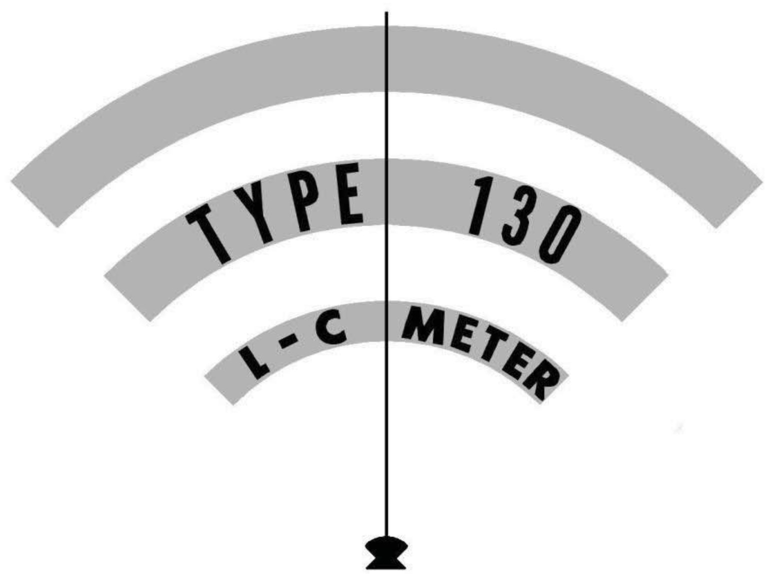
INSTRUCTION MANUAL

TYPE 130 L-C METER

MANUFACTURERS OF CATHODE-RAY OSCILLOSCOPES

INSTRUCTION MANUAL



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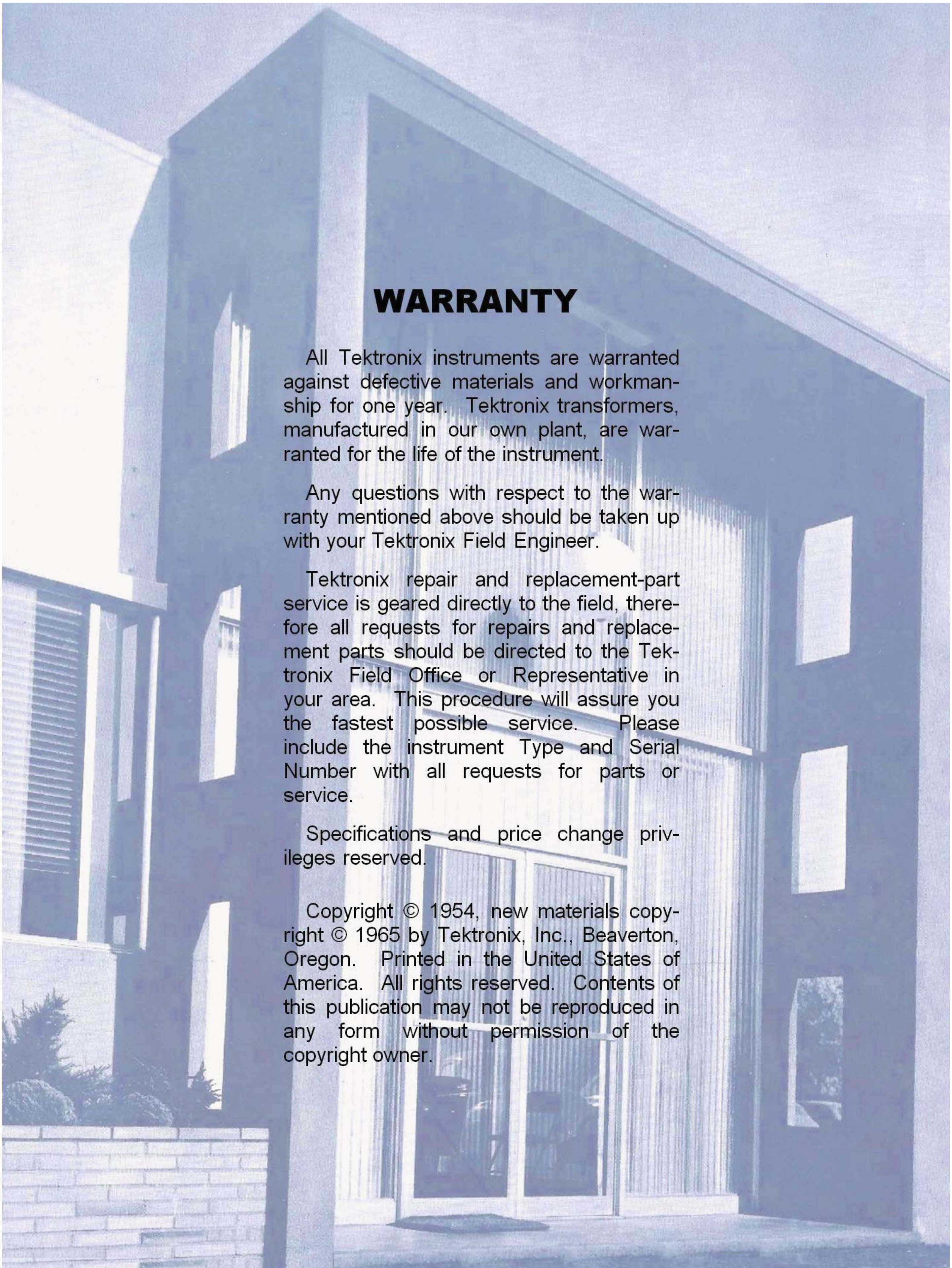


WARRANTY

All Tektronix instruments are warranted against defective materials and workmanship for one year. Tektronix transformers, manufactured in our own plant, are warranted for the life of the instrument.

