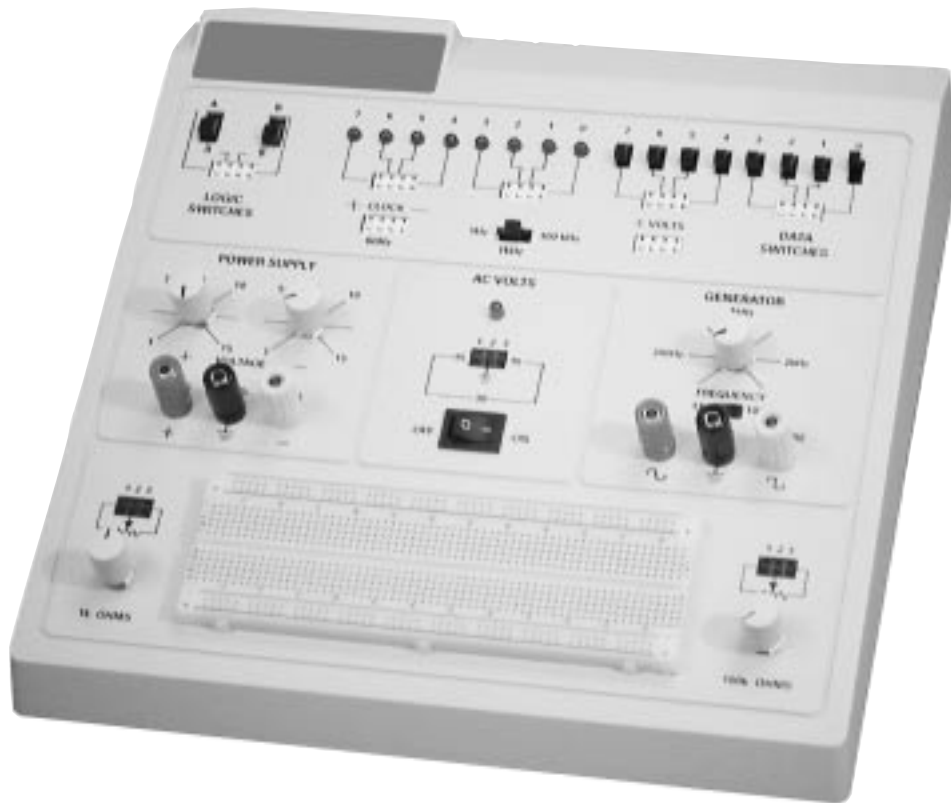


DIGITAL / ANALOG TRAINER

MODEL XK-150

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



Instruction Manual



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Elenco Electronics, Inc.

PARTS LIST

RESISTORS

Qty	Symbol	Description	Color Code	Part #
<input type="checkbox"/> 11	R15, 23, 26, 29, 32, 35, 38, 43, 46, VR6-7	150Ω 5% 1/4W	brown-green-brown-gold	131500
<input type="checkbox"/> 1	R9	200Ω 5% 1/4W	red-black-brown-gold	132000
<input type="checkbox"/> 1	R22	470Ω 5% 1/4W	yellow-violet-brown-gold	134700
<input type="checkbox"/> 2	R4, R2	470Ω 5% 1/2W	yellow-violet-brown-gold	134701
<input type="checkbox"/> 8	R8, 12, 13, 14, 16, 18, 19, 17	1kΩ 5% 1/4W	brown-black-red-gold	141000
<input type="checkbox"/> 1	R1	2.2kΩ 5% 1/4W	red-red-red-gold	142200
<input type="checkbox"/> 1	R3	2.7kΩ 5% 1/4W	red-violet-red-gold	142700
<input type="checkbox"/> 1	R20	15kΩ 5% 1/4W	brown-green-orange-gold	151500
<input type="checkbox"/> 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
<input type="checkbox"/> 1	R10	43kΩ 5% 1/4W	yellow-orange-orange-gold	154300
<input type="checkbox"/> 1	R11	47kΩ 5% 1/4W	yellow-violet-orange-gold	154700
<input type="checkbox"/> 1	R21	62kΩ 5% 1/4W	blue-red-orange-gold	156200
<input type="checkbox"/> 1	VR4	1kΩ POT		192439
<input type="checkbox"/> 2	VR1, VR2	2kΩ POT		192438
<input type="checkbox"/> 1	VR5	100kΩ POT		192638
<input type="checkbox"/> 1	VR3	1MΩ POT		192738

