Appendix A:
Technical Reference

This appendix provides information on the error messages that appear on the display of the data analyzer, information about probes that come with the data analyzer, conversion equations, and other technical information.

Error Messages

The data analyzer indicates an error by displaying "E." followed by a 2-digit hexadecimal number. The first digit indicates the command that caused the error, while the second digit indicates the parameter that caused the error message (first parameter indicated by 1, second parameter by 2, and so on).

Sample Error Message

E.13 E. ... Error message
1 ..... Error in Command 1
3 ..... Error in third parameter.

When an error occurs, press the data analyzer's [HALT] key to clear the error condition and message. Note that error messages must be cleared from the data analyzer before it can receive any other commands from a connected graphic scientific calculator.

- Since hexadecimal numbers are used to indicate errors, letters may appear in the second digit if the command has more than nine parameters: a = parameter 10, b = parameter 11, c = parameter 12.

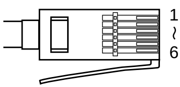
Probes

This section provides technical information about the probes that come with the data analyzer. It also includes general technical information about probes that can be connected to the data analyzer.

Light Probe

The light probe that comes with the data analyzer uses a photosensitive element called a Cds to measure brightness, which is then converted to a numeric value. The value produced does not correspond to any standard unit of measurement, but simply indicates a relative measure of brightness in the range of 100 to 999.

Light Probe Specifications

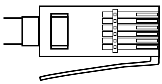
Channels:	**CH1, CH2, CH3 (analog)**
Range:	100 to 999
Chemical Tolerance:	None
Pins:	2 Ground
	3 Vres
	4 Auto-ID resistance
	6 Signal

Temperature Probe

The temperature probe that comes with the data analyzer uses a thermistor to measure the temperature of liquids. Changes in the temperature of the thermistor causes a corresponding change in its resistance, which is then converted to a temperature value.

Temperature Probe Specifications

Channels:	**CH1, CH2, CH3 (analog)**
Range:	–20°C to 130°C
Chemical Tolerance:	Cannot be used with strong acids or alkalis
Pins:	2 Ground
	3 Vres
	4 Auto-ID resistance
	6 Signal

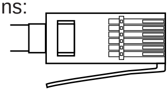

1 ~ 6

Voltage Probe

The voltage probe that comes with the data analyzer can be used to read a voltage in the range of ±10 Volts. This probe is designed with Auto-ID resistance, so connecting it to the data analyzer automatically switches to voltage sampling. The black probe should be connected to ground, while the red probe should be connected to signal voltage.

Voltage Probe Specifications

Channels:	**CH1, CH2, CH3 (analog)**
Range:	±10V
Chemical Tolerance:	None (air only)
Pins:	1 Signal
	2 Ground
	4 Auto-ID


1 ~ 6

- Never connect the analog input ground connection (black probe) to different potentials. These ground connections are all common (circuits are common). Connecting the black probe to a connection other than ground can seriously damage the data analyzer.

Probe Precautions

Temperature Probe

- Never use the temperature probe with strong acid or alkaline solutions.
- The measuring range of the temperature probe is –20°C to 130°C. Do not try to measure temperatures outside this range.
- Do not use the temperature probe for longer than two hours of continuous measurement when measuring temperatures greater than 80°C.
- When using the temperature probe to measure very high or very low temperatures, do not touch the area around the gold colored metal directly with your fingers.

Voltage Probe

- Never connect the voltage probe directly to an electrical outlet or other high voltage (30V or greater) source. Not only is the data analyzer unable to measure such voltages, doing so creates the danger of electrical shock.
- Never directly touch the metal tips of the probes with your fingers.

Light Probe

- Handle the light probe with care, and do not subject it to high temperatures or strong impact.

All Probes

- Never pull on the cables of the probes or swing the probes around by their cables.
- Do not forcibly bend a probe. Doing so can result in a short circuit or poor connection.
- Never pull on the cable of a probe to disconnect it from the data analyzer. Grasp on the connector and pull.
- Never allow water or any other liquid to get onto the connector of a probe.
- When using a probe that does not come with the data analyzer, be sure to read its documentation first.

Auto-ID Probe

The following describes how the data analyzer identifies Auto-ID probes based on their resistance values.