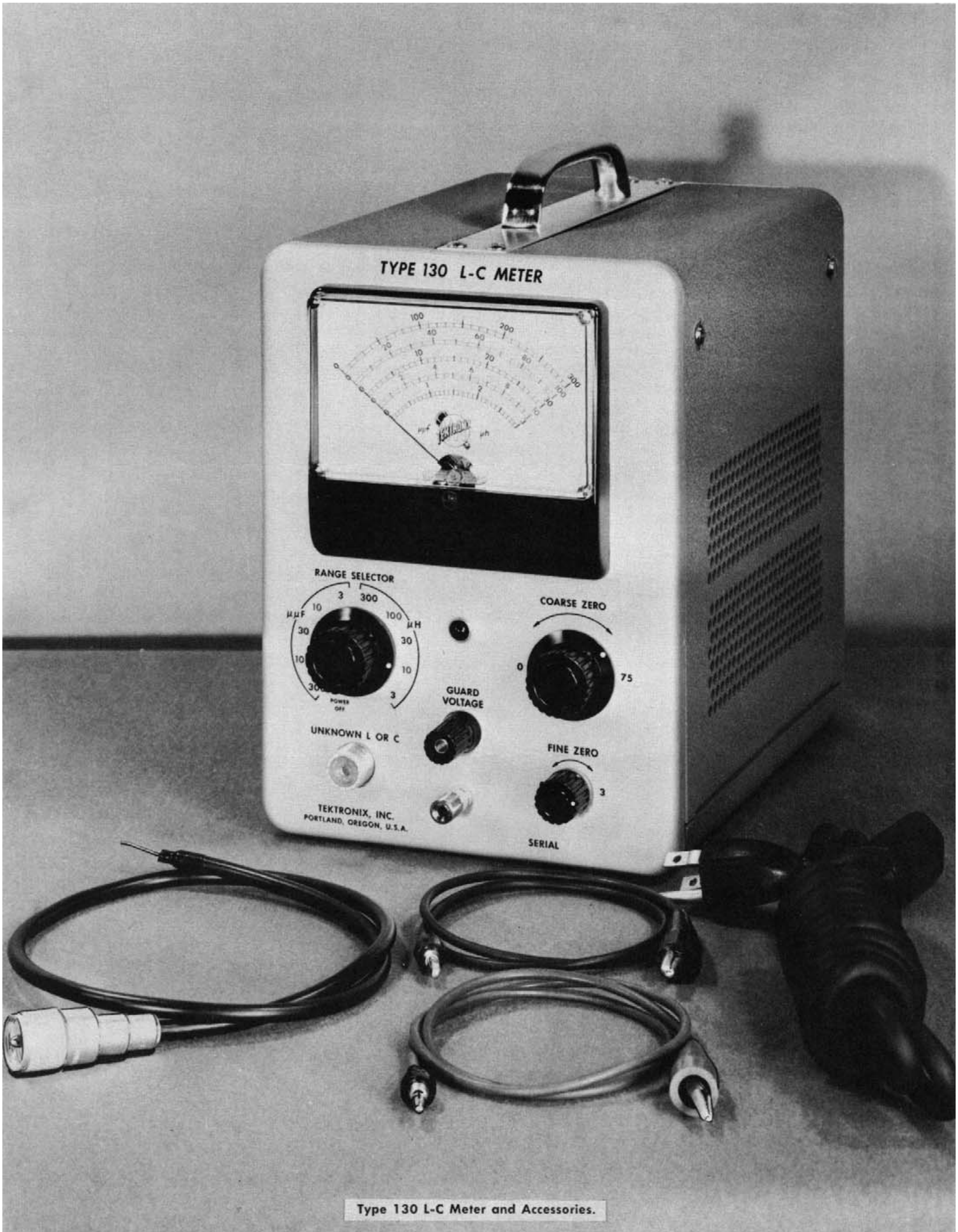
Any questions with respect to the warranty mentioned above should be taken up with your Tektronix Field Engineer.

Tektronix repair and replacement-part service is geared directly to the field, therefore all requests for repairs and replacement parts should be directed to the Tektronix Field Office or Representative in your area. This procedure will assure you the fastest possible service. Please include the instrument Type and Serial Number with all requests for parts or service.

Specifications and price change privileges reserved.

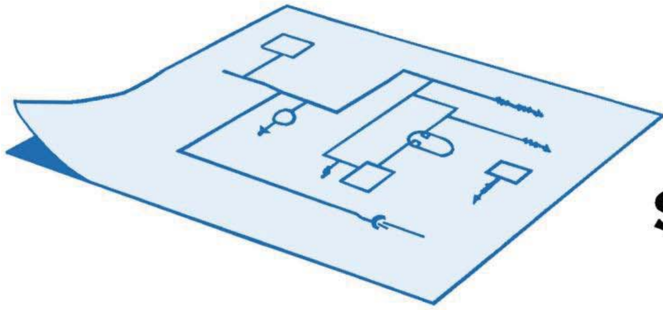
CONTENTS

A list of abbreviations and symbols used in this manual will be found at the beginning of the Parts List and Diagrams section. Change information is included in the Parts List and the Circuit Diagram.



Type 130 L-C Meter and Accessories.

SECTION 1



SPECIFICATIONS

General

The Tektronix Type 130 L-C Meter indicates inductance and capacitance directly on a calibrated meter, and includes a guard-voltage circuit for separating the stray capacitance of nearby conducting materials. The meter is designed for rapid measurements of small inductances and capacitances where possible errors of the order of 5 per cent are permissible.

This meter directly reads accurate inductance and parallel capacitance. To insure accurate measurements of series capacitance and shunt inductance, a graph is included for interpolating the correct figures from the known meter reading. The accuracy of the graph is decreased somewhat for shunt inductance.

Uses

The Type 130 is particularly useful in circuit development for such uses as measuring components already in place in the circuit, for sorting components , for measuring vacuum-tube direct interelectrode capacitances and so forth.

Method of Operation

The instrument operates by measuring the change in frequency the unknown reactance causes when it is added to an oscillator tank circuit. The amount of change in frequency is measured by a direct-indicating electronic counter that counts the frequency difference between a fixed oscillator and the oscillator affected by the reactance. With zero reactance added, the two oscillators zero beat and the counter reads zero.

Indicator

The electronic counter produces a deflection on a direct-current meter calibrated in capacitance and inductance. A rotary switch makes the meter more sensitive for lower counts and less sensitive for higher counts to provide five ranges of capacitance and five of inductance.

Guard Voltage

Any oscillator current flowing into a capacitance affects the oscillator frequency. But current flowing into a capacitance from the guard-voltage does not, because this circuit is isolated from the frequency-determining part of the oscillator. The guard-voltage circuit can keep stray capacitance from drawing oscillator current by driving the strays at exactly the same instantaneous voltage as the capacitance being measured. Since no oscillator current will then flow from the capacitance being measured into the stray capacitance, the meter reds only the desired capacitance.

