swing in the negative direction. Pin 1 of the UGN-3501LI does swing negative when a magnetic south pole approaches the device surface. Pin 1, therefore, is connected to the negative or inverting input of the LM324, and its output swings in the positive direction. Reversing connections to Pins 1 and 8 allows the output to respond to a magnetic north pole. If the application requires the output be capable of swing both negative and positive, then a dual power supply would most be used.

$$\text{Voltage amplification} \approx \frac{R_2}{R_1}$$

with

$$R_1 = R_3$$
$$R_2 = R_4$$

The LM324 can source 40 mA. Other operational amplifiers suitable for single supply operations are MC3403P, MC3458P1, and CA3160E.

GLOSSARY

Active Area—The site of the Hall element on the encapsulated IC chip.

Air Gap—The distance from the face of the magnetic pole to the face of the sensor.

Ampere-turn (NI)—The mks unit of magnetomotive force.

Ampere-turns/meter (NI/m)—The mks unit of magnetizing force. One ampere turn per meter equals 79.6 oersteds.

Bipolar—A method of operating a Hall sensor using both north and south magnetic poles.

Coercive Force (H_c)—The demagnetizing force that must be applied to reduce the magnetic flux density in a magnetic material to zero. Measured in oersteds.

Concentrator—Any ferrous metal used to attract magnetic lines of force.

Gauss (G)—The CGS unit of magnetic flux density. Equivalent to one maxwell per square centimeter (Mx/cm^2). One gauss equals 10^{-4} tesla.

Gilbert—The CGS unit of magnetomotive force.

Head-On—A method by which the Hall sensor is actuated. The magnetic field is increased and decreased by moving the magnetic pole toward and away from the sensor face.

Maximum Energy Product (BH_{max})—The highest product of B and H from the demagnetization curve of a magnetic material. Given in gauss-oersteds x 10^6 (MGOe).

Maxwell (Mx)—The CGS unit of total magnetic flux. One maxwell equals 10^{-8} webers.

Oersteds (Oe)—The CGS unit of magnetizing force. Equivalent to gilberts per centimeter (Gilberts/cm). One oersted equals 125.7 ampere-turns per meter.

Remanent Induction (B_d)—The magnetic induction that remains in a magnetic circuit after removal of an applied magnetomotive force. When there is no air gap in the magnetic circuit, remanent and residual induction are equal. With an air gap, remanence will be less than residual induction. Measured in gauss.

Residual Induction (B_r)—The flux density remaining in a closed magnetic circuit of magnetic material when the magnetizing force adequate to saturate the material is reduced to zero. Measured in gauss.

Slide-by—A method which a Hall sensor is actuated. The magnetic field is increased and decreased as a permanent magnet is moved laterally past the sensor face.

Tesla (T)—The mks unit of magnetic flux density. Equivalent to one weber per square meter (Wb/m^2). One tesla equals 10^4 gauss.

Toroid—A doughnut-shaped ring often composed of iron, steel or ferrite.

Total Effective Air Gap (TEAG)—The distance from the face of a magnetic pole to the active area of a Hall Effect sensor.

Unipolar—A method of operating a Hall sensor using a single magnetic pole, usually the south pole.

Vane—Any ferrous metal used to shunt a magnetic field away from the Hall sensor (at least 1.5 times the width of an associated magnet).

Window—An opening in a vane at least 1.5 times the width of an associated magnet.

SOURCES FOR FERRITE TOROIDS AND MAGNETS

As a convenience, some sources for ferrite toroids and magnets are listed below. Addresses and telephone numbers are correct to the best of our knowledge at time of printing.

TOROID SUPPLIERS

J.W. Miller Co.
Div. of Bell Industries
19070 Reyes Avenue
P.O. Box 5825
Rancho Dominguez, CA
90224
213/537-5200

Fair-Rite Products Corp.
P.O. Box J
Wallkill, NY 12589-0288
914/895-2055

Magnetics
900 East Butler Road
P.O. Box 391
Butler, PA 16001
412/282-8282

Permag Northeast Corp.
10 Fortune Drive
Billerica, MA 01865
617/663-7500

Stackpole Corporation
201 Stackpole Street
St. Marys, PA 15857
814/781-1234

MAGNET SUPPLIERS

MAGNET SUPPLIERS	Types
Arnold Engineering P.O. Box G Marengo, IL 60152 815/568-2000	Alnico, Ceramic, Multipole Ring
Bunting Magnetics Company 1165 Howard St. Elk Grove Village, IL 60007 312/593-2060	Alnico, Ceramic, Plastic
Ceramic Magnetics, Inc. 87 Fairfield Road Fairfield, NJ 07006 201/227-4222	Ceramic, Multipole Ring
Crucible Magnetics 101 Magnet Dr. Elizabethtown, NJ 42701 502/769-1333	Alnico, Rare Earth
Hitachi Magnetics 7800 Neff Road Edmore, MI 48829 517/427-5151	Alnico, Ceramic, Rare Earth
IG Technolog 405 Elm Street Valparaiso, IN 46383 219/462-3131	Alnico, Ceramic, Multipole Ring, Rare Earth
Ogallala Electronics P.O. Box 59 Ogallala, NE 69153 308/284-4093	Ceramic, Multipole Ring
Permag Corporation 400 Karin Lane Hicksville, NY 11801 516/822-3311	Representatives of various manufacturers. Permag also does custom grinding.
Recoma, Inc. 2 Stewart Place Fairfield, NJ 07006 201/575-6970	Rare Earth
Stackpole Corporation 700 Elk Ave. Kane, PA 16735 814/837-7000	Ceramic
TDK Electronics Co., Ltd. 14-2 2-Chome Uchikanda, Choyoda Ku Tokyo, Japan	Rare Earth
The Electrodyne Company 4188 Taylor Road Batavia, OH 45103 513/732-2822	Plastic
Xolox Corporation 6932 Gettysburg Pike Ft. Wayne, IN 46804 219/432-0661	Plastic, Multipole Ring
3-M Plastiform 3-M Center Industrial Electric Products Div. Building 225-4N St. Paul, MN 55144 Attn: Dorothy Landucci 612/733-8216	Plastic
Industrial Magnetics, Inc. 32 West Boyne Road Boyne City, MI 49712 616/582-3100	Alnico, Barium Ferrite, Ceramic, Flexible Vinyl, Rare Earth
Magnaquench Div. of Gen. Motors 6435 S. Scatterfield Rd. Anderson, IN 46011 317/646-2763	Neodymium

USING CALIBRATED DEVICES

UGN-3503U

The Sprague calibrated Type 3503 is an accurate, easy-to-use tool for measuring magnetic flux densities. Each device is individually calibrated and furnished with a calibration curve and sensitivity coefficient. Although calibration is performed in a south and north 500 G field, the UGN-3503 is useful for measuring fields in both polarities to 1000 G.

A closely regulated 5 V (± 10mV) power supply is necessary to preserve accuracy in calibrated UGN-3503 flux measurements. An ambient temperature range of 21°C to 25°C must also be maintained.

Connect Pin 1 to voltage Vcc, Pin 2 to ground, and Pin 3 to a high-impedance voltmeter. Before use, the device should be powered-up and allowed to stabilize for one minute.

The calibration curve affords the most convenient method of flux measurement. Subject the device to the field in question. Read the output voltage from the voltmeter and find that value on the chart X axis. Locate the intersection of the output level with the calibration trace and read the corresponding flux density on the chart's Y axis.

The sensitivity coefficient can be used to calculate flux densities somewhat more precisely. First, determine the null output voltage of the device under 0 G or null field condition. Then, read the output of the device under an applied field condition by subjecting it to the flux in question. Magnetic flux density at the device may be calculated by:

$$B = \Delta V_{OUT(B)} - V_{OUT(0)} * 1000/S$$

where $\Delta V_{OUT(B)}$ = Output voltage under applied field in volts.
$V_{OUT(0)}$ = Output null voltage in volts.
S = Sensitivity coefficient in mV/G.
B = Magnetic flux density at the device in gauss.

UGN-3604U

The most basic Sprague Hall Effect magnetic field sensor is the UGN-3604U. The differential output of the device is a function of magnetic flux density present at the sensor. Sensitivity is a function of the control current; sensitivity increases as the control current increases.

The UGN-3604 is frequently used for measurement of flux density, either in Hall applications as a design aid, or in Hall Effect device test equipment. The UGN-3604 is supplied with a calibration chart.

Each UGN-3604 Hall Effect sensor is individually calibrated at a temperature of +25°C using a supply-voltage of 5 V. Its calibration chart indicates differential output values for a magnetic flux density ranging from 0 G to 1000 G. Sensitivity at this supply-voltage level is typically 50 mV per 1000 G.

THE HALL-EFFECT SENSOR

Reprinted from *Sensors* March 1986

TRENT WOOD, SPRAGUE ELECTRIC COMPANY

The basic Hall sensor is simply a small sheet of semiconductor material. A constant voltage source forces a constant bias current to flow in the semiconductor sheet. The output, a voltage measured across the width of the sheet, reads near zero if a magnetic field is not present (Figure 1).