Resistance Value	**Probe Type**	**Operation Parameter Initial Default**	
33kΩ	Voltage Probe	2	±10V
10kΩ	Temperature Probe (Celsius)	7	–20°C to 130°C
4.7kΩ	Light Probe	9	100 to 999

Connector Pinouts

The data analyzer uses British Telecom-type 6-pin probe connectors.

Pin	CH1, CH2, CH3	SONIC	DIG IN	DIG OUT
1	Vin	Echo	Clock-In	Clock-Out
2	Gnd	Init	Gnd	Gnd
3	Vres	Auto-ID	D0 In	D0 Out
4	Auto-ID	+5 Volt DC	D1 In	D1 Out
5	+5 Volts DC	Gnd	D2 In	D2 Out
6	Vin-low	n/a	D3 In	D3 Out

	Vin	Vin-low
Channel	CH1, CH2, CH3	CH1, CH2, CH3
Input Signal	Analog Data	Analog Data
Input Range	±10V	0-5V
Input Impedance	740kΩ (at 2.0V)	748kΩ (at 0.03V)

- The data analyzer displays values of 30mV (Vin-low) and 2.0V (Vin) while there is no probe input. This is a normal operation to indicate internal system voltage.

Vres: .... Output reference voltage from the data analyzer through a 15kΩ resistor. When using this function, Vres should be connected to Vin-low and measurement should be between Vin-low and Gnd.

Gnd: .... Ground (common for all channels)

Auto-ID: .... Auto-ID probe detection data input (Auto-ID resistor connected from pin 4 to ground)

Echo: .... Distance sensor input

Init: .... Distance initialization signal

Clock-In: .... External clock signal input (digital)

D0 In to D3 In: ...... Input pins for digital input signals

Clock-Out: .... Clock output (digital)

D0 Out to D3 Out: . Output pins for digital output signals

Conversion Equations

Command 4 Type, Form, and Restrictions

Command 4 conversion equations have certain calculation limitations. In particular, some conversion equations cannot perform calculations for negative values.

If a division by zero, power of a negative number, or other such error is encountered by an equation, an overflow value is automatically applied to the operation.

Conversion Equations

Equation Name		Format	Restrictions
1	Polynomial	$K_0+K_1X+K_2X^2+......+K_nX^n$	n=1 to 9
2	Mixed polynomial	$K_{-m}X^{-m}+......K_{-1}X^{-1}+K_0+K_1X+......+K_nX^n$	m=0 to 4 n=0 to 4 m+n > 0 $X \neq 0$
3	Power	$K_0 X^{(K_1)}$	X > 0
4	Modified power	$K_0 K_1^{(X)}$	$K_1 \geqq 0$
5	Logarithmic	$K_0+K_1 \ln(X)$	X > 0
6	Modified logarithmic	$K_0+K_1 \ln(1/X)$	X > 0
7	Exponential	$K_0 e^{(K_1X)}$	
8	Modified exponential	$K_0 e^{(K_1/X)}$	$X \neq 0$
9	Geometric	$K_0 X^{(K_1X)}$	$X \geqq 0$
10	Modified geometric	$K_0 X^{(K_1/X)}$	X > 0
11	Reciprocal logarithmic	$[K_0+K_1 \ln(K_2X)]^{-1}$	$K_2X > 0$
12	Steinhart-Hart model	$[K_0+K_1(\ln 1000X)+K_2(\ln 1000X)^3]^{-1}$	X > 0

Other Technical Information

Clock-In Line Operation

A low-going pulse (0-5V) on the External Clock-In line (part of the DIG IN channel) is used as the external clock.

Data from the DIG IN channel can be read based on the internal sampling clock, so the External Clock-In line is not necessarily required. Conversely, the external clock line can be used to control the sampling time for signals on other channels.

Clock-Out Line Operation

The low pulse width of the external clock line is 1.6 microseconds. Pulse output can be performed by simply using Command 1 (CHANNEL SETUP) to specify the DIG OUT channel.

Digital Output Buffer

The digital output buffer (DOB) is a circular buffer that can contain up to 22 data elements. Data elements output from the DOB are 4-bit (TTL 0 to 5V) binary data nibbles, such as 0 = 0000, 1 = 0001, 2 = 0010, 10 = 1010, 15 = 1111. One data nibble is output on the DIG OUT D0 through D3 lines for each sample time.

The drive (output current) function for each data nibble and clock is as shown below.