Probe

The probe at the end of a two-foot insulated shielded cable provides a means for measuring reactances wherever they are in a circuit. The zero adjustments can set the meter to read zero with or without the 30-μμf probe-cable capacitance so the meter reads directly.

Electrical Characteristics

Indicating Meter—D'Arsonval, 200-microamp movement.

Meter Ranges—All five scales begin at zero. Full-scale readings are 3, 10, 30, 100 and 300 microhenries or micromicrofarads. Minimum scale division, 0.1 microhenry or micromicrofarad.

Accuracy—within 3 per cent of full scale. The reset-ability is excellent. By calibrating with the type S-30 Delta Standard, the accuracy at full scale will be about 1 per cent.

Voltage Across Unknown—The instrument places an ac voltage across the unknown, 1 volt maximum across a capacitance, ¼-volt maximum across an inductance with frequency between 124 and 140 kc.

Maximum Permissible Load Resistance—The following loads will not appreciably alter the indication:

Capacitance, 0.1 megohm shunt.

Inductance, 20 kilohms shunt, 10 ohms series.

A table included in this instruction manual (in Operating Instruction Section) provides corrections for increased loads.

Guard-Voltage Output Impedance—A cathode follower with internal impedance of 250 ohms can safely drive 200 μμf.

Power Requirements—105 to 125 and 210 to 250 volts, 50 to 60 cycles ac. A voltage regulator keeps the instrument accurate over this voltage range. Power consumption 40 watts at 117 or 234 volts.

Physical Characteristics—Size, 6¾" wide by 9½" high by $9\frac{3}{8}$" deep. Weight, 9 lbs. Construction, welded aluminium alloy with blue-wrinkle baked enamel cabinet and photo-etched anodized aluminium panel.

Accessories

1 P93C probe (010-003)

1 W130R lead (012-015)

1 3-conductor power cord (161-008)

1 W130B lead (012-014)

2 Instruction Manuals

Functions of Controls and Connectors

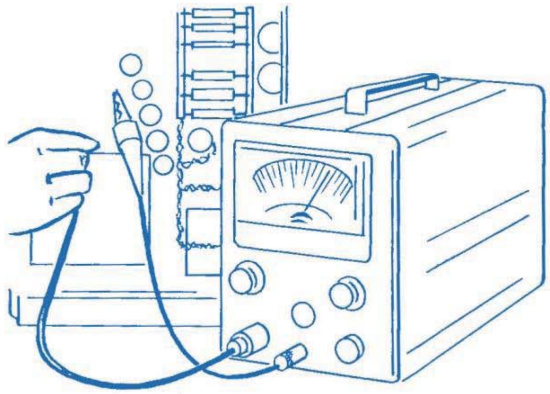
RANGE SELECTOR Eleven-position switch turns off ac power in one position and selects fives ranges of capacitance and five of inductance in the remaining 10 positions.

COARSE ZERO Adjustable capacitor sets the variable oscillator to the fixed-oscillator frequency to accommodate inclusion of the probe capacitance or other incidental capacitance. .

FINE ZERO Adjustable capacitor with one-twenty-fifth the range of the above control for accurately setting zero.

UNKNOWN L OR C UHF (SO-239) coax connector through selector switch to oscillator circuit.

GUARD VOLTAGE Binding post provides ac voltage through cathode follower equal to oscillator voltage but isolated from frequency-determining portion of oscillator. For removing effects of stray capacitances from measurements.



SECTION 2

OPERATING INSTRUCTIONS

General

No special operating precautions are necessary. The instrument will withstand the usual amount of shock and vibration that a meter movement can take, and any ambient temperature the operator is likely to tolerate.

First-Time Operation

Connect the power cord to a 117-volt 60 cycle source and connect the probe plug to the UNKNOWN uhf connector. Set the RANGE SELECTOR to 100$\mu\mu$f. The ac power switch energizes the pilot light, which indicates that the instrument is getting power. Connect a ground lead between the TYPE 130 and one end of the capacitance that you want to measure.

Centre the FINE ZERO control with the index up, and adjust the COARSE ZERO control so the meter reads zero. Keep the index line above horizontal. Do not be concerned if the meter goes off scale at any time. The maximum possible current through the meter movement is safe for any settings of the controls. Let the instrument warm up for a minute or two so that it can become stabilized.

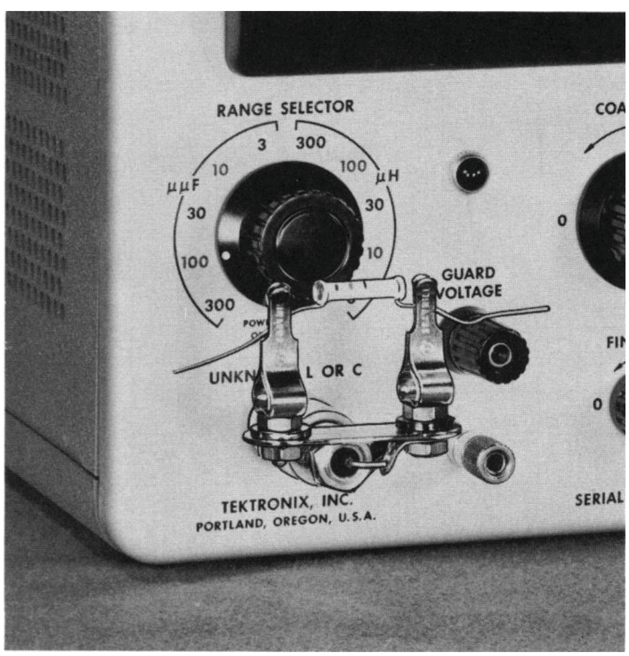


Fig. 2-1. Capacitance measurement using Production Test Fixture.

Capacitance Measurement

First set the meter accurately on zero with the capacitance disconnected. You can connect the capacitance you want to measure either directly at the instrument panel or at the end of the probe. Tektronix Type F30 Production Test Fixture (013-001) is an accessory that can be obtained for measuring inductance and capacitance directly at the instrument panel. It speeds sorting and testing of capacitors and inductors. The probe cable introduces an additional 30$\mu\mu$f which the COARSE ZERO can easily compensate. Set the COARSE ZERO control with the SELECTOR on 100 or 300 $\mu\mu$f and then switch to 3 or 10 $\mu\mu$f to set the FINE ZERO.