CAPACITORS

Qty	Symbol	Description	Part #
<input type="checkbox"/> 1	C17	10pF (10) Discap	211011
<input type="checkbox"/> 1	C12	68pF (68) Discap	216816
<input type="checkbox"/> 1	C7	470pF (470) Mylar	224717
<input type="checkbox"/> 1	C8	.0047μF (472) Mylar	234717
<input type="checkbox"/> 1	C13	.01μF (103) Mylar	241017
<input type="checkbox"/> 2	C9, 15	.1μF (104) Discap	251010
<input type="checkbox"/> 5	C4, 5, 6,10,11	10μF 25V Electrolytic Radial	271045
<input type="checkbox"/> 4	C1, 2, 3, 14	1,000μF 25V Electrolytic Radial	291045

SEMICONDUCTORS

Qty	Symbol	Description	Part #	Qty	Symbol	Description	Part #
<input type="checkbox"/> 9	D1 - 9	1N4001 Diode	314001	<input type="checkbox"/> 1	IC7	555 IC	330555
<input type="checkbox"/> 2	ZD1 - 2	Zener Diode 1N5234B	315235	<input type="checkbox"/> 1	IC4	XR2206	332206
<input type="checkbox"/> 9	Q1 - 9	2N3904 Transistor	323904	<input type="checkbox"/> 1	IC1	LM7805 IC	337805
<input type="checkbox"/> 1	IC2	LM317 IC	330317	<input type="checkbox"/> 9	LD1 - 9	LED Red	350002
<input type="checkbox"/> 1	IC3	LM337 IC	330337	<input type="checkbox"/> 2	IC5, IC6	74LS03 IC	37LS03

MISCELLANEOUS

Qty	Description	Part #	Qty	Description	Part #
<input type="checkbox"/> 1	Transformer	440111	<input type="checkbox"/> 2	Binding Post Black	625031
<input type="checkbox"/> 1	PC Board digital	514000	<input type="checkbox"/> 6	Nut Binding Post	625031HN
<input type="checkbox"/> 1	PC Board analog	514001	<input type="checkbox"/> 6	Lockwasher Binding Post	625031LW
<input type="checkbox"/> 2	PC Board 1k, 100k POT	514002	<input type="checkbox"/> 2	Binding Post Red	625032
<input type="checkbox"/> 1	Fuse .25A	531005	<input type="checkbox"/> 2	Binding Post Yellow	625034
<input type="checkbox"/> 9	Switch Slide 2P2T (SW5 - 13)	541023	<input type="checkbox"/> 6	Screw M3 x 10mm	642358
<input type="checkbox"/> 1	Switch Slide 2P3T (SW4)	541208	<input type="checkbox"/> 13	Screw #4 x 5/16" AB Phil	642442
<input type="checkbox"/> 1	Switch Rocker (SW1)	541209	<input type="checkbox"/> 5	Nut Pot 7mm	644101
<input type="checkbox"/> 7	Connector 4-pin	591104	<input type="checkbox"/> 5	Nut 3mm x .5	644104
<input type="checkbox"/> 1	Connector 3-pin	596032	<input type="checkbox"/> 2	Washer Flat #4	645000
<input type="checkbox"/> 3	Heat Sink	615005	<input type="checkbox"/> 5	Washer Flat 7mm x 12mm	645111
<input type="checkbox"/> 8	Spacer Nylon	624117	<input type="checkbox"/> 2	Lockwasher #4 INT	646401
<input type="checkbox"/> 1	Socket IC 8-pin	664008	<input type="checkbox"/> 4	Feet Rubber	662003
<input type="checkbox"/> 2	Socket IC 14-pin	664014	<input type="checkbox"/> 1	Fuse Holder Assembly	663005,LB,UB,W,N
<input type="checkbox"/> 1	Socket IC 16-pin	664016	<input type="checkbox"/> 1	Label XK-150 Case	723100
<input type="checkbox"/> 5	Knob Push-on	622017	<input type="checkbox"/> 1	Line Cord	862105
<input type="checkbox"/> 1	Plastic Case top/bottom	623027	<input type="checkbox"/> 2	Switch Slide 2P2T (SW2 - 3)	920000
<input type="checkbox"/> 1	Bushing Strain	624002			