- Voutput-high > 3.98V (Ioutput-high > –6mA)(negative current flow from the data analyzer)
- Voutput-low < 0.26V (Ioutput-low < 6mA)(positive current flow from the data analyzer)

The number of times the DOB contents are output is determined by the number of data elements defined by Command 1 and the number of samples defined by Command 3.

Digital Output Buffer Example

Command 1:

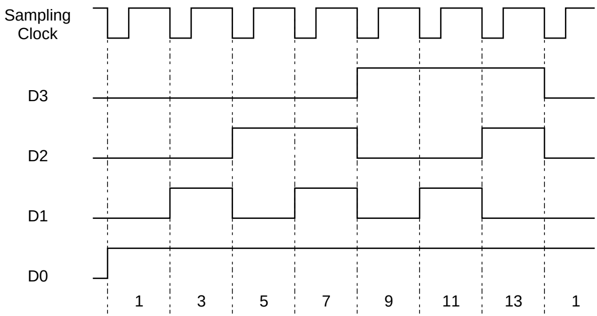
{1,6,7,1,3,5,7,9,11,13}	1 = CHANNEL SETUP
	6 = DIG OUT
	7 = Number of data elements
	1 = 0001 (data nibble)
	3 = 0011 (data nibble)
	5 = 0101 (data nibble)
	7 = 0111 (data nibble)
	9 = 1001 (data nibble)
	11 = 1011 (data nibble)
	13 = 1101 (data nibble)

Command 3:

{3,1,70}

3 = SAMPLING AND TRIGGER SETUP
1 = Sampling time (1 second)
70 = Number of samples
The manual trigger default is applied as the trigger source.

The DOB outputs signals that correspond to the seven data nibbles. This sequences is repeated to the DIG OUT channel 10 times (70 samples/7 data elements). The following diagram shows the output for the first seven data elements.



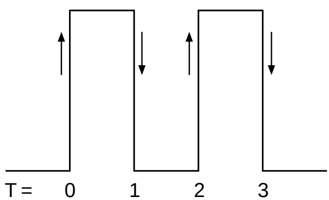
Period and Frequency Measurement

Period and frequency can be measured using Channel 1, Channel 2, or Channel 3 (simultaneous multiple-channel measurements are not allowed), and only when the operation parameter is 5 (period) or 6 (frequency). Period and frequency are measured on the Vin pin (pin 1). Period and frequency measurements always use the hard trigger.

One of the two following methods is used for period and frequency measurements.

A. Counting of the number of trigger edges for 0.25 second

B. Measuring the time between edges specified by Command 1 (see illustration below)



Trigger Edge	Edges for Measuring the Time
0	Rising edge to rising edge (T = 0 to 2)
1	Falling edge to falling edge (T = 1 to 3)
2	Rising edge to falling edge (T = 0 to 1)
3	Falling edge to rising edge (T = 1 to 2)

- Frequency measurement cannot be performed correctly whenever 2 or 3 is specified for the trigger edge.

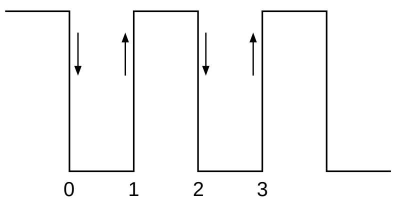
Hard Trigger

The hard trigger is automatically used for period and frequency measurements, and then an external clock signal is being used as the clock. Any one of seven voltage levels can be selected as the trigger point. The voltage level is defined by the Command 1 trigger level parameter.

Voltage Level	Trigger Level Parameter
–5.0V	–10.0 ≦ Vthresh < –2.45
–1.0V	–2.45 ≦ Vthresh < –0.35
–0.2V	–0.35 ≦ Vthresh < –0.05
0.0V	–0.05 ≦ Vthresh < 0.05
0.2V	0.05 ≦ Vthresh < 0.35
1.0V	0.35 ≦ Vthresh < 2.45
5.0V	2.45 ≦ Vthresh < 10.0

Soft Trigger

Soft trigger measurements start at the point the data sampling signal rises or falls (see the illustration below). The actual point where measurement starts is defined by the Command 3 trigger edge and clock edge parameters.



Trigger Edge	Tripper Point
0	HIGH TO LOW (T = 0, 2,...)
1	LOW TO HIGH (T = 1, 3,...)