The meter needle will follow the beats below 10 cycles so you will have am accurate zero setting when the needle is at zero and not vibrating.

The percentage accuracy and resolution are better on the upper parts of the scales so you should shift to the next lower range where possible.

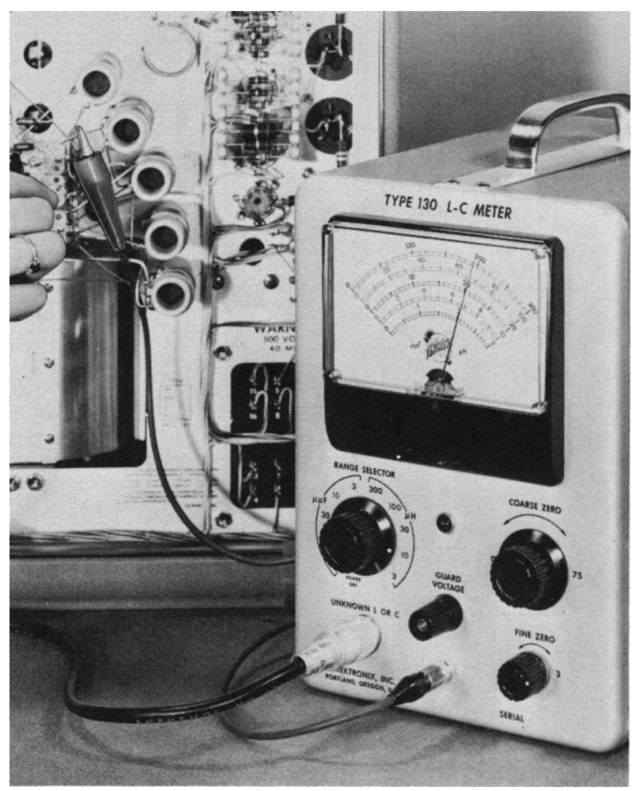


Fig. 2-2. Using the Type 130 L-C Meter to check inductance in a circuit.

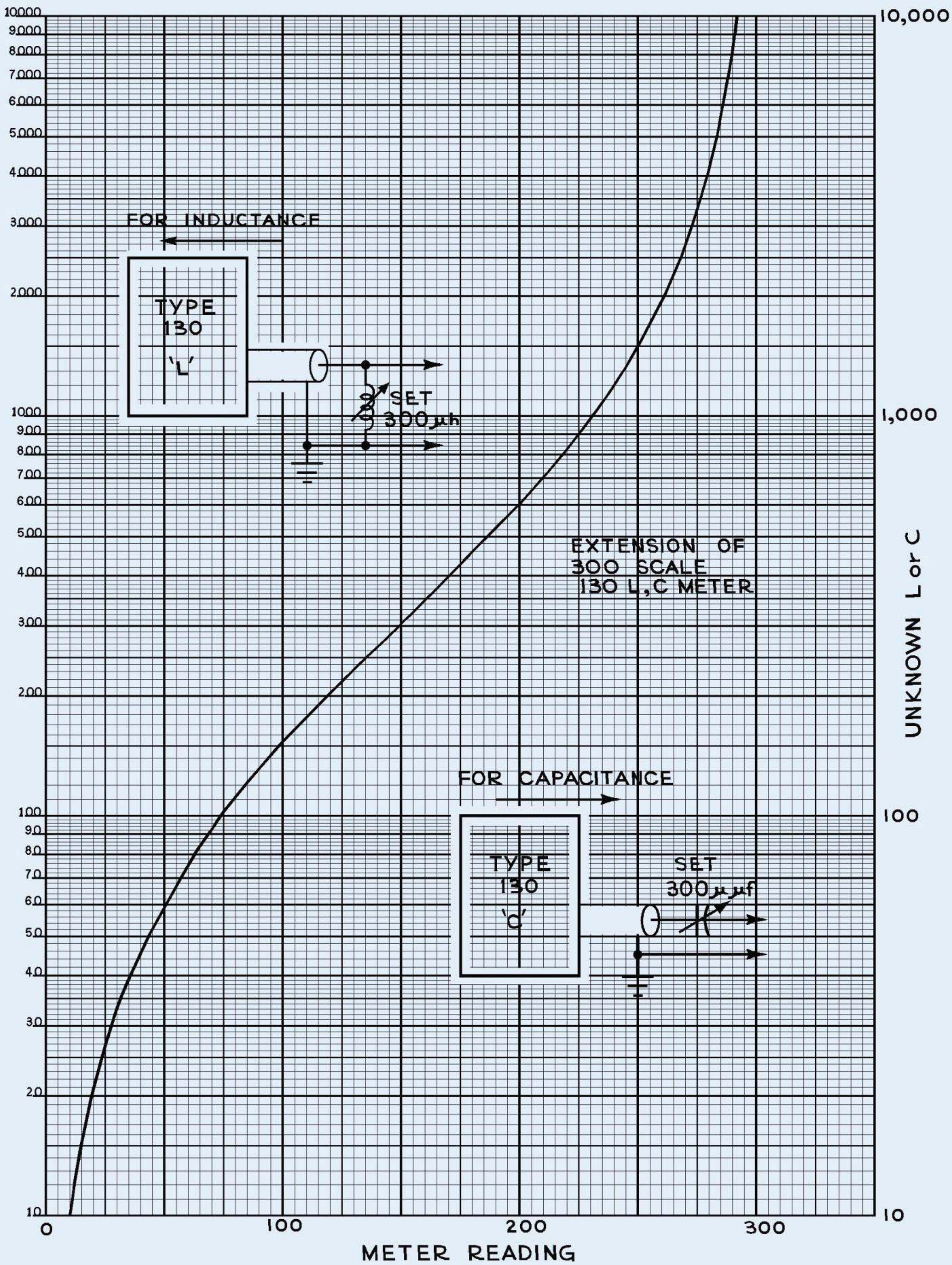


Fig. 2-3. Shunt inductance and series capacitance correction curve.

