DIGITAL / ANALOG TRAINER
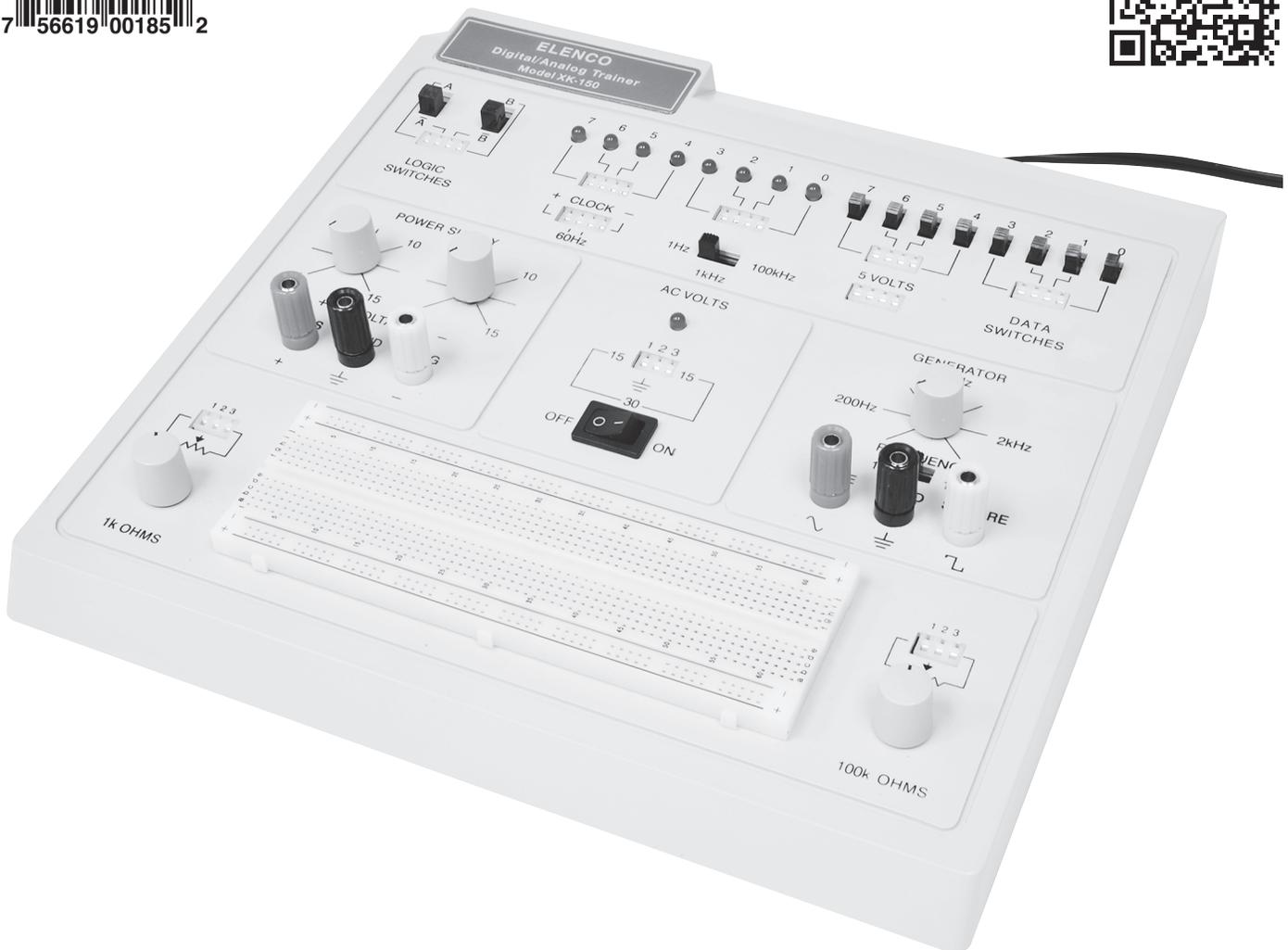
MODEL XK-150

A COMPLETE MINI-LAB FOR BUILDING, TESTING AND PROTOTYPING ANALOG AND DIGITAL CIRCUITS

7 56619 00185 2

Instruction Manual

ELENCO®

PARTS LIST

RESISTORS

Qty	Symbol	Description	Color Code	Part #
❏ 11	R15, 23, 26, 29, 32, 35, 38, 43, 46, VR6-7	150Ω 5% 1/4W	brown-green-brown-gold	131500
❏ 1	R9	200Ω 5% 1/4W	red-black-brown-gold	132000
❏ 1	R22	470Ω 5% 1/4W	yellow-violet-brown-gold	134700
❏ 2	R4, R2	470Ω 5% 1W	yellow-violet-brown-gold	134702
❏ 8	R8, 12, 13, 14, 16, 18, 19, 17	1kΩ 5% 1/4W	brown-black-red-gold	141000
❏ 1	R1	2.2kΩ 5% 1/4W	red-red-red-gold	142200
❏ 1	R3	2.7kΩ 5% 1/4W	red-violet-red-gold	142700
❏ 1	R11	4.7kΩ 5% 1/4W	yellow-violet-red-gold	144700
❏ 1	R20	15kΩ 5% 1/4W	brown-green-orange-gold	151500
❏ 17	R7, 24, 25, 27, 28, 30, 31, 33, 34, 36, 37, 39-42, 44, 45	18kΩ 5% 1/4W	brown-gray-orange-gold	151800
❏ 1	R10	43kΩ 5% 1/4W	yellow-orange-orange-gold	154300
❏ 1	R21	62kΩ 5% 1/4W	blue-red-orange-gold	156200
❏ 1	VR4	1kΩ Potentiometer		192439
❏ 2	VR1, VR2	2kΩ Potentiometer		192458
❏ 1	VR5	100kΩ Potentiometer		192638
❏ 1	VR3	100kΩ Potentiometer (reverse audio)		192641

CAPACITORS

Qty	Symbol	Description	Part #
❏ 1	C17	10pF (10) Discap	211011
❏ 1	C16	30pF (30) Discap	213010
❏ 1	C12	68pF (68) Discap	216816
❏ 1	C7	4700pF (472) Mylar	234717
❏ 1	C8	0.047μF (473) Mylar	244717
❏ 1	C13	0.01μF (103) Mylar	241017
❏ 2	C9, 15	0.1μF (104) Discap	251010
❏ 5	C4, 5, 6, 10, 11	10μF 25V Electrolytic radial	271045