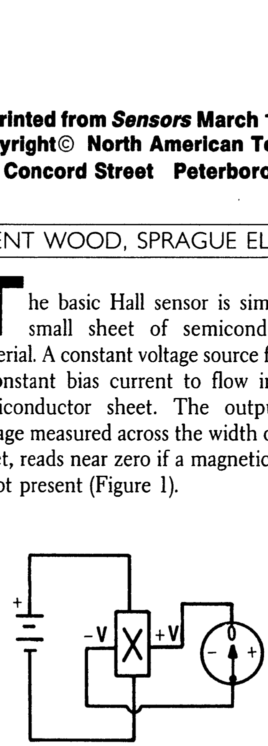


Figure 1. *If no magnetic field is present, the voltage measured across the width of the semiconductor material of the Hall-effect sensor is zero.*

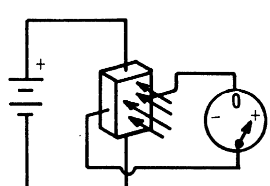


Figure 2. *The output voltage of a Hall-effect sensor is directly proportional to the magnetic field present at right angles to the direction of current flow through the sensor.*

If the biased Hall sensor is placed in a magnetic field oriented at right angles to the Hall current, the voltage output is in direct proportion to the strength of the magnetic field. This is the Hall effect, discovered by E.H. Hall in 1879 (Figure 2).

The basic Hall sensor is essentially a transducer that will respond with an output voltage if the applied magnetic field changes in any manner. Differences in the response of devices are generally related to tolerances and specifications, such as operate (turn on) and release (turn off) thresholds, as well as temperature range and temperature coefficients of these parameters. Also available are linear output sensors that differ in sensitivity or respond per gauss change.

A Hall sensor is activated by a magnetic field created by either electromagnets or permanent magnets. Magnetic fields have two important characteristics: magnitude and direction (or orientation). In the absence of any magnetic field, the most common Hall-effect digital switches are designed to be off (open circuit at output). They will turn on only if subjected to a magnetic field that has both sufficient strength and the correct polarity.

If the approach of the South pole of a magnet would cause switching action of a digital sensor, the approach of the North pole of a magnet would have no effect. In practice, a close approach by the South pole of a magnet will cause the output transistor to turn on.

The transfer characteristics graph (Figure 3) shows input vs output. The input variable, which is the strength of the activating magnetic field (magnetic flux density, measured in gauss), is plotted along the horizontal axis. The output variable, which is the digital (on, off) output from a Hall switch, is plotted along the vertical axis.

In the absence of any magnetic field (zero gauss), the Hall-effect switch is off

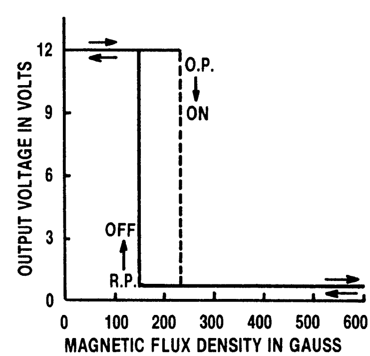


Figure 3. *The transfer characteristic graph plots input on the horizontal axis vs output on the vertical axis. With no magnetic field present, the Hall-effect switch is off; as the field increases, the switch will turn on at a predesigned operating point. This particular device exhibits hysteresis of 90 gauss.*

Figures of Merit Commonly Applied to Magnetic Materials

► *Residual Induction (B_r) in Gauss. How strong is the magnetic field? A magnet must have sufficient flux density to satisfy the Hall switch maximum operating point specification at the required air gap.*

► *Coercive Force (H_c) in Oersteds. How well will the magnet resist external demagnetizing forces? This property becomes important if the operating environment will subject the magnet to a strong demagnetizing field, such as might be encountered near the rotor of an A.C. motor. For such applications, a permanent magnet with high coercive force (ceramic, alnico-8, or, best of all, RE cobalt) is clearly indicated.*

► *Maximum Energy Product [(B_d x H_d) Max x 10^6] in Gauss-Oersteds. A strong magnet that is also very resistant to demagnetizing forces would have a high maximum energy product. Generally, the larger the energy product, the better, stronger, and more expensive the magnet.*

► *Temperature Coefficient in Percent per Degree Celsius. How much will the strength of the magnet change as the temperature changes?*

and the output voltage equals the power supply (12 V). As the strength of the magnetic field increases, at some point (240 gauss in this case) the output transistor will turn on and the output voltage goes to zero. The output does not change even if the magnetic field's strength continues to increase.

The switch stays on until the magnetic field falls well below the 240 G operating point. This is a circuit design characteristic (hysteresis) that prevents oscillations. Our example uses a 90 gauss hysteresis (240-150), which will turn the device off at 150 gauss.

All switches turn on at or below their maximum operating point flux density, and when the magnetic field is reduced, all devices turn off before the flux density drops below their minimum release point value. Additionally, each device has a minimum amount (typically, 20 gauss) hysteresis to ensure clean switching action. This hysteresis ensures that even if mechanical vibration or electrical noise is present, the switch output is fast, clean, and occurs only once per threshold crossing.

Linear Hall-effect sensors differ from digital Hall-effect sensors with respect to the output response from the sensor. The digital sensor has an off/on or high/low output; the linear sensor has an output proportional to the magnetic field subjected to the "active area." Hall-effect linear sensors are used primarily to sense relatively small changes in magnetic fields, changes too small to operate a Hall-effect digital switch.

The exact magnetic flux density values required to activate Hall sensors differ for several reasons, including design criteria and manufacturing tolerances. Extremes in temperature also affect the response characteristics of the sensors.

For each device type, worst-case magnetic specifications can be set out for the user by a Hall-effect sensor marketing or applications engineer, if it has been determined that a catalogue item will not meet required tolerances.

APPLICATIONS

With an understanding of how Hall-effect sensors work, it is possible to build devices around them. The physical aspects of their characteristics form the basis of Hall device applications.

► **Analysis.** The field created by a magnet must be compatible with the characteristics of the Hall-effect device it is expected to operate. Measure the strength of the magnetic field, which is greatest at the magnet's pole face, with a gaussmeter or a calibrated linear Hall sensor. Then plot a graph of field strength (magnetic flux density) vs distance of the magnet from the device along the intended line of travel of the magnet. Then, by using the Hall device specifications (sensitivity of mV/gauss for a linear device, or operate and release points in gauss for a digital device) one can find the critical distances for a particular magnet and type of motion. These field strength plots are not linear, and the shape of the plot depends greatly upon magnet shape, magnetic circuit (concentrators), and path traveled.

► **Total Effective Air Gap.** Hall-effect switches are offered in many different packages, such as epoxy three-pin SIPs, ceramic substrate mounted chips, ceramic three-pin SIPs, and surface mount packages. The most critical difference between packages is the distance from the face of the package to the surface of the Hall cell: the active area depth, which effectively adds to the total effective air gap.

The total effective air gap (TEAG) is the sum of the active area depth and the distance between the package's surface and the magnet's surface. For Hall device applications, the TEAG should be as small as possible, consistent with the limitations of the activating mechanical system. This will ensure that the magnetic flux will always be great enough to switch the device. Remember, magnetic flux decreases very sharply as the total effective air gap increases.

► **Modes of Operation.** There are many ways to operate a Hall sensor. For example, with a simple bar or rod magnet there are two possible paths for the magnet to travel—head-on and slide-by. In the head-on mode, the magnetic pole moves along a perpendicular path straight at the active face of the Hall device. The head-on mode is simple, works well, and is relatively insensitive to lateral motion; however, if the mechanism moving the magnet overshoots the mark, the sensor package could be damaged.

A second possible path is to move the magnet in from the side of the Hall device in the slide-by mode of operation. The slide-by mode is commonly used to avoid contact with the sensor package. The use of strong magnets or ferrous flux concentrators in well-designed slide-by magnetic circuits allows better sensing precision with a shorter travel path than the head-on mode.

Magnet manufacturers generally can provide head-on flux density curves for

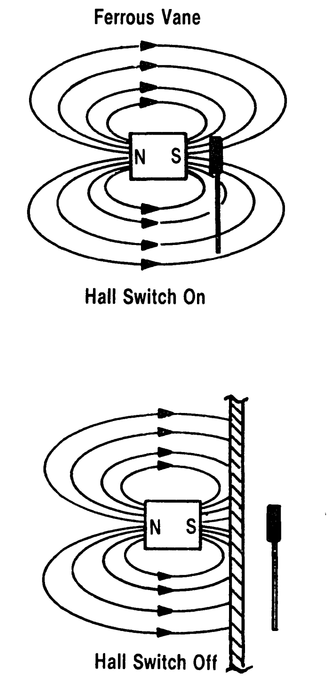


Figure 4. *The ferromagnetic vane moves between the activating magnet and the Hall-effect switch shunting the flux field from the switch. These assemblies can be used for precision switching over large temperature ranges.*

their magnets, but they often do not characterize magnets for slide-by operation, possibly because different air gap choices lead to an infinite number of these curves. Once a TEAG is chosen, however, the head-on magnet curves can be used to find the peak flux density (a single point) for slide-by applications by noting the value of magnetic flux at the chosen TEAG.

A third mode of operation keeps the Hall-effect sensor and magnet a fixed distance from one another and switches the sensor with a movable ferromagnetic vane. The Hall device and magnet can be molded together as a unit in a single rigid assembly, separated by an air gap. This eliminates alignment problems and produces an extremely rugged switching assembly.