Inductance Measurements

Set the ZERO controls with the UNKNOWN terminal short circuited and the SELECTOR set to one of the five positions at the right marked μh. Set ZERO by the same adjustment technique you use for capacitance, using the 3-μH setting while setting the FINE ZERO control.

Guard Voltage

The purpose of the guard voltage is for measuring capacitances not isolated from other capacitances, such as vacuum-tube interelectrode capacitance, or the capacitance between switch points on a selector switch, or between terminals on a terminal strip.

The guard voltage drives the capacitance you want to exclude from the measurement, so connect the GUARD VOLTAGE terminal to all elements whose capacitance you want to exclude from the measurements and then make the capacitance measurement as usual. The driving impedance of the guard voltage is about 250 ohms. It can safely drive 200 μμf without appreciably affecting a measurement, or a shunt resistance to 50 kilohms.

For example, to measure the plate-to-grid capacitance of a pentode, ground the grid, connect the plate to the UNKNOWN terminal and connect the cathode, screen, suppressor, and shield to the GUARD VOLTAGE terminal. With this arrangement the cathode, screen, suppressor, and shield will stay at the same instantaneous ac voltage as the plate, and will not contribute to the meter reading.

As another example, consider the output capacitance of the pentode. This measurement should exclude the grid-to-plate capacitance. Connect the grid to the GUARD VOLTAGE circuit and ground the screen, suppressor, cathode and shield. The grid-to-plate capacitance will not be included in the measurement.

Small Reactances

Warm-up drift after a minute or so will not appreciably affect readings on the three highest scales but may be of consequence on the 0-3 μh or μμf scales. Let the Type 130 warm up for 10 to 15 minutes so it will have minimum drift for best accuracy when you use these scales.

For small capacitances or inductances in the order of 0.2 μμf or μh, where you use the 0-3 scales, the needle of the indicator will vibrate (about 62 cps/μμf). The vibrating needle is hard to read accurately, so a better way to measure smaller values is to preset zero reactance at 1.0 on the scale. You then subtract 1.0 from the readings. Be sure to turn the ZERO control clockwise and keep the index mark above horizontal when you advance the meter needle.

Large Reactances

The useful range of the Type 130 can be extended up to essentially 10,000 μμf or 10,0000 μh. Accuracy of the range extension is within 15% up to 1500 μμf or 15000 μh.

To extend the capacitance range, simply add an accurate 300 μμf capacitor in series with the unknown. To extend the inductance range, add an accurate 300 μh inductor in parallel with the unknown. Use Fig. 2-3 to obtain the value of the unknown.

An accurate 300 μμf capacitor can be obtained by setting the Type 130 RANGE SELECTOR to 300 μμf, connect a 270 μμf fixed, and a 5 to 25 μμf variable capacitor (in parallel) to the unknown L or C terminals. Adjust the variable capacitor for full scale reading. Then, place the large unknown in series with the new 300 μμf capacitor and read the meter. Fig. 2-3 will give you the value of the unknown.

An accurate 300 μh inductor can be made using a variable unit adjusted for full scale meter reading with the RANGE SELECTOR switch at 300 μh. Leave the inductor in place, the meter reading at full scale, and connect the unknown inductor across the new 300 μh inductor and read the meter. Fig. 2-3 will give you the value of the unknown.

Suppressed Zero

Comparisons between large capacitors can be made more accurately by setting the zero off scale to the left, and using a lower scale. Actually, the indicator never goes below zero. It rises again on scale as the oscillator goes through zero beat and on above the fixed oscillator. However, when you raise the frequency of the variable oscillator above the fixed oscillator in order to develop frequency difference to make the meter indicate, you operate the oscillator over an uncalibrated range. For this reason you cannot simply read the meter to see how far you have suppressed zero.

To use the suppressed-zero method therefore, you must first accurately determine the size of the capacitance that suppresses the zero, and then add this amount of capacitance to the meter indication you get.

You may use the suppressed zero method to determine the value of small capacitors more accurately than by reading their capacitance directly. For example, if you wish to make a more accurate determination of the value of a 12 μμf capacitor, first measure the value of a 10 μμf capacitor on the 10 μμf range. Make a notation of the exact value indicated. With the capacitor still connected to the instrument, zero the meter reading with the COARSE and FINE ZERO controls. Turn the RANGE SELECTOR to the 3 μμf range. Remove the first capacitor and connect the 12 μμf capacitor to the instrument. Adding this new reading to the notation already made will give you a more accurate reading of the capacitance than could be obtained by measuring it directly.

WARNING: Do not forget to zero the meter after completing the measurement.

Resistance-Loading Corrections

Add these corrections to the readings you get to increase accuracy or when there is more resistance loading than 10 ohms in series with an inductance, or 0.1 megohm shunt resistance. Interpolate between resistance and reactance values, if desired.

If you correct the zero reading in the presence of the loading, add the difference between the listed zero correction and the interpolated correction at the approximate inductance or capacitance you are measuring. Add the correction value when the sign is +, subtract when the sign is –.

Inductance with Series Resistance

Correction, μh

Series Resistance	At 0 μh	At 100 μH	At 300 μH
0 Ω	0.00	0.00	0.00
1 Ω	–0.06	–0.04	+0.03
2 Ω	–0.12	–0.08	+0.06
4 Ω	–0.18	–0.12	+0.18
6 Ω	–0.19	–0.11	+0.35
8 Ω	–0.15	–0.03	+0.55
10 Ω	–0.06	+0.10	+0.80
15 Ω	+0.37	+0.60	+1.66
20 Ω	+1.11	+1.40	+2.80
30 Ω	+3.60	+3.86	+6.08
40 Ω	+7.40	+7.90	+10.80

Precautions

Reactors much greater than 300 μμf or μh can cause erroneous readings. The counter circuit may be unable to follow the large difference in frequency that results, but still develop dc current that will put the meter on scale. The meter needle will flutter and be unstable and the COARSE ZERO adjustment will give erratic results to warn you to question the reading. Be sceptical of any reading you get if it is at all unstable.