❏ 4	C1, 2, 3, 14	1,000μF 25V Electrolytic radial	291045

SEMICONDUCTORS

Qty	Symbol	Description	Part #	Qty	Symbol	Description	Part #
❏ 9	D1 - 9	1N4001 Diode	314001	❏ 1	IC7	555 IC	330555
❏ 2	ZD1 - 2	Zener diode 1N5231	315231	❏ 1	IC4	XR2206	332206
❏ 9	Q1 - 9	2N3904 Transistor	323904	❏ 1	IC1	LM7805 IC	337805
❏ 1	IC2	LM317 IC	330317	❏ 9	LD1 - 9	LED red	350002
❏ 1	IC3	LM337 IC	330337	❏ 2	IC5, IC6	74LS03 IC	37LS03

MISCELLANEOUS

Qty	Description	Part #	Qty	Description	Part #
❏ 1	Transformer	440111	❏ 2	Binding post black	625031
❏ 1	PC board digital	514000	❏ 6	Nut binding post	625031HN
❏ 1	PC board analog	514001	❏ 6	Lockwasher binding post	625031LW
❏ 2	PC board 1k, 100k pot	514002	❏ 2	Binding post red	625032
❏ 1	Fuse 0.25A	531005	❏ 2	Binding post yellow	625034
❏ 9	Switch slide 2P2T (SW5 - 13)	541023	❏ 6	Screw M3 x 10mm	642358
❏ 1	Switch slide 2P3T (SW4)	541208	❏ 13	Screw #4 x 5/16" AB phillips	642442
❏ 1	Switch rocker (SW1)	541209	❏ 5	Nut pot 7mm	644101
❏ 7	Connector 4-pin	591104	❏ 5	Nut 3mm x 0.5	644104
❏ 1	Connector 3-pin	596032	❏ 2	Washer flat #4	645000
❏ 3	Heat sink	615005	❏ 5	Washer flat 7mm x 12mm	645111
❏ 8	Spacer nylon	624117	❏ 2	Lockwasher #4 int.	646401
❏ 1	Socket IC 8-pin	664008	❏ 4	Feet rubber	662003
❏ 2	Socket IC 14-pin	664014	❏ 1	Fuse holder assembly	663005,LB,UB,W,N
❏ 1	Socket IC 16-pin	664016	❏ 1	Label XK-150 case	723100
❏ 5	Knob push-on	622017	❏ 1	Line cord	862105
❏ 1	Plastic case top/bottom	623027	❏ 2	Switch slide 2P2T (SW2 - 3)	920000
❏ 1	Bushing strain	624002	❏ 1	Breadboard	99830