The Hall device is held in the on state by the activating magnet. Placing the vane between the magnet and the Hall device (Figure 4) forms a magnetic shunt that distorts the flux field away from the Hall device. The vane can be made in many configurations to repeatedly sense position within ±0.002 in. over a 125°C temperature range.

The ferrous vane or vanes that interrupt the flux could have linear motion or rotational motion (as for a shaft encoder). Ferrous vane assemblies, due to the steep flux density/distance curves that can be achieved, are often used where precision switching over a large temperature range is required.

► **Steep Slopes and High Flux Densities.** For linear Hall devices, greater flux changes for a given displacement give greater outputs, clearly an advantage because the voltage output of the sensor will be much greater, reducing the possibility of instruments picking up electrical noise. The same property is desirable for digital Hall devices, but the reasons are more subtle. To achieve consistent switching action in a given application, the Hall device must always switch on and off at the same positions relative to the magnet.

Consider, for example, the flux density curves of the two different magnet configurations in Figure 5. With an operating point flux density of 200 gauss, a digital

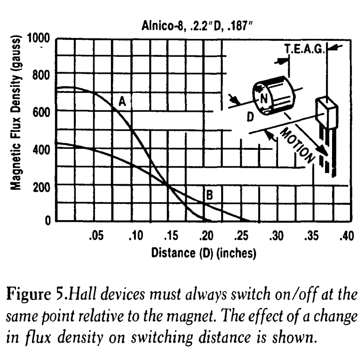


Figure 5. *Hall devices must always switch on/off at the same point relative to the magnet. The effect of a change in flux density on switching distance is shown.*

Hall-effect device would turn on at a distance of approximately 0.14 in. from either magnet. If manufacturing tolerance or temperature effects shifted the operating point of the sensor to 300 gauss, notice that in the curve for magnet "A" (steep slope) there is very little change in the distance at which switching occurs, while in the case of the curve of magnet "B," the change is considerable. The release point would be affected in much the same way.

The basic principles illustrated in this example can be modified to include mechanism and device specification tolerances and used for worst-case design analysis.

ELECTRICAL INTERFACE FOR DIGITAL HALL DEVICES

A typical application for a Hall-effect sensor is interfacing the sensor signal to a microprocessor. The output of the Hall element is quite small; therefore, Hall ICs have been developed that contain a voltage regulator to allow a wide range of operating voltages, a high-quality DC amplifier to boost the element signal to a more easily used signal, a Schmitt trigger threshold detector to produce digital logic, and output stages for universal interfaces capable of current sinking or sourcing. The output of the Hall-effect digital switch can be either linear (proportional to the magnetic field present) or clean-switching (no bounce) digital logic. Energy consumption is very low, and frequency responses are well over 100 kHz.

The output stage of a digital switch is simply an open collector npn transistor switch, and the rules for use are the same as those for any similar switching transistor. When the transistor is off, there is a small leakage current (typically a few nanoamps) that usually can be ignored and a maximum (breakdown) voltage specification that must not be exceeded.

When the transistor is on, the device output is shorted to the circuit common, and the current flowing through the switch must be externally limited to less than the maximum specified value to prevent damage (usually 20 mA).

Hall devices switch very rapidly; typical rise and fall times are in the 400 nanosecond range. This is rarely significant, since switching times are almost universally controlled by the much slower mechanical parts of the device.

Interfacing with digital logic integrated circuits usually requires only an appropriate power supply and pull-up resistor.

Loads that require sinking currents up to 20 mA can be driven directly by a Hall switch. A good example is a light emitting diode (LED) indicator that requires only a resistor to limit current to an appropriate value.

Sinking more current than 20 mA requires a current amplifier. For example, if a certain load to be switched requires 4 amperes and must turn on when the activating magnet approaches, the circuit shown in Figure 6 could be used. To turn on a 115 or 230 VAC load, consider Figure 7. Note, however, that the +12 V supply common is connected to the low side of the AC line, and in the event of a mixup, the Hall switch and associated low voltage circuitry would be 115 volts above ground.

Due to the magnetic field around any current-carrying conductor, Hall-effect devices can be used to measure and limit current by converting this magnetic field to an electrical signal. The sensor response ranges from DC to the kHz range, and the

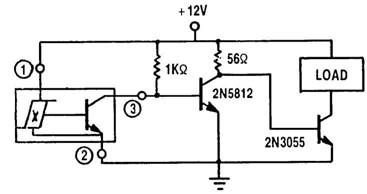


Figure 6. *This circuit could be used if a load required a current of 4 A to switch.*

conductor need not be interrupted. In low current applications, the magnetic field about a conductor is not normally intense enough to operate a Hall-effect digital switch; therefore, it would be best to use a toroid or closed magnetic circuit to increase the flux density.

Hall-effect linear sensors are used primarily to sense relatively small changes in magnetic fields—changes that are too small to operate a Hall-effect switching device. They are customarily capacitively coupled to an amplifier that boosts the output to a higher level (Figure 7).

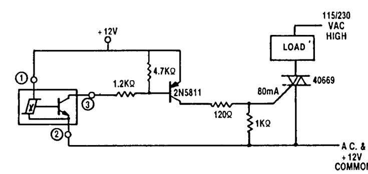


Figure 7. *This circuit could be used to switch a 115 or 230 VAC load.*

As motion detectors, gear tooth sensors, and proximity detectors, linear Hall-effect sensors produce an electrical output that is a magnetically driven mirror of mechanical events. As sensitive monitors of electromagnets, they can effectively measure a system's performance with negligible system loading while producing isolation from contaminated and electrically noisy environments.

Hall-effect sensors, both digital and linear, are used in the commutation of brushless DC motors, speed sensors, shaft encoders, current limiters and monitors, position sensors, and gear tooth sensors. Recent technology breakthroughs in Hall-effect devices have made available sensors for temperature ranges as high as 170°C. These sensors have been integrated into a vast array of innovative high-technology applications where reliability, efficiency, and cost competitiveness are a must.

Magnetic Materials Most Commonly Used

▶ **Rare Earth—Cobalt.** *An alloy of rare earth metal, such as samarium, with cobalt (abbreviated RE cobalt). These magnets are the best in all categories but are also the most expensive. Too hard for machining, these magnets must be ground, if shaping is necessary. Maximum energy product, perhaps the best single measure of magnet quality, is approximately 16 x 10^6.*

▶ **Alnico.** *A class of alloys containing aluminum, nickel, cobalt, iron, and additives, which can be varied to give a wide range of properties. The magnets are strong and fairly expensive, but less so than RE cobalt. Alnico magnets can be cast or sintered by pressing metal powders into a die and heating. Sintered alnico is well suited to mass production of small, intricately shaped magnets, has a more uniform flux density, and is mechanically superior, but cast alnico magnets are generally magnetically stronger. The nonoriented or isotropic alnico alloys (alnico-1, alnico-2, alnico-3, alnico-4) are less expensive and magnetically weaker than the oriented alloys (alnico-5, alnico-6. . .alnico-9). Alnico is too hard and brittle to be shaped except by grinding. Maximum energy products range from 1.3 to 10 x 10^6.*

▶ **Ceramic.** *These magnets contain barium or strontium (or another element from that group) ferrite in a matrix of ceramic material that is compacted and sintered. They are poor conductors of heat and electricity, chemically inert, and have high values of coercive force. As with alnico, ceramic magnets can be fabricated with partial or complete orientation for additional magnetic strength. Less expensive than alnico, they are also too hard and brittle to shape except by grinding. Maximum energy products range from 1 to 1.3 x 10^6.*

▶ **Cunife.** *A ductile copper base alloy with nickel and iron, cunife can be stamped, swaged, drawn, or rolled into final stage. Maximum energy product is approximately 1.4 x 10^6.*

▶ **Iron-Chromium.** *These magnets have magnetic properties similar to alnico-5 but are soft enough to undergo machining operations before the final aging treatment hardens them. Maximum energy product is approximately 5.25 x 10^6.*

▶ **Plastic and Rubber.** *These magnets consist of barium and strontium ferrite in a plastic matrix material. They are very inexpensive and can be formed in numerous ways, including stamping, molding, and machining, depending on the particular matrix material. Since synthetic rubber is a plastic, the distinction between the two materials is not very precise. If a plastic magnet is flexible like rubber, it is generally called a rubber magnet. Maximum energy products range from 0.2 to 1.2 x 10^6.*

LIGHT SENSING USING OPTICAL INTEGRATED CIRCUITS

RAVI VIG, SPRAGUE ELECTRIC COMPANY

Light sensing has traditionally been used for a variety of transducing applications including absolute light measurement position encoding, rotary speed measurement, optical communications, and electrical isolation. Most of these applications use light emitters and detectors along with additional driving-sensing circuitry to enable the sensing of electrical or mechanical stimuli.

Light emitters come in several varieties: incandescent lamps (or light bulbs), light-emitting diodes (LEDs), and lasers. In most transducer applications, incandescent lamps are not used due to their slow response to electrical stimuli and the lack of focused light emission. LED's are more popular because they respond to fast electrical impulses, emit focused light of a narrow bandwidth, and the intensity of emitted light can easily be changed by changing the current through the device. However, the maximum intensity of the light emitted by LEDs is severely limited. This problem has been overcome by lasers, which have more power than LEDs, but laser usage is constrained by the need for expensive driving electronics and the inability to easily change the intensity of the emitted light. Therefore, most electrical transducing applications use LEDs.