GENERAL SPECIFICATIONS FOR MODEL XK-150

Power Supplies:

- +1.25V to 15VDC @ .25 amp
- -1.25 to -20VDC @ .25 amp
- +5V \pm 5% @ .5 amp
- 30V AC center tapped at 15VAC @ .25 amp.
- Load regulator all DC supplies less than .2V no load to .25A
- Line regulator all DC supplies less than .2V 105 to 135V
- Hum and ripple all DC supplies less than .01V RMS
- Short protection all DC supplies-Internal IC thermal cutoff
- Fuse - .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 12Vpp
- Output impedance 600 Ω :

Digital Section:

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

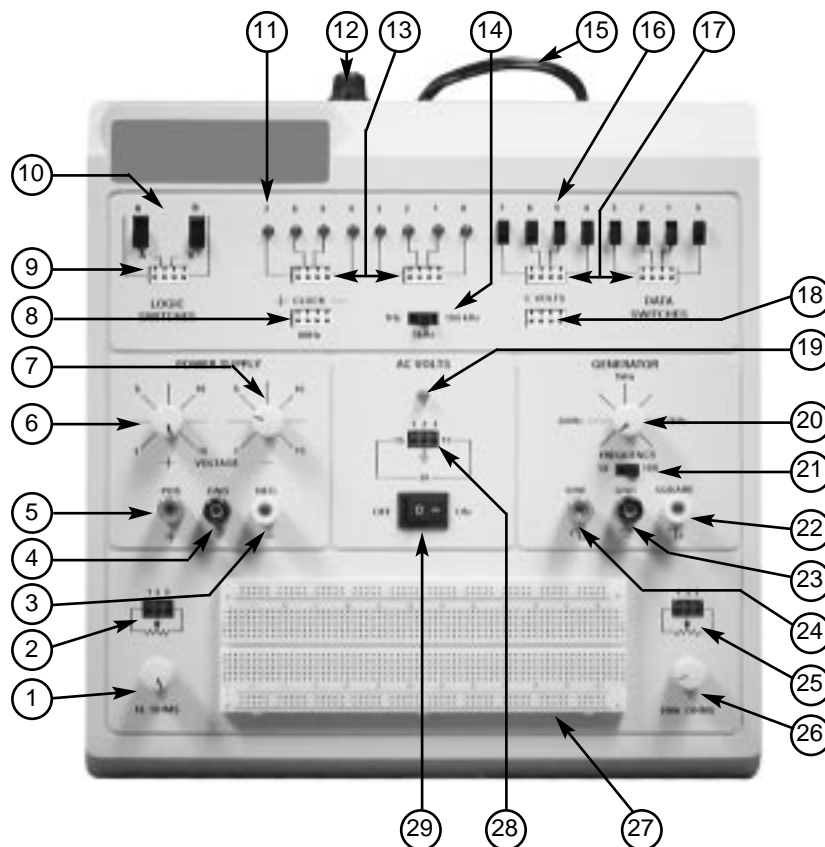
Breadboards Section:

- One breadboards containing 830 tie points including to bus strips

Variable Resistance (undedicated):