GENERAL SPECIFICATIONS FOR MODEL XK-150

Power Supplies:

- +1.25V to 15VDC @ 0.25A
- −1.25 to −15VDC @ 0.25A
- +5V $\pm$5% @ 0.5A
- 30VAC center-tapped at 15VAC @ 0.25A
- Load regulator all DC supplies less than 0.2V no load to 0.25A
- Line regulator all DC supplies less than 0.2V 105 to 135V
- Hum and ripple all DC supplies less than 0.01V RMS
- Short protection all DC supplies - internal IC thermal cutoff
- Fuse - 0.25A 250V

Function Generator Analog Section:

- Waveforms sine, square, complimentary square
- Frequency - adjustable from 200 - 40kHz in 2 ranges
- Amplitude - sine wave 4Vpp
    square wave 9.5Vpp
- Output impedance 600Ω

Digital Section:

- Data switches, eight DPDT, high 5V, low 0V
- Logic switches, two no bounce with complimentary output
  "On" voltage level 2.8V min., "Off" voltage level 1V max.
  Input impedance 100kΩ.
- Eight LED readouts, 100kΩ input impedance
- Clock frequency, 1Hz,1kHz, 100kHz, 60Hz
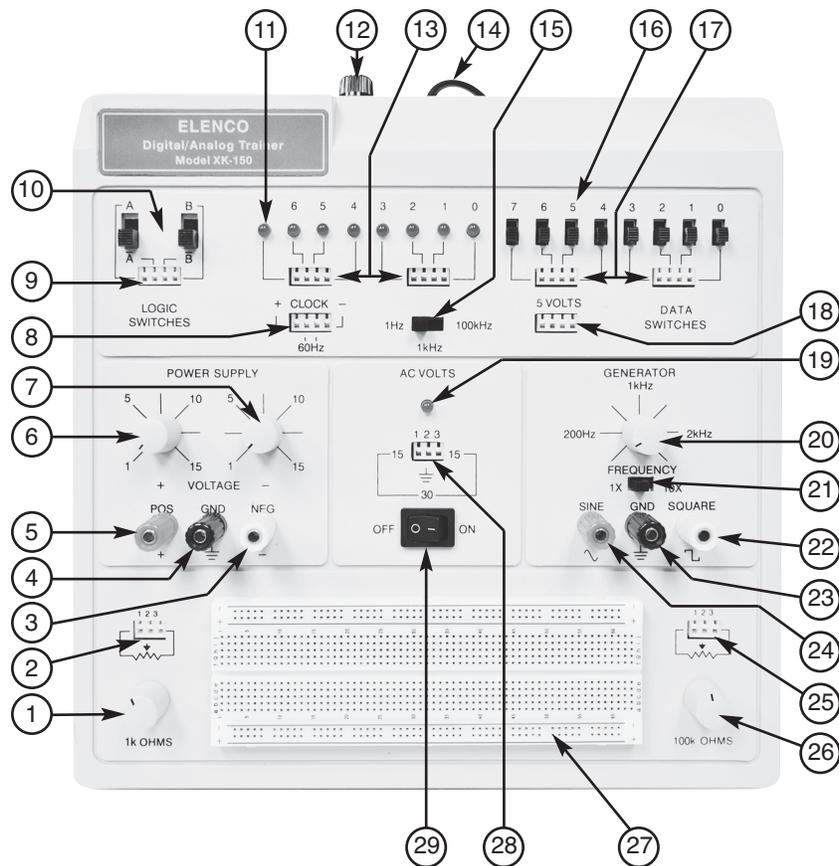- Clock amplitude, 5Vpp squarewave
- Clock rise time, better than 100nsec.