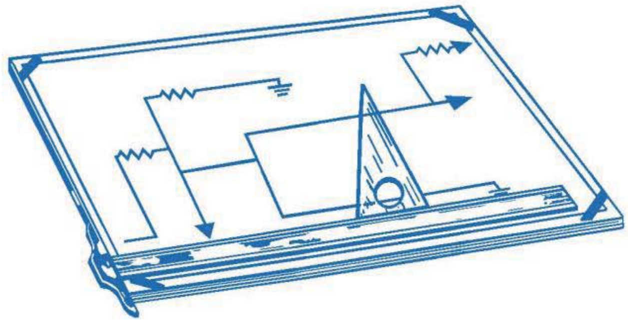
Be sure you raise the frequency of the oscillator when you suppress zero. You can be sure of this if turning ZERO control clockwise sends the needle toward zero, and the white index on the knob is up.

Capacitance with Parallel Resistance

Correction, μμf

Shunt Resistance	At 0 μμf	At 100 μμf	At 300 μμf
4 meg	–0.02	–0.01	+0.01
2 meg	–0.04	–0.02	+0.02
1 meg	–0.09	–0.04	+0.03
.5 meg	–0.13	–0.08	+0.10
300 k	–0.18	–0.06	+0.22
200 k	–0.20	–0.01	+0.39
150 k	–0.18	+0.08	+0.56
100 k	–0.08	+0.36	+1.14
80 k	+0.09	+0.60	+1.64
60 k	+0.06	+1.45	+2.70
50 k	+1.15	+2.15	+3.68
40 k	+2.20	+3.35	+5.40
30 k	+4.70	+6.05	+9.00

Do not suppress zero for inductance measurements, and do not compensate for large residual inductance with the ZERO adjustment. Additional inductance in the oscillator circuit changes the amount of total capacitance required to cause the meter to read zero, and therefore affects the scale accuracy. If there is unavoidable residual inductance in a measurement, measure the residual and subtract it from the total inductance you measure. Correction of 10 μh of residual inductance by the ZERO controls will cause noticeable error in the inductance reading.



SECTION 3

CIRCUIT DESCRIPTION

Variable Oscillator

V4 is the variable-oscillator tube, with T1, C2, C3, C4, C5 and the unknown in the tuned circuit. Feedback from the plate of the pentode section of V4 is coupled to its grid through the triode section, which is connected as a cathode follower. The output signal of the pentode is such as to drive the cathode follower below cutoff except during positive peaks, so that the cathode current consists of pulses. The pulses are fed back to a winding on the oscillator transformer, T1, through C10.

Screen current for the pentode is the cathode current for the cathode follower, filtered by means of R10, C11. This arrangement stabilizes the operating point of the pentode plate, which in turn determines the average current of the cathode follower. For example, if the average plate voltage becomes too high it will raise the cathode-follower grid and cathode voltage, which will raise the pentode screen. The increased pentode plate current returns the pentode plate back down toward its original level.

The phase of the pentode plate voltage can be adjusted by means of C7 so that the feed-back signal will be in phase with the tuned-circuit voltage. When this adjustment is properly made, reduction in Q of the tuned circuit, caused by resistance components in the unknown, will not appreciably affect the oscillator frequency for effective shunt resistance of 100 kilohms or higher. (10 ohms series resistance for inductance.)

When the selector switch is set for inductance measurement and no coil is connected, the grid of the oscillator is held toward positive by R6 and R14, which are connected to the plate supply, so that grid current flows. The resulting low grid-input impedance reduces the voltages coupled in to the grid through stray capacitances on the grid lead, and so reduces any tendency for the circuit to oscillate spuriously. Oscillator input to the mixer, V60, is coupled through buffer V15A.

The selector switch, sections A and B, arranges the oscillator tuned circuit so that the UNKNOWN terminal either shunts the tuned circuit for capacitance measurements, or is in series with the tuned circuit inductance for inductance measurements.

Guard-Voltage Circuit

V110 is a cathode follower whose gain is slightly less than one. The voltage at its grid is increased over the voltage at the UNKNOWN terminal by a small additive winding on T1. The additional voltage is just enough to make up for the slight voltage loss in the cathode follower, so that the GUARD VOLTAGE output voltage is equal to the UNKNOWN terminal voltage. Voltage divider R122, R113, sets the dc grid voltage at about +50 volts so that about 5 ma of cathode current flows. The output impedance with this amount of cathode current is about 250 ohms.

Fixed Oscillator

V30 is the fixed oscillator that can be adjusted to 140 kc by means of the powered-iron tuning slug in T30. The circuit is similar to the variable oscillator circuit, but without the feedback phase adjustment. V45A is the buffer amplifier.

Buffer Amplifiers

V15A and V45A are the buffer amplifiers that reduce the coupling between the two oscillators. When two oscillators couple to each other, they tend to pull together to a common frequency when their natural frequencies are nearly the same, and actually lock together at the same frequency with enough coupling. The two buffer amplifiers reduce the coupling so that there is no lock-in above about one cycle per second, and the pull-in produces no error above about three cycles per second. Output from the buffers has approximately sawtooth waveform because of the high-resistance plate loads.

Mixer

V60 is the mixer. The purpose of the mixer is to produce an output at the frequency difference between the two oscillators. Higher frequency output components of the mixer are reduced by a low-pass rc filter with C61, C62, c^3, and R61, R62. The 124- to 140-kc carrier components are additionally reduced by a bridge-T rejection filter with R64, C64, and C65. The output dc level of the filter is adjustable by means of R68, labelled ADJ. 1.

Multivibrator

V70 is a multivibrator that generates a square pulse for each cycle of the difference frequency. The square wave is practically symmetrical, regardless of the frequency, when the ADJ. 1 control is properly set.

The multivibrator is arranged to shift rapidly from one stable state to a second stable state when the input grid goes past a transition point. For example when the B section of V70 is conducting its plate is down and divider R73, R72 between plate and ground hold the A-section grid below plate-current cutoff. The A-section plate will therefore be positive, and the common cathode voltage will be determined only by current through the B-section. If the B-section grid drops, its plate current will rise carrying the A-section grid more positive, and the common cathode voltage will drop placing the A-section grid-to-cathode bias nearer to conduction.

When the input grid drops far enough it reaches the transition point and the A section conducts thereby diverting some of the cathode current from the B section. The resulting positive signal at the plate further raises the A-section grid. C73 bypassing R73 improves the ac transmission so that a large positive signal reaches the grid and raises the cathode so high that the B section of V70 is cut off.