While there are several types of light detectors, the most popular detectors are semiconductor-based devices, which fall into two major categories: photoconductors and photodetectors. Photoconductors are devices whose resistance decreases with incident light. Cadmium sulfide and cadmium selenide are examples of photoconductors that are sensitive to visible light. These devices are relatively large, typically ranging in diameter from 5 to 25 mm.

Typical junction photodetectors, such as photodiodes, Schottky photodiodes, phototransistors, and avalanche photodetectors, work under the principle of carrier transport across material interface junctions. Photodiodes respond to optical radiation by generating electron-hole pairs, which are then transported across a p-n junction. Carrier transport in Schottky photodiodes takes place across a metal-semiconductor junction. While both types of photodiodes exhibit a high degree of linearity, Schottky devices have lower junction capacitance and are, thus, faster than p-n junction photodiodes. In phototransistors, incident light on the base of a transistor controls the collector current. These devices are typically used in switching and modulation applications where high gain and fast response are more important than linearity. Avalanche photodetectors are reverse biased junction detectors wherein the optically generated carriers are accelerated so as to further generate carriers by impact. These devices are typically used in high-speed communication applications.

Since several of the junction photodetectors mentioned can be fabricated from silicon, it is possible to incorporate the receiver circuitry with the photodetector to create a low-cost solution to light detection problems. (The processing of the optical signals is performed using decoding receiver circuitry.) Incorporating a preamplifier with the photodetector also permits smaller photodetectors, resulting in lower junction capacitance and smaller device size. Extremely sensitive optical detectors may be constructed since lower light currents can now be amplified without external noise coupling. Integrated circuit optical sensors typically use silicon-based photodiodes since they are easy to fabricate and are compatible with the IC process.

PHOTODIODES

Photodiodes are reverse biased p-n junctions that respond to optical radiation. Photons captured close to the p-n junction release electrons into the conduction band which are swept across the junction. This electron flow represents the photocurrent (or light current) of the diode.

Light current is greatly dependent on the spectrum of the incident light. The spectral response of a photodiode is determined by the material from which it is fabricated and the diode junction depth. The response of the long wavelength of the photodiode is controlled by the band-gap energy of the material, that is, the energy needed to release an electron from the valence

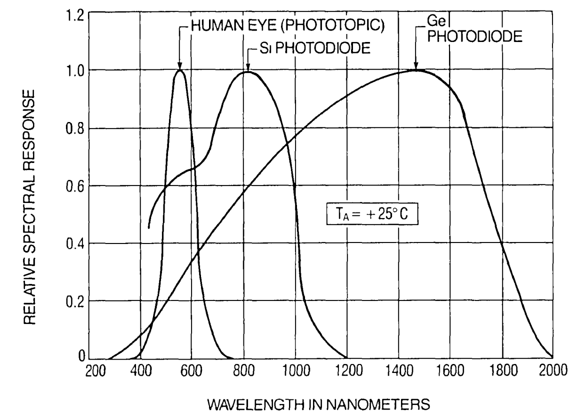


Figure 1. *The CIE spectral response curve is overlaid on the spectral responsivity curves of silicon and germanium (1,3).*

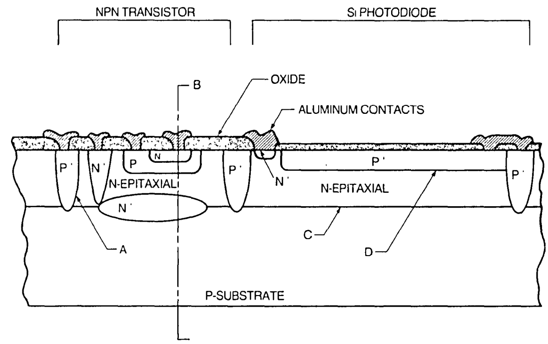


Figure 2. *A cross section of a silicon IC shows a typical npn transistor and a photodiode (drawing is not to scale).*

band to the conduction band. The energy of an incident photon is given by:

$$E = h\nu$$

where:

h = Planck's constant
$\nu = c / \lambda$ is the frequency of light
c = velocity of light

The electron will be released only when:

$$E \geqslant E_g$$

where E_g is the energy gap of the semiconductor defined in electronvolts, or:

$$h\nu \geqslant E_g$$

The longest wavelength absorbed is given by:

$$\lambda = E_g/hc$$

The short wavelength response of the photodiode is determined by the depth of the junction from the surface. Shorter wavelengths are absorbed near the surface, generating electron-hole pairs. These pairs recombine before they reach the p-n junction, so do not result in photocurrent. Deep junction photodiodes have low responses to short wavelength radiation.

These processes result in spectral responsivity curves that are nonuniform with wavelength. Figure 1 shows the spectral responsivity curves of Si and Ge, along with the CIE photopic response curves. The peak response of Ge is at 1.5 μm, while Si is at 0.85 μm. This corresponds to a band-gap energy of 1.1 eV for Si and 0.67 eV for Ge. The drop in responsivity at low wavelengths is due to lower efficiencies for a deep junction. Note the low photodiode spectral response in the region of the photopic curve.

Since the diode is reverse biased, ideally no other current should flow; however, fabrication impurities cause leakage current that flows even when no light is incident on the junction. This leakage current (also known as dark current) is a function of reverse bias, diode junction size, and ambient temperature. Large dark current values limit the signal-to-noise ratio of the photodiode and place constraints on the maximum operational temperature of the receiver circuitry. Dark current is given by:

$$I_{Dark} = -I_0 \left(e^{(V/V_t)} - 1\right)$$

where:

I_0 = reverse saturation current
V = reverse bias voltage
V_t = kT/q (k = Boltzmann's constant, q = electron charge, T = absolute temperature)

From this equation it can be seen that for no incident light, the dark current is dependent on the applied voltage and the absolute temperature. It can also be noted that theoretically, dark current goes to zero for no applied voltage and, hence, loses its temperature dependence.

► **Light Measurement.** Due to the nonuniform response of a photodiode to the spectrum of incident light, photodiode sensitivity is generally specified in radiometric units as the power of light incident (μA/μW/cm^2) for a given wavelength. Absolute light levels are specified in power incident (μW/cm^2) for a given light bandwidth. Since it is difficult to generate a light source of a single wavelength, the light is assumed to have the spectral output of a specified LED, e.g., an AlGaAs LED is normally used with a silicon photodiode. Other optical units, such as footcandles and lumens, are not appropriate since they assume a photopic spectral response.

► **Integrated Circuit Optical Sensors.** Traditionally, photodiodes have been used in conjunction with hybrid amplifier circuitry to perform certain signal processing applications. These operations may include light current amplification, light threshold detection, and light demodulation. Building photodiodes out of silicon has given the IC designer the ability to fabricate both the hybrid circuitry and the photodiode on the same silicon substrate, thus eliminating the need for additional circuitry.

Figure 2 shows the cross section of a silicon IC containing an npn transistor and a photodiode fabricated using a bipolar integrated circuit process. Most bipolar processes are fabricated

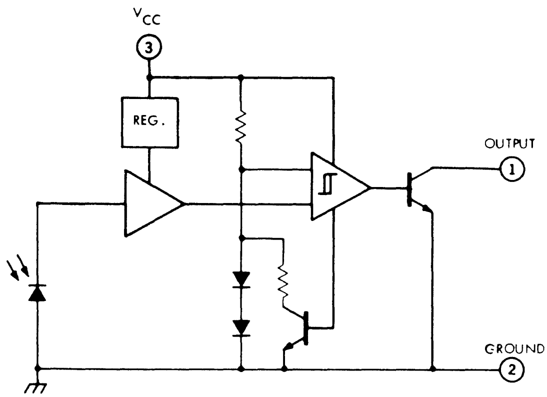


Figure 3. *A functional block diagram of the Sprague ULN-3330 IC optical receiver is shown.*

Table 1
Electrical Characteristics at $T_A = +25°C$, $V_{CC} = 6.0$ V, $\lambda = 880$ nm

Characteristic	Symbol	Test Conditions	Limits Min.	Typ.	Max.	Units
Supply Voltage Range	V_{CC}		4.0	6.0	15	V
Supply Current	I_{CC}		—	4.0	8.0	mA
Light Threshold Level	E_{ON}	Output ON	45	55	65	$\mu W/cm^2$
	E_{OFF}	Output OFF	—	62	—	$\mu W/cm^2$
Hysteresis	ΔE	$(E_{OFF}-E_{ON})/E_{OFF}$	10	12	14	%
Output ON Voltage	V_{OUT}	$I_{OUT}=15$ mA	—	300	500	mV
		$I_{OUT}=25$ mA	—	500	800	mV
Output OFF Current	I_{OUT}	$V_{OUT}=15$ V	—	—	1.0	μA
Output Fall Time	t_f	90% to 10%	—	200	500	ns
Output Rise Time	t_r	10% to 90%	—	200	500	ns

by growing an n-type epitaxial layer on a p-type substrate. Individual devices are separated into epitaxial pockets by forming a reverse biased isolation-epitaxial junction A ($p^+ - n$) at the pocket walls. Impurities are then diffused into these epitaxial pockets to create devices (npn and pnp transistors, resistors).