Breadboard Section:

- One breadboard containing 830 tie points including two bus strips

Variable Resistance (undedicated):

- 1kΩ Potentiometer
- 100kΩ Potentiometer

USERS DESCRIPTION OF FRONT PANEL CONTROL

1) 1kΩ undedicated potentiometer.

2) **Output Terminal** for 1kΩ undedicated potentiometer.

3) **Output Terminal** for −1.25 to −15V power supply.

4) **GND Terminal** for the ±15 variable power supply.

5) **Output Terminal** for 1.25 to 15V power supply.

6) **Variable Positive Voltage Control** - Varies positive voltage from 1.25 to 15V at indicated output terminal.

7) **Variable Negative Voltage Control** - Varies negative voltage from −1.25 to −15V at indicated output connector pin.

8) **Output Terminal** for the CLOCK frequencies.

9) **Output Terminal** for the logic switches.

10) **Two Logic Switches** - These are no bounce logic switches. Give one signal state change per movement of switch.

11) **Logic Indicators LEDs**, total eight.

12) **Fuse Holder** - Easy access for replacement of 0.25A 250V fuse.

13) **Input Points For Logic Indicator LEDs.** "0" input corresponds with 0 lamp, etc.

14) **Power Cord**

15) Selects CLOCK frequency range 1Hz, 1kHz, and 100kHz.

16) **Eight Data Switches** - Lets output of 5V or 0V depending on position.

17) **Output Terminals For the DATA Switches 0-1.**

18) **Output Terminal** for +5V power supply.

19) **Power ON LED** - Lights when unit is on.

20) **Frequency Control** - Allows easy selection of desired function generator frequency.

21) **Frequency Multiplier Switch** - Range from x1 (200 to 4,000Hz) or x10 (2,000 to 40,000Hz).

22) **Output Terminals** for SQUARE wave.

23) **Gnd Terminals** for SINE and SQUARE wave.

24) **Output Terminals** for SINE wave.

25) **Output Terminals** for 100kΩ undedicated potentiometer.

26) 100kΩ undedicated potentiometer.

27) **One Breadboard** containing a total of 830 tie points including two (2) independent bus lines.

28) **Power Output Terminals** - This provides 30VAC center-tapped at 15VAC.

29) **ON-OFF Switch** - Allows power to be applied to all outputs. LED will light when on.

INTRODUCTION

Congratulations on your purchase of the ELENCO®
Model XK-150 Digital / Analog Trainer. This trainer is
designed to simplify designing of digital and analog
circuits. It contains most of the necessary test
equipment needed to build and test these circuits.

Your XK-150 has four basic trainers in a single
package. They are, four (4) independent power
supplies, an analog trainer, a digital and a
breadblock assembly trainer. We shall proceed in
describing each trainer in the following sections.

POWER SUPPLY

Model XK-150 has four built-in power supplies which
will satisfy most design needs. There are two
variable power supplies giving up to +15V and –15V
at 0.25A. The two other supplies consists of a fixed
+5V at 0.5A, and a 30VAC center-tapped at 15VAC
at 0.25A. All the DC supplies are regulated to within
0.2V. This means that you can increase the current
draw from no load to 0.25A and the voltage will
change less than 0.2V. The supplies are also short
circuit protected by using integrated circuit regulator
devices.

ANALOG TRAINER SECTION FUNCTION GENERATOR

The analog trainer contains a function generator
capable of producing sine and square waveform.
The frequency of this generator is variable in two
ranges from 200Hz to 40,000Hz. The output voltage
amplitude for the sine wave is 4Vpp and the square
wave at 9.5Vpp. The output impedance is
approximately 600Ω.

DIGITAL TRAINER SECTION

The digital trainer has the necessary functions to do
your digital designs. They consist of a clock
generator, two no bounce logic switches, eight (8)
LED indicator lamps and eight (8) data switches.
These functions will make it easy to do your digital
experiments.

TESTING THE XK-150 DIGITAL ANALOG TRAINER

The following paragraphs give detailed instructions on testing the digital / analog trainer.