The plate of the A section generate a square pulse for each cycle. The positive level of the square pulse is determined by diode-connected V76B at about +150 volts. The bottom of the pulse is determined by cathode follower V76A. The grid voltage of this cathode follower determines the clipping level and provides a means of adjusting the meter sensitivity on the 300-*μ*h and *μμ*f ranges. The adjustment is labelled ADJ. 2 300.

Counter Circuit

The square pulses from the plate of multivibrator V70A are applied to the left-hand end of one of the capacitors, C90, C91, C92, C93 or C94, for example C90. Charge diode V15B holds the right-hand end of C90 at about +150 volts during the negative excursion while the multivibrator pulls down the left hand end to about +100 volts, thus charging C90 to about 50 volts.

During the positive excursion, the multivibrator raises the left-hand end of C90 to about +150 volts and the right-hand end thus goes above +150 volts toward +200 volts. This places the plate of diode V45B above its cathode so that it conducts and discharges C90 into the +150-volt bus through the indicating meter.

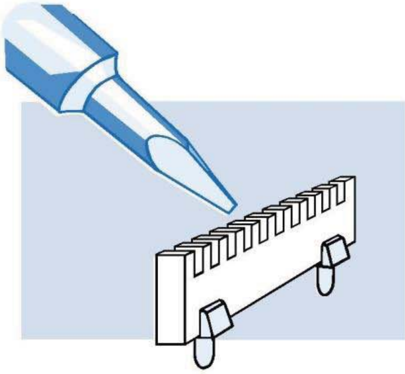
The capacitor always charges completely to the same voltage, so the current it discharges through the meter depends linearly on how many times it discharges per second and on the size of the capacitor. The range-selector switch selects the capacitor sizes in ratios of about 3 to provide ranges of 3, 10, 30, 100, and 300. The largest capacitor is used for the lowest range to increase the quantity of charge per cycle. Resistors R97, R98, R99 and R100 are adjustable shunts across the meter, selected by the range switch to provide individual sensitivity adjustment. The 300 range has no shunt and its sensitivity is adjusted by the negative-peak-clamper grid voltage.

Power Supply

DC power is furnished by a full-wave rectifier and capacitor filter. V403 is a voltage stabilizer that supplies the circuits likely to be affected by line-voltage variations. Heaters of all tubes are biased halfway between ground and +150 volts to reduce the heater-to-cathode voltage of several cathodes that operate at +150 volts.

The transformer primary has two equal 117-volt windings that are normally connected in parallel for 117-violt service. For 234-volt service, they can be connected in series.

The range selector switch opens the input to the primary in the OFF position.



SECTION 4

MAINTENANCE

Replacement of Components

Replacements for all parts in the Type 130 L-C Meter can be purchased directly from Tektronix at current prices. However, since most of the components are standard electronic and radio parts, they can be generally be obtained locally in less time than is required to obtain them from the factory. Before purchasing or ordering parts, be sure to consult the parts list to determine the tolerances and ratings required. The parts list gives the values, tolerances, ratings and Tektronix parts number for each component in the instrument.

In addition to the standard components, special parts are manufactured by Tektronix or manufactured by other companies to the Tektronix specifications. These parts and most mechanical parts should be obtained directly from Tektronix or the local Tektronix filed office, since they are difficult or impossible to obtain from other sources.

Parts Ordering Information

You will find a serial number in the frontispiece of this manual. This is the serial number of the instrument for which this manual was prepared. Be sure the manual number matches the number of the instrument when you order parts.

We make some of the changes in the instrument, the diagrams, parts list and manual to include the latest circuit improvements. The hand-made changes show changes that have been made after the printing of the manual.

Since production of your instrument, some of the parts may have been superceded by improved components. In such cases, the parts numbers will not be listed in your Parts List. However, if you order a part from Tektronix and it has been superceded by an improved component, the new part will be shipped in place of the part ordered. Your local Tektronix Filed Engineering Office has knowledge of these changes and may call you if a change in your purchase order is necessary. Replacement information sometimes accompanies the improved components to aid their installation.

When ordering parts, be sure to include both the description of the part and the 6-digit Tektronix part number found in the Parts List. For example, if the serial number of your Type 130 L-C Meter were 352, a certain capacitor would be ordered as follows: C30, .001 microfarad, fixed, mica, 500 v, 1 %, part number 283-526, for Type 130 L-C Meter, serial Number 351.

Trouble Shooting

If the instrument fails to operate and the pilot light does not light, check the source of ac power and see whether the connecting cord is firmly seated. Then check the .8-amp line fuse at the back of the instrument near the power plug. A good way to check the fuse is to replace it with a good one. The ac circuit to the power transformer is completed through the RANGE SELECTOR switch. Check the switch contacts. To make the check, you will need to remove the case.

Some cases have side panels held in place by small screwhead fasteners. To remove the panels, use a screwdriver to rotate the fasteners approximately two turns counterclockwise. Then pull the upper portion of the panels outward from the handle. Other cases do not have the side panel fasteners, but the whole case is removed. To remove this case, twist the slotted fastener, at the rear of the case, counter-clockwise and the case will come loose. Disconnect the power plug and you can then slide the instrument forward out of the case. Cases are replaced by reversing the order of their removal.

WARNING: The power supply furnishes 270 volts dc across a 30-*μf* capacitor, so be careful to avoid contact with it when the instrument is operating.

Troubles are usually caused by tube failure, and you can frequently correct them by simply finding the bad tube and replacing it with a good one. However, sometimes a bad tube burns resistors or overstresses capacitors when it fails, and in these cases you will also have to find the bad components. Sometimes you can find them by visual inspection.

Since troubles are usually caused by tube failure, be sure you investigate this possibility before adjusting the interior controls. One way to find bad tubes is to replace all the tubes with good ones. If this helps the troubles, try putting the old ones back, one at a time, until the bad tube is discovered.

Tube failure will often show up in the voltage readings of the power supply. So, another early step to take in looking for trouble is to check the dc voltages. The two supply voltages appear conveniently at the two ends of R403, a ceramic wire-wound resistor mounted behind the power transformer on the same side of the chassis (see Figure 5-3). The outside terminal should measure +150 volts ±5 volts and the terminal nearest the chassis should read approximately 270 volts, depending on the line voltage. There is no voltage adjustment, and if the voltages are off it is a sign of trouble elsewhere in the circuit. The +150 volt can be checked also at the check point indicated in Figure 5.2.