- 1k Ω Potentiometer
- 100k Ω Potentiometer

USERS DESCRIPTION OF FRONT PANEL CONTROL



- 1) 1k Ω undedicated potentiometer.
- 2) **Output Terminals** for 1k Ω undedicated potentiometers.
- 3) **Output Terminals** for -15V power supply.
- 4) **Gnd Terminals** for the +/-15 variable power supply.
- 5) **Output Terminals** for +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 Terminals** for the Clock frequencies.
- 9) **Output Terminals** 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 .25A 250V fuse.
- 13) **Input Points For Logic Indicator LEDs**. "0" input corresponds with 0 lamp, etc.
- 14) Selects CLOCK frequency range 1Hz,1kHz, and 100kHz.
- 15) **Power Cord**.
- 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 2,000Hz) or X100 (2,000 to 20,000Hz).
- 22) **Output Terminals** for SQUARE wave.
- 23) **Gnd Terminals** for SINE and SQUARE wave.
- 24) **Output Terminals** for SINE wave.
- 25) **Output Terminals** for 100k Ω undedicated potentiometers.
- 26) 100k Ω undedicated potentiometer.
- 27) **One Breadboard** containing a total of 830 tie points including 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, 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 +15 volts and -15 volts at .25 amp. The two other supplies consists of a fixed +5V at .25 amp, and a 30VAC center-tapped at 15VAC at .25 amp. All the DC supplies are regulated to within 150mV. This means that you can increase the current draw from no load to .25 amp and the voltage will change less than 150 millivolts. 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 200 hertz to 20,000 hertz. The output voltage amplitude for the sine wave is 4Vpp and the square wave at 12Vpp. The output impedance is approximately 600 ohms.

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, 8 LED indicator lamps and 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 clock wise. Obtain a digital voltmeter and measure the voltage at POS (+15V) binding post. The voltage should be approximately 1.25 volts. Measure the voltage at the NEG (--15V) binding post. The voltage should be approximately --1.25 volts. Then turn both knobs fully clockwise and measure the outputs again. The outputs voltage should be between 14.5 to 16 volts.

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 +15 volt supply to 15 volt. If you have a 60 ohm 4 watt resistor, place it across the POS and GND binding posts. The output of the 15V supply should not change more than .15 volts. 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 .15 volts.

Measure the voltage at the +5V output. The voltage should read between 4.75 and 5.25 volts. 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 20 Ω , 2 watt resistor from the output to the GND binding post and measure the voltage. Again, the output should not change more than .15 volts.

Set you 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 2000 hertz. Turn the switch to 10X and vary the frequency control. The frequency should vary between 2,000 and 20,000 hertz. Check the square wave output in the same manner. The amplitude of should be 12Vpp.

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 1 hertz. 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 “A” terminal to the “7” LED logic indicator terminal. Connect another from the “ \bar{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 “ \bar{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 .25 ampere maximum current. All supplies are regulated to better than .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.

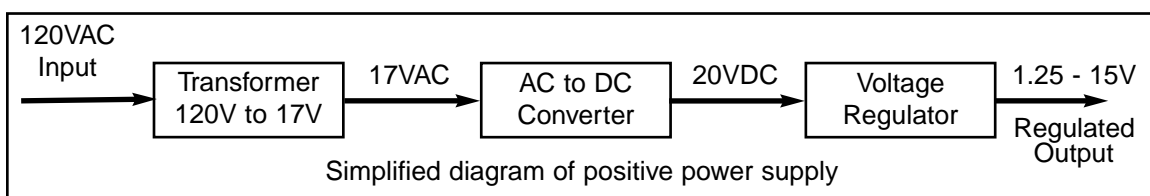


Figure 1

TRANSFORMER

The transformer T1 serves two purposes. First, it reduces the 120VAC input to 34VAC 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 degree 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 1000 μ F capacitors are used, which allows about 1 volt AC ripple when .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 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.

The DC load current may be .25A but the peak diode current may be three times that. Therefore, the diode rating must be sufficient to handle the peak current. The IN4001 has peak current rating of 10 amps.

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 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.