Note that in the XK-150 trainer there are five major functions, (1) Power Supply (2) Logic Indicators (3) Function Generator (4) Logic Switches and (5) Data Switches. We shall proceed in testing out each section.

POWER SUPPLY TESTING

Plug the trainer into 120VAC outlet and set the power switch to the "ON" position. The red LED will light when the unit is on. Set the the knobs for the +15 and –15 volts fully counter-clockwise. Obtain a digital voltmeter and measure the voltage at POS (+15V) binding post. The voltage should be approximately 1.25V. Measure the voltage at the NEG (–15V) binding post. The voltage should be approximately –1.25V. Then turn both knobs fully clockwise and measure the outputs again. The output voltage should be between 14.5 to 16V.

Short the POS binding post or the NEG binding post to the GND binding post. **DO NOT short the positive and negative posts together.** The voltage regulators will turn off and the voltage drops to zero. Remove the shorts and voltage should recover.

Set the +15V supply to 15V. If you have a 60Ω, 4W resistor, place it across the POS and GND binding posts. The output of the 15V supply should not change more than 0.2V. In making this test, the voltmeter leads should be clipped to the terminal directly and not to the load leads. This is to prevent errors in voltage drop due to contact resistance of the load. Do the same for the –15V output, connecting the resistor between the NEG and GND binding posts. The output should not change more than 0.2V.

Measure the voltage at the +5V output. The voltage should read between 4.75 and 5.25V. Short the output to the GND binding post. The voltage regulators will turn off and the voltage drops to zero. Remove the short and voltage should recover. Place a 10Ω, 4W resistor from the output to the GND binding post and measure the voltage. Again, the output should not change more than 0.2V.

Set your meter to measure AC volts. Measure the AC voltage across the 1 and 3 terminal of the AC output. The voltage should be about 30VAC. Move one of the leads to the 2 terminal the the voltage should be about 15VAC. **WARNING!! DO NOT SHORT THE AC OUTPUT TO GND.**

TESTING THE FUNCTION GENERATOR

To test the function generator, you will need an oscilloscope. Connect the scope to the SINE wave binding post and the ground clip to the GND binding post. Set the switch the to 1x position. Your scope should show a sine wave with an output of about 4Vpp. Turn the frequency control, the frequency should vary between 200 and 4,000Hz. Turn the switch to 10x and vary the frequency control. The frequency should vary between 2,000 and 40,000Hz. Check the square wave output in the same manner. The amplitude of should be 9.5Vpp.

TESTING THE CLOCK

If your scope is a dual trace, connect one probe to the +CLOCK terminal and the other to the –CLOCK terminal. Set the switch the 1kHz. You will note the two frequencies are 180 degrees out of phase. Check the 1kHz and 100kHz settings. Check the 60Hz terminal a for 60Hz square wave signal.

If no scope is available, connect a wire from the +CLOCK terminal to the "7" LED logic indicator terminal. Connect another wire from the –CLOCK terminal to the "6" LED logic indicator. Set the clock frequency switch to 1Hz. The two LEDs should blink alternately. In the 1kHz and 100kHz position, both LEDs will be on. Remove the wire from the +CLOCK terminal and connect it to the 60Hz terminal. The LED should be on.

TESTING THE LOGIC INDICATOR FUNCTION

There are eight logic indicators which you will be testing. Place a wire to the 5V terminal and touch the "0" LED logic indicator terminal. The "0" LED should light up. Remove the wire and the LED should go out. Do the same for the 1, 2, 3, 4, 5, 6, and 7 logic terminals.

TESTING THE LOGIC SWITCHES

There are two logic switches and four conditions to be tested. Connect a wire from the "$\overline{A}$" terminal to the "7" LED logic indicator terminal. Connect another from the "A" terminal to the "6" LED logic indicator terminal.

Note that the "7" LED logic indicator should be lit when the logic switch is in the "A" positions and the "6" LED is not lit. Moving the logic switch to "$\overline{A}$" should reverse the indicator LEDs, that is the "6" LED should light and the "7" LED not light. Check the B logic switch in the same manner.