The npn transistor shown in Figure 2 is manufactured using the above techniques. The collector of the transistor is the lightly doped epitaxial layer. Diffused into this layer is a heavily doped p^+ layer that forms the base of the transistor. The emitter is the strongly doped n^+ layer. The npn junctions are formed along the vertical axis B. Aluminum contacts are directly made to the emitter and base. Contact to the collector is made by the aluminum through a low-resistance n^+ plug and buried layer.

The substrate-epitaxial interface C forms a p-n junction which, when reverse biased, can be used as a photodiode. P-type impurities in the form of base diffusion form an additional junction D, across which optically generated carriers may be transferred. The photodiode is normally the largest single component on the IC. Photodiodes can vary in size from 20 by 20 mils to 30 by 30 mils.

► **Typical Optical Receiver.** Using these techniques, an IC designer can fabricate a high-quality, low-noise receiver that can be incorporated onto a single silicon substrate. There are two basic types of integrated sensors: linear and digital. The output of a linear sensor is proportional to the incident light level. This device is generally factory calibrated for repeatable sensitivity. A digital sensor is a level detector that switches on at a fixed light level. The device incorporates positive feedback circuitry that induces a hysteresis that inhibits release until the output moves much lower than the previous trip point.

Figure 3 describes a typical digital optical sensor, the Sprague ULN-3330. This device has an on-chip ground-referenced photodiode whose photocurrent is fed into a current amplifier. This amplified current is then converted into a voltage level by dropping it through an adjustable load resistor. A comparator checks this voltage level and switches on at a predetermined threshold level. For noise immunity, internal feedback disables switching until the light level falls approximately 12 percent below the switching threshold. The output interface allows switching of TTL and CMOS devices, as well as the ability to drive low-current relays.

Circuit designers benefit from the use of IC technology in the design of optoelectronic sensor circuits. Low photodiode currents on the order of a few hundred nanoamperes can be amplified without worrying about external noise sources; hence, smaller diodes can be used. Matching accuracy of transistors and resistors helps create high-quality, low-offset amplifiers. Amplifier and photodiode characteristics can be internally compensated using the repeatable temperature characteristics of IC resistors and diode junctions, while switching thresholds can be adjusted at wafer test by trimming on-chip resistors. In addition, the reliability of these devices may be much greater than for hybrid assemblies.

OPTICAL SENSOR APPLICATIONS

Optical ICs do not, however, replace careful engineering review on the part of the optical assembly designer. Several factors contribute to a successful optical system design. These factors include light threshold levels, ambient light interference, output load conditions, and voltage supply.

Table 1 shows a typical specification table for a digital output optical sensor (in this case, the ULN-3330). Defined in this table are the supply voltage ranges, supply current limits, and sink current capabilities. An important specification is the light threshold level. The ULN-3330 is a highly sensitive device, with light threshold levels under 65 $\mu W/cm^2$ and a hysteresis of 10–14 percent. When designing transducing assemblies using a sensitive optical receiver, ambient light levels may provide a significant and unwanted noise contribution. In addition, the light emitted by a commercial LED may vary a great deal for a given LED driver current. If optical measurements are not carefully taken, high ambient light levels (noise) may keep the detector always switched, while low LED light outputs (signal) may never switch the detector.

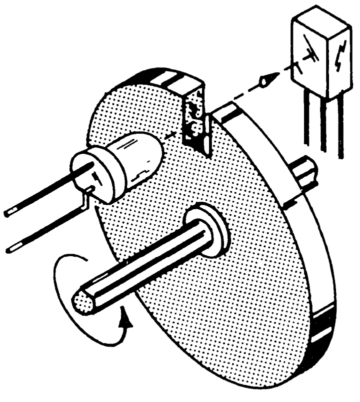


Figure 4. *Shown is a commonly used speed-sensing assembly. The light field between the emitter-detector pair is interrupted by the rotating code wheel.*

When measuring light levels it is important to use a linear receiver whose photodiode is of the same material and is roughly the same area as that of the digital sensor. If a different material is used, the difference in spectral responsivity will result in inaccurate readings. If the linear receiver is much larger in area, then optical patterns on the receiver may not be the same as those on the digital sensor, thereby creating faulty readings. When using the ULN-3330 or any other Sprague optical IC, the ambient light level can be accurately measured using the ULN-3310.

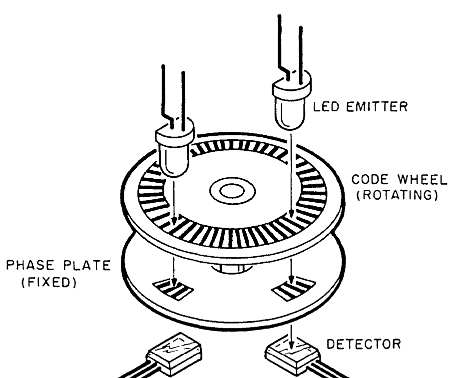
By carefully following the device specification table and by making the appropriate optical measurements, optical integrated circuit sensors can be used in a variety of detection applications. The availability of vast amounts of circuitry in a small package provides optical system designers with a powerful tool.

► **Absolute Light Measurements.** The Sprague ULN-3310 has been used in several applications for the measurement of light such as automatic brightness control for CRTs, feedback for photocopiers, and light measurement for cameras. This linear optical IC is preferred over other photodetectors because of the factory calibration of its sensitivity.

Absolute light sensing is also used for switching street, emergency, and automotive lighting. In these applications, the light level is measured using a photosensor (usually a cadmium sulfide photoconductor) and the switching assembly is designed so as to trip when the light falls below a specified value. Photoconductors are highly sensitive to ambient temperature, making the trip points difficult to stabilize over temperature extremes. The same function can be accomplished using the internally compensated ULN-3390. This device is a highly sensitive digital output device that trips and releases at 10 $\mu W/cm^2$ and 20 $\mu W/cm^2$ respectively. Internal hysteresis provides immunity to small light variations (due, for example, to changing cloud cover), thus lowering the chances of oscillations in the switching circuitry.

► **Optocouplers-Optoisolators.** Emitter-detector pairs are linked together through an optical waveguide to couple electrical signals for communications and isolation applications. In communication applications, the waveguide is generally a fiber-optic cable. Low-speed communications problems may be solved using digital ICs. The ULN-3395, with a propagation delay time of less than 5 μs, is one example of a commercially available IC. Higher speed applications demand fast responding avalanche photodiodes and hybrid receiver circuitry.

Optical isolation is accomplished by inserting an emitter-detector assembly between sensitive electronics and controller switching circuitry. The waveguide is the package itself. This



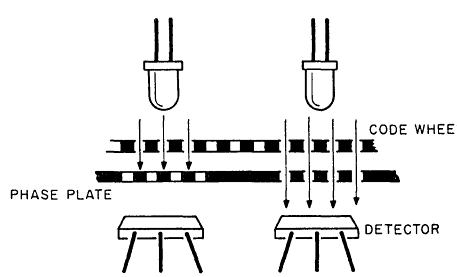


Figure 5a and b. *This high-resolution rotary encoder shows the fixed phase plate along with the rotating code wheel. The two photodetectors are placed such that a light field on one device corresponds to a dark field on the other.*

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isolates electrical processes on the receiver end from those on the emitter end—a technique that is used to protect expensive circuitry from the effects of shorts or faults on the controller switching lines.

► **Rotary Encoding.** Speed sensing and rotary position encoding are best done using optical emitter-detector assemblies. Figure 4 shows a common assembly used in speed measurement applications. Here, the rotating wheel interrupts the light field, causing the detector to switch, generating a pulse for each slot in the wheel. In this assembly the number of pulses per revolution is limited by the emitter beam width as well as the detector element size. Typical interrupter widths of 200–300 mils are used.

A newer technique used in high-resolution rotary encoding is illustrated in Figure 5. Interrupting the light path are a rotating code wheel and a fixed phase plate. The code wheel has a fixed number of apertures (as many as 256) around its circumference. The fixed phase plate also has a number of apertures of the same size as those in the code wheel and is fixed directly above the light sensing photodetector, as shown in Figure 5a. Rotation of the code wheel creates alternate light and dark periods on the surface of the detector. Using this technique, high-resolution measurements have been obtained by sensing code wheel apertures of 10 to 20 mils. In addition, the phase plate can be coded to allow placement of another photodetector IC that is 90 degrees out of phase with the first detector, as shown in Figure 5b. This allows the sensing of both position of the wheel and direction of rotation.

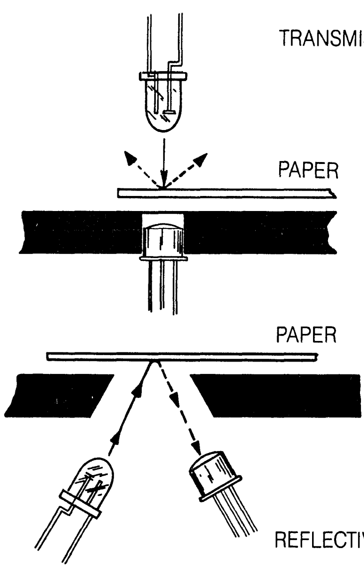

Figure 6. *Sheet detector configurations using transmissive and reflective modes of operation are shown.*

► **Miscellaneous Applications.** Optical sensors are used in several other applications. Some smoke detectors use sensitive optical detectors to ascertain the presence of smoke in the assembly. Emitter-detector pairs are used as sheet edge detectors in photocopiers for detection of paper size. Detection can be done in both the transmissive and reflective modes, as shown in Figure 6. Fluid level measurement systems use emitter-detector pairs that cause the detector to switch when fluid in a tube interrupts the beam path. Burglar alarm systems use infrared emitter-detector pairs that switch when the beam path

Glossary of Terms

band-gap energy (E_g): The energy difference between energy levels of the conduction band and the valence band. It is also the minimum energy required to free an electron from the valence band to the conduction band.