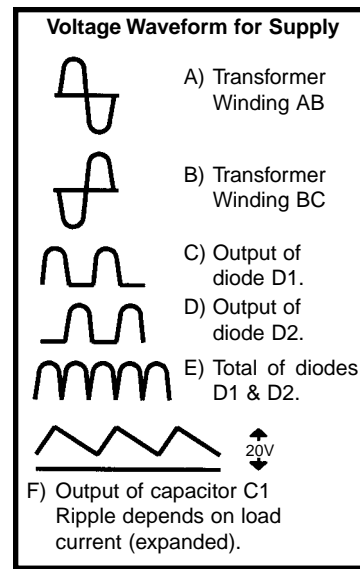


Figure 2

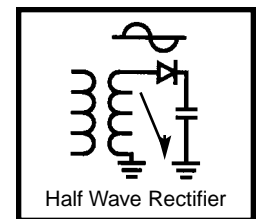


Figure 3

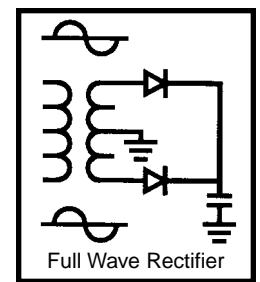


Figure 4

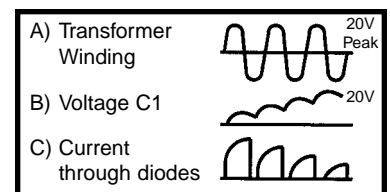


Figure 5

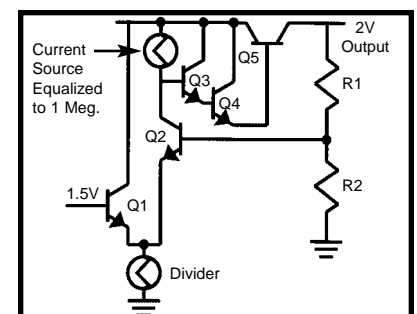


Figure 6

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 close 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 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 1.25 volts. When R1 equals VR1, the voltage across VR1 will equal the 1.25 volts across R1, therefore the output voltage will be 2.5 volts. When VR1 is 5 times R1, the output voltage is 6.25 volts. As you can see, varying resistor VR1 will vary the voltage from 1.25 to 15V.

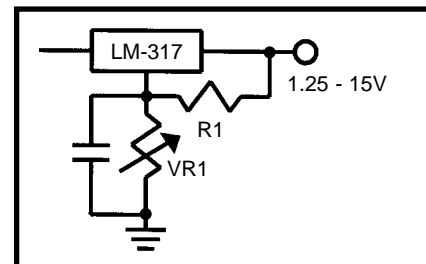


Figure 6A

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 \bar{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 \bar{A} or B and \bar{B} .

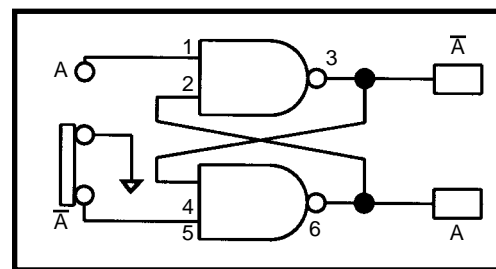


Figure 7

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 1MΩ 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.

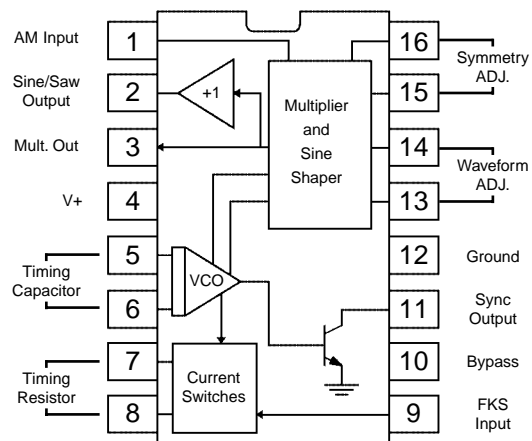


Figure 8

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.