TESTING THE DATA SWITCHES

There are eight data switches to be tested. When the switch is in the up position, the output is at 5V. When the switch is in the down position, the output is at ground. Place all the switches in the down position. Connect a wire from the SW0 terminal and the "0" LED terminal. The "0" LED should light when the switch is placed toward the top case. Repeat the same test on SW1, SW2, SW3, SW4, SW5, SW6, and SW7.

This completes the testing of the trainer.

CIRCUIT DESCRIPTION

The XK-150 Power Supply features two variable output voltages and a fixed 5V. The variable voltages are 1.25V to 15V and –1.25 to –15V at up to 0.25A maximum current. All supplies are regulated to better than 0.2V when going from no load to full load. Varying the input AC voltage from 105 to 135V will have practically no effect on the output voltages. This is because of the specially designed IC circuits used in the XK-150 circuits. Severe overloading or even shorting the output circuits will not damage the supplies. Special turn-off circuits in the IC sense the overload and turn off the output.

THE POSITIVE 1.25 TO 15V POWER SUPPLY

Figure 1 shows a simplified circuit diagram of the positive supply. It consists of a power transformer, a DC rectifier stage and the regulator stage.

Simplified diagram of positive power supply
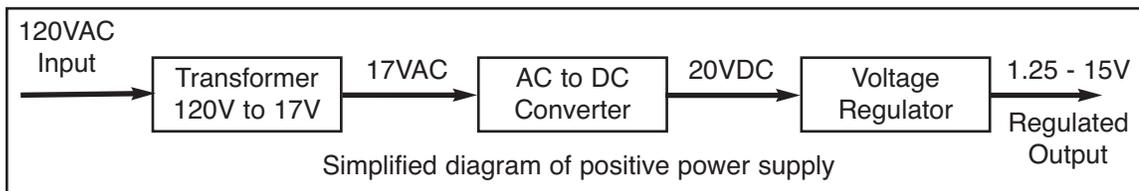
Figure 1

TRANSFORMER

The transformer T1 serves two purposes. First, it reduces the 120VAC input to 17VAC to allow the proper voltage to enter the rectifier stages. Second, it isolates the power supply output from the 120VAC line. This prevents the user from dangerous voltage shock should he or she be standing in a grounded area.

AC TO DC CONVERTER

The AC to DC converter consists of diodes D1, D2 and capacitor C1. Transformer T1 has two secondary windings which are 180 degrees out of phase. The AC output at each winding is shown in Figure 2A and 2B.

Diodes are semiconductor devices that allow current to flow in one direction. The arrow in Figure 3 points to the direction current will flow. Only when the transformer voltage is positive will current flow through the diodes. Figure 3 shows the simplest possible rectifier circuit. This circuit is known as a half-wave rectifier. Here the diode conducts only half of the time when the AC wave is positive as shown in 2C. Use of this circuit is simple but inefficient. The big gap between cycles require much more filtering to obtain a smooth DC voltage.

By the addition of a second diode and transformer winding we can fill in the gap between cycles as shown in Figure 4. This circuit is called full-wave rectification. Each diode conducts when the voltage is positive. By adding the two outputs, the voltage presented to capacitor C1 is more complete, thus easier to filter, as shown in Figure 2E. When used in 60 cycles AC input power, the output of a full wave rectifier will be 120 cycles.

Capacitor C1 is used to store the current charges, thus smoothing the DC voltage. The larger the capacitor, the more current is stored. In this design 1000μF capacitors are used, which allows about 1 volt AC ripple when 0.25A is drawn.

In practice, the current through the diodes is not as shown in Figure 2C. Because capacitor C1 has a charge after the first cycle, the diode will not conduct
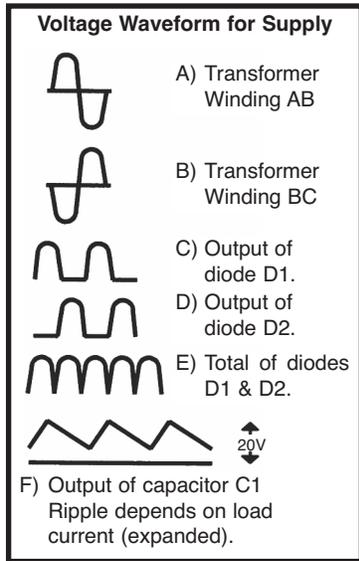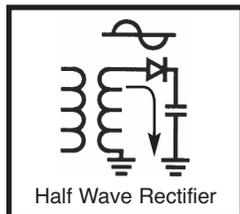

Voltage Waveform for Supply

A) Transformer Winding AB

B) Transformer Winding BC

C) Output of diode D1.