CIE: Acronym for the Commission Internationale de l'Eclairage. The International Commission on Illumination has been responsible for setting several lighting standards.

conduction band: The band of energy levels occupied by a valence electron when it is liberated from an atom. Electrical conduction in a semiconductor crystal takes place through the transport of electrons in the conduction band.

epitaxial material: A material whose atoms are arranged in single crystal fashion upon a crystalline substrate so that its lattice structure duplicates that of the substrate.

hysteresis: To provide noise immunity, the switch points of a comparator are altered using positive feedback so that the voltage required to switch the comparator output low (operate point voltage) is greater than the voltage required to switch the output high (release point voltage). The difference between these switch points is a measure of the hysteresis of the comparator.

n^+ -type material: Heavily doped n-type material, formed by introducing donor impurities into a silicon substrate. Conduction takes place by the movement of free electrons.

p^+ -type material: Heavily doped p-type material, formed by introducing acceptor impurities into a silicon substrate. Conduction takes place by the movement of holes.

p-n junction: Material interface between positively doped (p-type) and negatively doped (n-type) semiconductor. These junctions are fundamental to the performance of switching, rectification, and amplification functions in electronic devices and circuits.

photometric units: Radiometric quantities spectrally weighted by the spectral response of the human eye (also called the photopic response). Typical units of illuminance are foot-candles or lumens.

photopic response: Spectral response of vision mediated essentially or exclusively by the cones in the human eye. Standards for this response have been laid down by the International Commission on Illumination (CIE).

valence band: The electrons in the outermost shell of an atom (valence electrons) occupy a band of energy levels called the valence band. Electrons in this band do not participate in electrical conduction in silicon.

is interrupted by an object. The same strategy can also be used to generate signals for counting moving objects such as bottles and cans on a moving assembly line.

CONCLUSION

Optical integrated circuits give the designer the ability to design complex transducing functions using a small number of integrated components at a low cost. The small package sizes allow for use in a large number of size-critical applications. Clearly, in many measuring and sensing applications, optical integrated circuit-based transducers are the sensors of choice.

REFERENCES

1. Budde, W. "Optical Radiation Measurements," *Physical Detectors of Optical Radiation*, v.4, Academic Press, p. 239.
2. Streetman, Ben. *Solid State Electronic Devices*, 2nd ed., Prentice-Hall, p. 211-212.
3. Silicon and CIE, Photodiode spectral response from Sprague Integrated Circuit Bulletin 27480B, p. 3.

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SECTION 8—PACKAGE INFORMATION

8

HALL EFFECT ICs PACKAGE CHARACTERISTICS

Package Designator	Package Type	Lead Material	Page
HH	3-Lead Ceramic SIP	Alloy 42	8-5
K	4-Lead Plastic SIP	Copper	8-6
LI	8-Lead Plastic SOIC (MS-012AA)	Copper	8-7
LL	3-Lead Plastic SOT 89 (Long Leads)	Copper	8-8
LT	3-Lead Plastic SOT 89 (TO-243AA)	Copper	8-9
T	3-Lead Plastic SIP	Copper	8-11
U	3-Lead Plastic SIP	Copper	8-12
UA	3-Lead Plastic SIP	Copper	8-13

PLASTIC PACKAGES FOR HALL EFFECT ICs

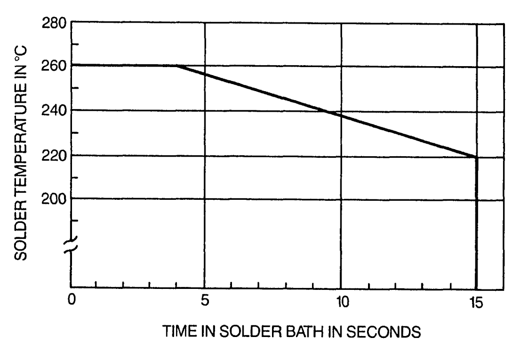
Sprague Hall Effect ICs are packaged in a state-of-the-art epoxy material formulated to withstand severe environments. Its properties include:

1. Excellent moisture resistance—typically over 200 hours of pressure cooker exposure and 1000 hours of +85°C/85% RH with zero failures.
2. Excellent chemical resistance.
3. Excellent thermal stability—typically over 3000 hours of continuous operation at +175°C.
4. High glass transition temperature— $(t_g) = +160°C$.
5. Good thermal expansion characteristics—
   25°C − 125°C = 30 × 10^{-6} in./in./°C.
   150°C − 220°C = 80 × 10^{-6} in./in./°C.
6. Underwriters listed flammability rating— V-O @ 1/16 in. (self-extinguishing).
7. Device leads meet solderability requirements of Military Standard MIL-STD-202 (95% or better solder wetting without special preparation).

GUIDE TO INSTALLATION

1. All Hall Effect integrated circuits are susceptible to mechanical stress effects. Caution should be exercised to minimize the application of stress to the leads or the epoxy package. Glues and potting compounds shrink while curing and can shift the operating parameters of a Hall Effect device.

2. To prevent permanent damage to the Hall cell, heat-sink the leads during hand-soldering. Recommended maximum conditions for wave soldering are shown in the graph at right.



Dwg. No. A-12,062A

OPTOELECTRONICS PACKAGE CHARACTERISTICS

Package Designator	Package Type	Lead Material	Page
D	3-Lead Metal Hermetic TO-52	Kovar	8-4
M	8-Lead Plastic DIP	Copper	8-10
T	3-Lead Plastic SIP	Copper	8-11

METAL PACKAGES

Sprague optoelectronic sensors are supplied in a hermetically sealed metal package with a glass end cap. The package meets JEDEC specification TO-52.

GUIDE TO INSTALLATION

Clear epoxy packages can be damaged by excess heat during soldering. Time at temperature should be maintained at absolute minimums necessary for normal soldering, or leads should be attached for heat sink during soldering.

PLASTIC PACKAGES

Sprague optoelectronic sensors are packaged in clear epoxy formulated for maximum optical transmission. Its properties include:

1. Excellent chemical resistance.
2. Good moisture resistance.
3. High glass transition temperature— (T_g) = +120°C.
4. Good thermal expansion characteristics— 25°C − 125°C = 65×10^{-6} in./in./°C.

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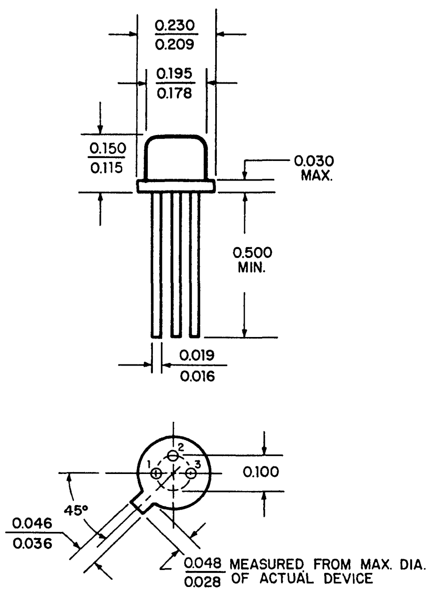
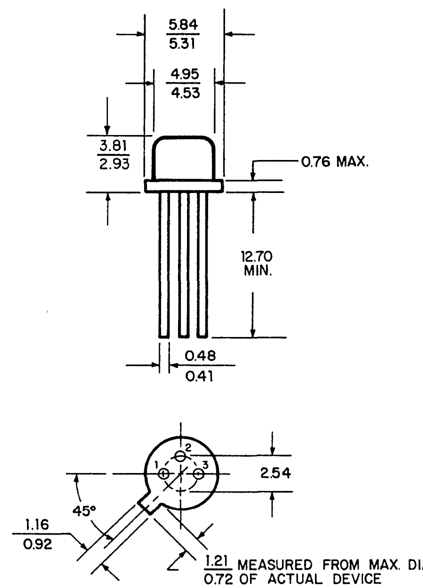
METAL TO-52 (TO-206AC)
SPRAGUE PACKAGE DESIGNATOR 'D'

DIMENSIONS IN INCHES



Dwg. No. A-3893B IN

DIMENSIONS IN MILLIMETERS
Based on 1″ = 25.4 mm



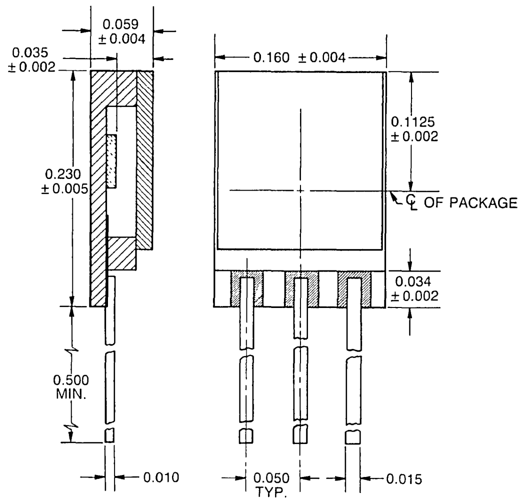
Dwg. No. A-3893B MM

NOTE: Lead spacing diameter is controlled in the zone between 0.050″ (0.13 mm) and 0.250″ (6.35 mm) from the seating plane. Between 0.250″ (6.35 mm) and 0.500″ (12.7 mm) from the seating plane, a maximum lead spacing diameter of 0.021″ (0.53 mm) is specified. Outside of these zones the lead spacing diameter is not controlled.