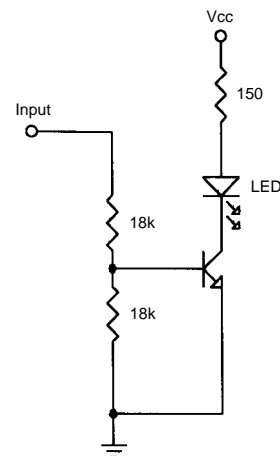


Figure 9

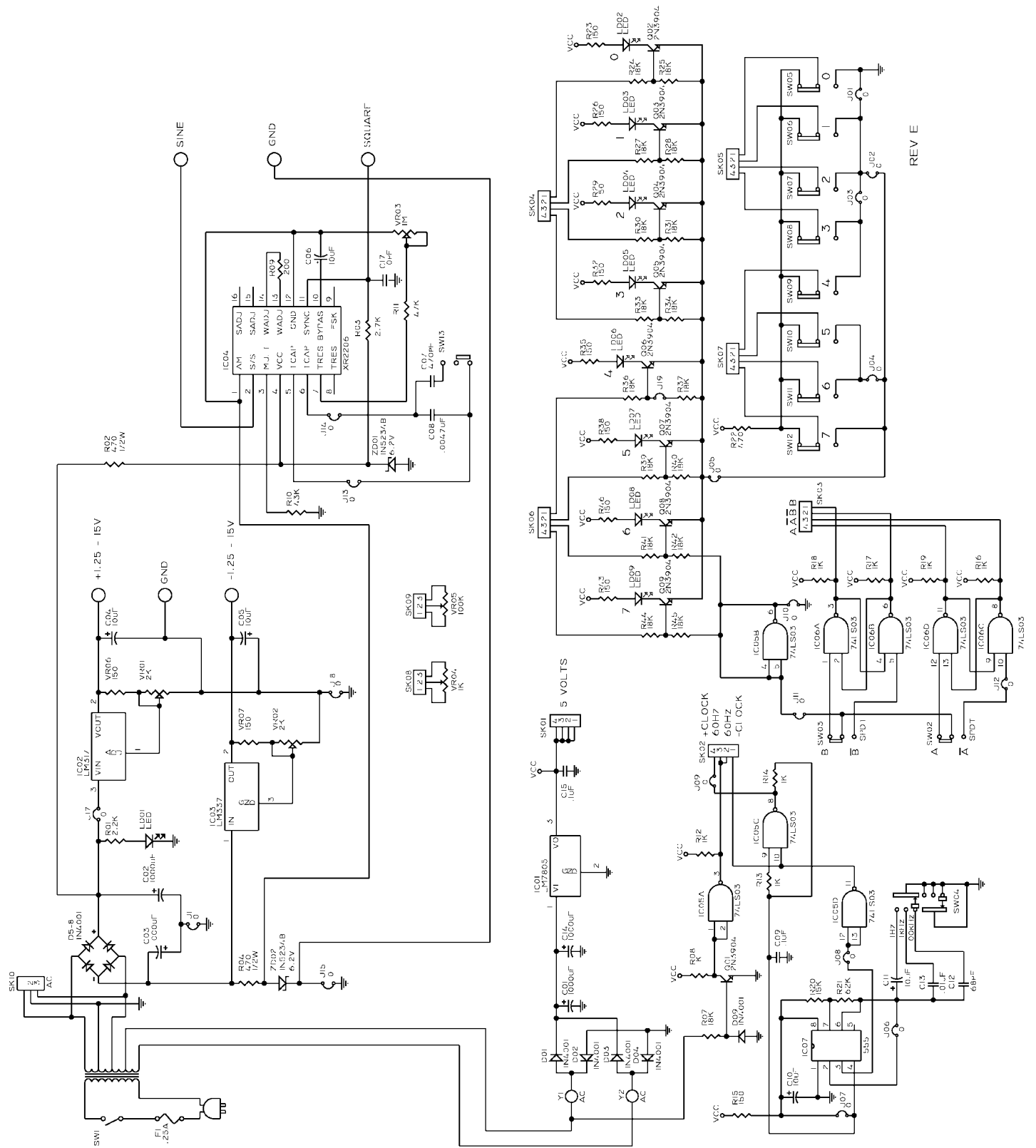
WARRANTY POLICY

Your XK-150 Digital / Analog Trainer has been tested and conforms to our rigid requirements on performance and durability. It is guaranteed to be free of defects in workmanship, materials and construction for a period of 2 years. If this product should fail during normal use within the first 3 months from the date of purchase, Elenco will repair or replace the unit at no cost. For the remainder of the warranty period, a nominal service charge is required to cover shipping and handling.

When returning merchandise for repair, please include proof of purchase, a brief letter of explanation of problem and sufficient packing material. Before returning any merchandise, please call our service department at (847) 541-3800 to obtain a return authorization number (RA).

Elenco Electronics, Inc. Service Department
150 W. Carpenter Avenue Wheeling, IL 60090

SCHEMATIC DIAGRAM



REV E



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