D) Output of diode D2.

E) Total of diodes D1 & D2.

F) Output of capacitor C1 Ripple depends on load current (expanded).

Figure 2

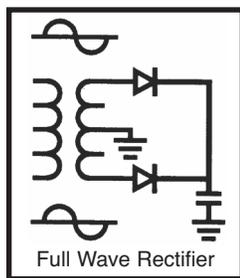Half Wave Rectifier

Figure 3

Full Wave Rectifier

Figure 4

until the positive AC voltage exceeds the positive charge in the capacitor. Figure 5 shows a better picture of what the current flow looks like assuming no loss in the diode.

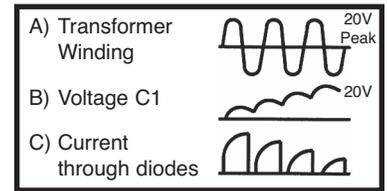It takes a few cycles for the voltage to build up on the capacitor. This depends on the resistance of the winding and diode. After the initial start-up, there will be a charge and discharge on the capacitor depending on the current drawn by the output load. Remember, current only flows through the diodes when the anode is more positive than the cathode. Thus, current will flow in short bursts as shown in Figure 5.

A) Transformer Winding

B) Voltage C1

C) Current through diodes

Figure 5

The DC load current may be 0.25A but the peak diode current may be three times that. Therefore, the diode rating must be sufficient to handle the peak current. The 1N4001 has peak current rating of 10A.

REGULATOR CIRCUIT

The regulator circuit in the Model XK-150 power supply consists of a LM-317 integrated circuit. This IC is specially designed to perform the regulation function. Figure 6 shows a simplified circuit of how the LM-317 IC works.

Transistors Q1 and Q2 form a circuit known as a differential amplifier. Transistor Q1 base is connected to a stable 1.5V reference voltage. The base of Q2 is connected to the regulator output
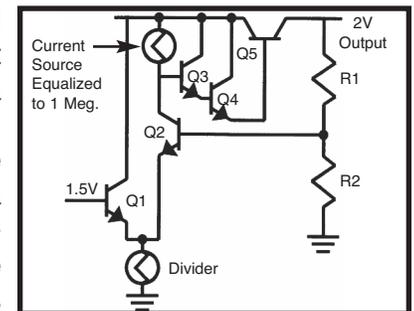

Figure 6

circuit through a voltage divider network. The collector of transistor Q2 is connected to a current source. This basically is a PNP transistor biased to draw about 1mA current. Transistor Q2 sees the current source as a very high resistor of about 1 meg ohms. Thus, the gain of transistor Q2 is extremely high.

Transistor Q5 is called the pass transistor. It controls the current reaching the output. Transistor Q3 and Q4 are emitter followers. Their function is to raise the impedance of the pass transistor. Note that transistor Q2, Q3, Q4, Q5 and resistor R1 form a closed loop. Also note that the feedback to the base of Q2 is negative, that is, when the base of Q2 goes positive, the output at emitter Q5 goes negative. Now if the 2V output voltage goes down because of current drain at the output, the base of Q2 will drop forcing the the collector voltage of Q2 to go higher. This will bring the output voltage back to 2V. This is the basis of all negative feedback regulators.

Another feature of the LM-317 regulator is to protect the IC against overload and output shorts. If the IC is overloaded, the junction of an overload transistor will overheat. A transistor will sense this overheating and shut down transistor Q5.