CERAMIC SIP

SPRAGUE PACKAGE DESIGNATOR 'HH'

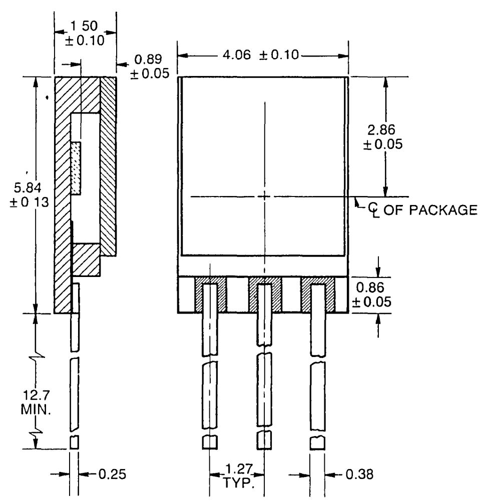
DIMENSIONS IN INCHES



Dwg. No 13,085 A

DIMENSIONS IN MILLIMETERS

(Based on 1″ = 25.4 mm)



Dwg No. 13,086 A

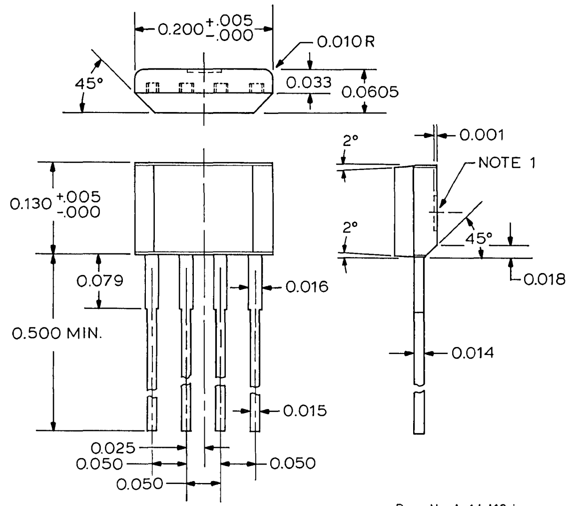
NOTE:

1. Tolerances, unless otherwise specified, are ± 0.005″ (0.13 mm)

PLASTIC SIP

SPRAGUE PACKAGE DESIGNATOR 'K'

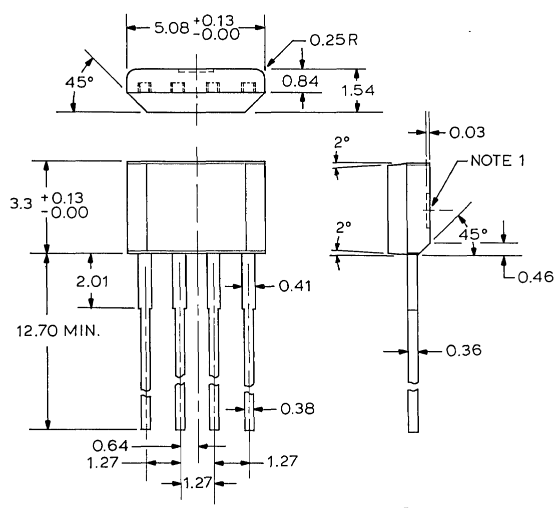
DIMENSIONS IN INCHES



Dwg. No. A-14,413,in.

DIMENSIONS IN MILLIMETERS

(Based on 1″ = 25.4 mm)



Dwg No A-14,413,mm

NOTES:

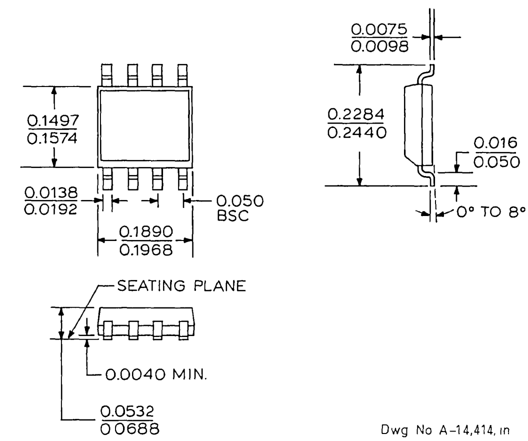
1. Ejector pin is centrally located.
2. Tolerances on package height and width represent allowable mold offsets. Dimensions given are measured at the widest point (parting line).
3. Tolerances, unless otherwise specified, are ±0.005″ (0.13 mm) and ±½°.

PLASTIC SOIC

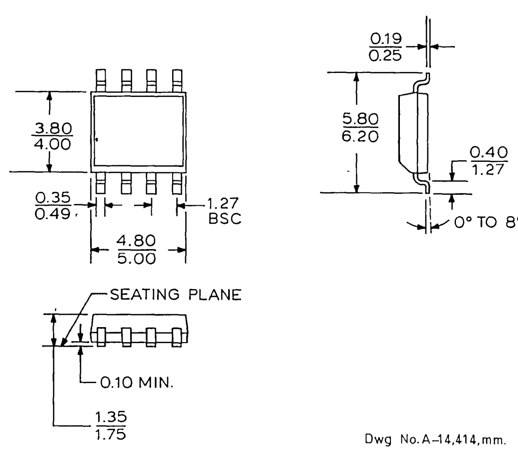
SPRAGUE PACKAGE DESIGNATOR 'LI'

DIMENSIONS IN INCHES

(Based on 1 mm = 0.394")



DIMENSIONS IN MILLIMETERS



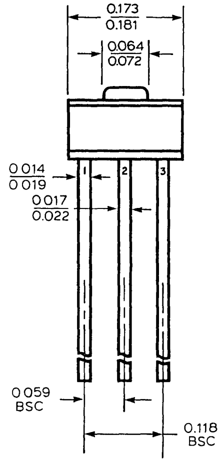
NOTES:

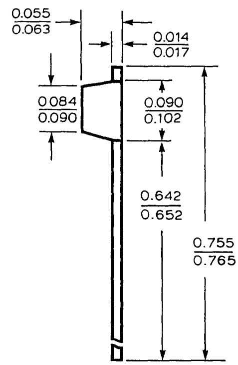
1. Lead spacing tolerance is non-cumulative.
2. Exact body and lead configuration at vendor's option within limits shown.
3. Lead gauge plane is 0.303 in. (0.76 mm) max. below seating plane.

8

PLASTIC SOT 89 (Long Leads)
SPRAGUE PACKAGE DESIGNATOR 'LL'

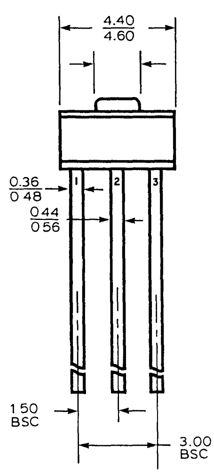
DIMENSIONS IN INCHES
(Based on 1 mm = 0.394")

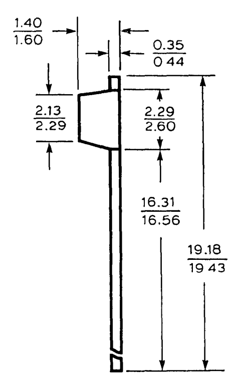




Dwg. No. A-12,657A IN

DIMENSIONS IN MILLIMETERS





Dwg. No. A-12,657A MM

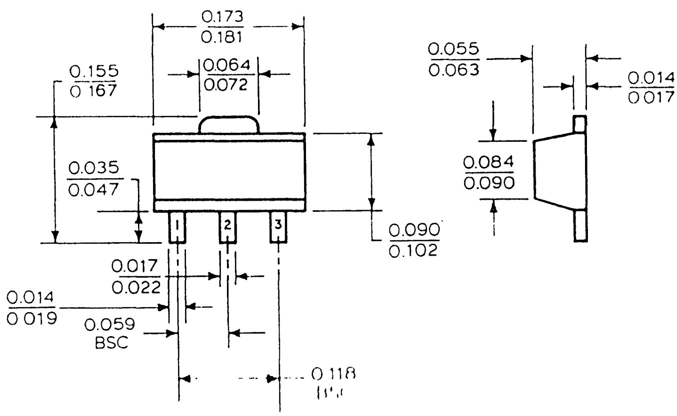
NOTE:
1. Tolerances, unless otherwise specified, are ±0.005" (0.13 mm)

PLASTIC SOT 89 (TO-243AA)

SPRAGUE PACKAGE DESIGNATOR 'LT'