The LM-317 IC is basically a 1.25 regulator. To be able to vary the output 1.25 to 15V we stack the IC on a DC voltage as shown in Figure 6A. When VR1 equals 0, the output voltage is 1.25V as determined by the LM-317 IC. Note that the voltage across R1 is always 1.25V. When R1 equals VR1, the voltage across VR1 will equal the 1.25V across R1, therefore the output voltage will be 2.5V. When VR1 is 5 times R1, the output voltage is 6.25V. As you can see, varying resistor VR1 will vary the voltage from 1.25 to 15V.
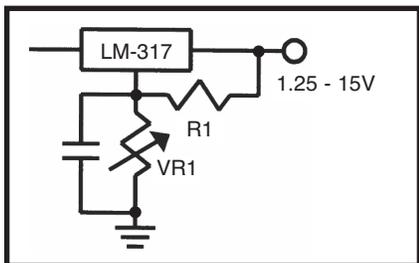

Figure 6A

THE NEGATIVE VOLTAGE REGULATOR

The theory of the voltage regulator is the same as the previously discussed positive regulator. The basic difference is that diodes D1 and D2 are reversed producing a negative voltage across capacitor C1. The LM-337 IC is designed to operate from a negative supply.

THE DATA SWITCHES

There are eight data switches labeled "0" to "7". The circuit is very simple. To perform the desired functions there is a double throw-double pole switch. One end is connected to the 5V, the other to ground and the center lug is connected to the output.

THE LOGIC SWITCHES

The logic switches perform the same function as the data switch, that is, they produce high or low states. But there is one big difference. When switching the data switches, many pulses may be produced due to bouncing of the contacts.

In the logic switches, only one pulse is produced, no matter how many times the contacts bounce. This is extremely important if you are producing pulses for counting circuits. Figure 7 shows the wiring of the logic switch. The two NAND gates are connected so that when A input is grounded the output A goes high. Opening and closing the ground at A will not change the output. Only when $\overline{A}$ is grounded will the output change to low. Thus, only one output change is produced with one movement of the A switch. There are two outputs from logic switch, A and $\overline{A}$ or B and $\overline{B}$.
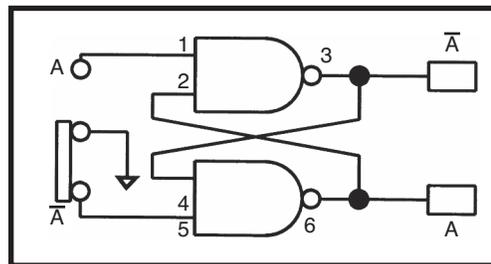

Figure 7

THE FUNCTION GENERATOR

The function generator frequencies are produced by an XR-2206 integrated circuit. This IC is capable of producing high quality sine and square waveform of high stability and accuracy. Figure 8 shows the block diagram of the XR-2206 IC.

The XR-2206 is comprised of four functional blocks, a voltage controlled oscillator (VCO), an analog multiplier & sine shaper, a unity gain buffer amplifier and a set of current switches.

The VCO actually produces an output frequency proportional to an input current. Across pins 5 and 6, two timing capacitor are switched between to give different frequency ranges. On pin 7, the 100kΩ variable resistor controls the actual frequency output. These two components form the RC time constants for the oscillator frequency.

The VCO produces a square wave signal. This square wave is sent to a shaper and converted into a sine wave.
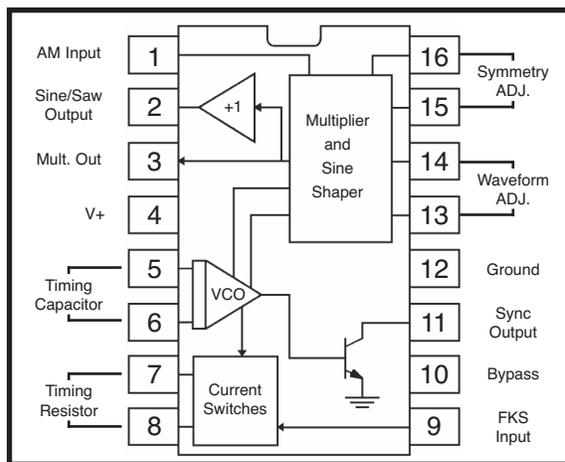
Figure 8

THE LOGIC INDICATORS

There are eight logic indicators. Figure 9 shows the circuit. It consists of a transistor, LED, and three resistors. The two 18kΩ resistors form a voltage divider. When the input is over 1.4V, the transistor will turn on allowing current to flow through the LED to ground, thus turning it on. The 150Ω resistor limits the current in the LED to about 30mA.

Figure 9

SCHEMATIC DIAGRAM