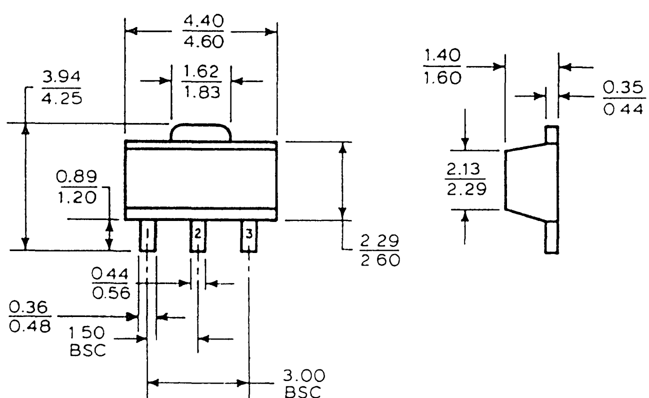
DIMENSIONS IN INCHES

(Based on 1 mm = 0.394")



Dwg No. A-12,608A IN

DIMENSIONS IN MILLIMETERS



Dwg No. A-12,608A MM

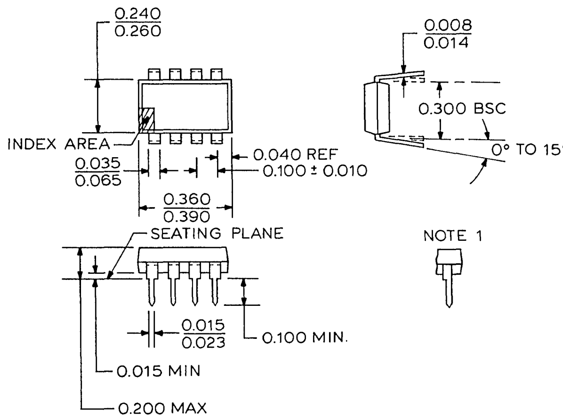
NOTE:

1. Tolerances, unless otherwise specified, are ±0.005" (0.13 mm)

8

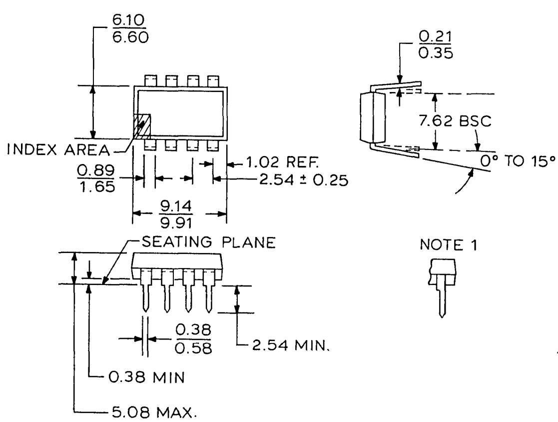
PLASTIC DIP
SPRAGUE PACKAGE DESIGNATOR 'M'

DIMENSIONS IN INCHES



Dwg. No. A-14,415, in.

DIMENSIONS IN MILLIMETERS
(Based on 1" = 25.4 mm)



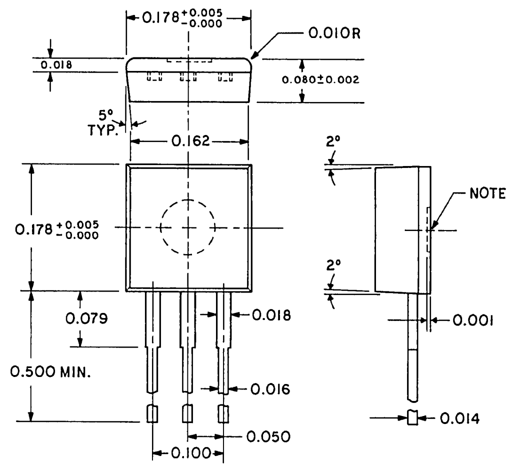
Dwg. No. A-14,415, mm.

NOTES:
1. Leads 1, 4, 5, and 8 may be half-leads, at vendor's option.
2. Lead spacing tolerance is non-cumulative.
3. Exact body and lead configuration at vendor's option within limits shown.
4. Lead guage plane is 0.030" (0.76 mm) max. below seating plane.

PLASTIC SIP

SPRAGUE PACKAGE DESIGNATOR 'T'

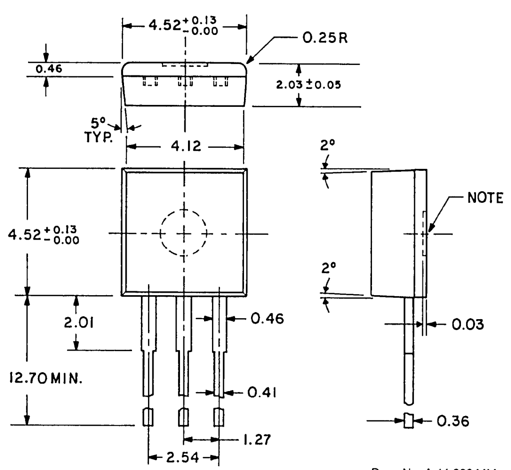
DIMENSIONS IN INCHES



Dwg. No A-11,900 IN

DIMENSIONS IN MILLIMETERS

(Based on 1" = 25.4 mm)



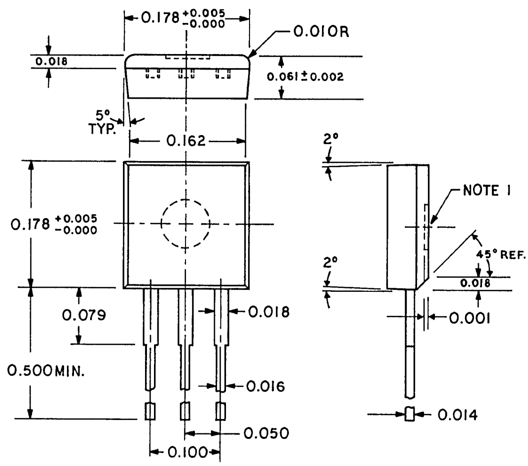
Dwg. No A-11,900 MM

NOTES:

1. Ejector pin is centrally located.
2. Tolerances on package height and width represent allowable mold offsets. Dimensions given are measured at the widest point (parting line).
3. Tolerances, unless otherwise specified, are ±0.005" (0.13 mm) and ±½°.

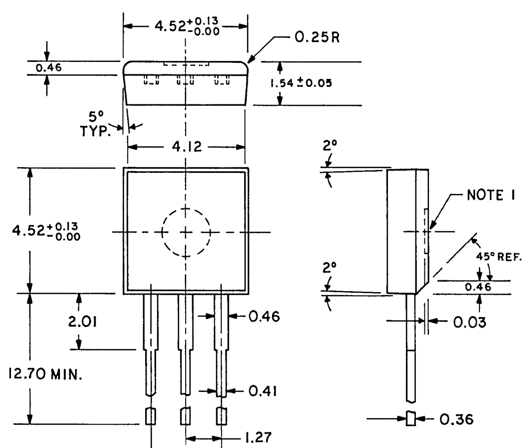
PLASTIC SIP
SPRAGUE PACKAGE DESIGNATOR 'U'

DIMENSIONS IN INCHES



Dwg No. A-11,901 IN

DIMENSIONS IN MILLIMETERS
(Based on 1″ = 25.4 mm)



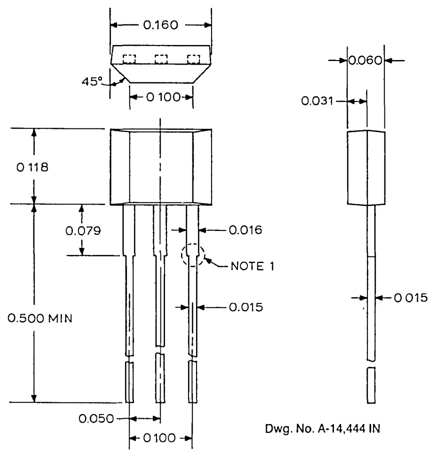
Dwg. No. A-11,901 MM

NOTES:
1. Ejector pin is centrally located.
2. Tolerances on package height and width represent allowable mold offsets. Dimensions given are measured at the widest point (parting line).
3. Tolerances, unless otherwise specified, are ±0.005″ (0.13 mm) and ±½°.

PLASTIC SIP

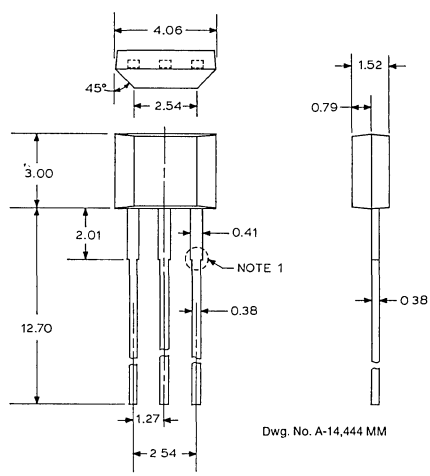
SPRAGUE PACKAGE DESIGNATOR 'UA'

DIMENSIONS IN INCHES



DIMENSIONS IN MILLIMETERS

(Based on 1" = 25.4 mm)



NOTE:

1. Transition area from 0.016 to 0.015 is uncontrollable.

NOTES

NOTES

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