Total dc current from the rectifier should be about 40 ma, of which 21 ma goes to the circuits connected to the 150-volt bus and the remainder, about 20 ma, goes through the regulator tube, when the ac supply is at 115 volts. Current to other circuits connected to the 270-volt bus is but fraction of a milliampere.

You can check the indicating meter by connecting another milliameter across it. The meter is connected to the +150-volt bus, so be careful not to get a terminal grounded.

The variable oscillator may be checked for operation by connecting an oscilloscope to the GUARD VOLTAGE terminal. The guard voltage will be about one volt peak-to-peak at 124 to 140 kc. The fixed oscillator can be checked at point 6 of V45. These points can also be checked with an ac voltmeter capable of reading a fraction of a volt at 140 kc.

This is a fairly complex electronic device and there is no simple way to find troubles. With a good understanding of the circuits you will be able to make a good guess at the source of the trouble from the symptoms. Be sure that any difficulty you are having does not come from the settings of the front panel controls.

Soldering and Ceramic Strips

Many of the components in your Tektronix instrument are mounted on ceramic terminal strips. The notches in these strips are lined with silver alloy. Repeated use of excessive heat, or use of ordinary tin-lead solder will break down the silver-to-ceramic bond. Occasional use of tin-lead solder will not break the bond if excessive heat is not applied.

If you are responsible for the maintenance of a large number of Tektronix instruments, or if you contemplate frequent parts changes, we recommend that you keep on hand a stock of solder containing about 3% silver. This type of solder is used frequently in printed circuitry and should be readily available from radio-supply houses. If you prefer, you can order the solder directly from Tektronix in one-pound rolls. Order by Tektronix part number 251-514.

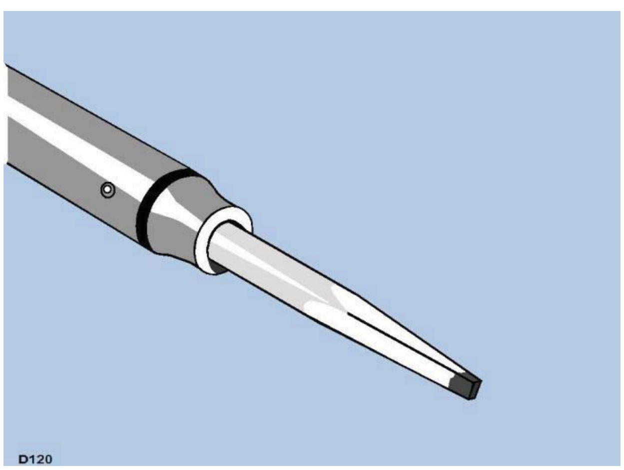


Fig. 4-1. Soldering tip preparation.

Because of the shape of the terminals on the ceramic strips it is advisable to use a wedge-shaped tip on your soldering iron when you are installing or removing parts from the strips. Fig. 4-1 will show you the correct shape for the tip of the soldering iron. Be sure and file smooth all surfaces of the iron which will be tinned. This prevents solder from building up on rough spots where it will quickly oxidize.

When removing or replacing components mounted on the ceramic strips you will find that satisfactory results are obtained if you proceed in the manner outlines below.

1. Use a soldering iron of about 75-watt rating.
2. Prepare the tip of the iron as shown in Fig. 4-1.
3. Tin only the first 1/16 or 1/8 inch of the tip. For soldering to ceramic terminal strips tin the iron with solder containing about 3% silver.
4. Apply one corner of the tip to the notch where you wish to solder (see Fig. 4-2).
5. Apply only enough heat to make the solder flow freely.
6. Do not attempt to fill the notch on the strip with solder; instead, apply only enough solder to cover the wires adequately, and to form a slight fillet on the wire as shown in Fig. 4-3.

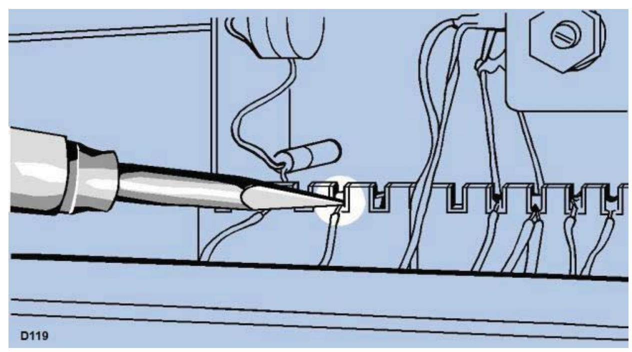


Fig. 4-2. Applying iron tip to strip.

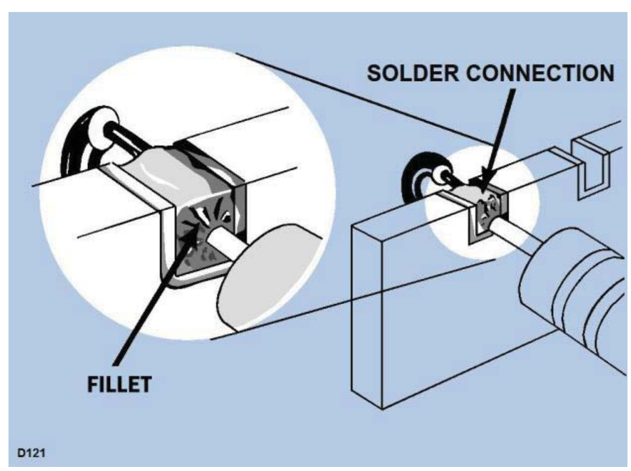


Fig. 4-3. Fillet on wire.

In soldering to metal terminals (for example, pins on a tube socket) a slightly different technique should be employed Prepare the iron as outlined above , but tin with ordinary tin-lead solder. Apply the iron to the part to be soldered as shown in Fig. 4-4. Use only enough heat to allow the solder to flow freely along the wire so that a slight fillet will be formed as shown in Fig. 4-3.

General Soldering Considerations

When replacing wires in terminal slots clip the ends neatly as close to the solder joint as possible. In clipping the ends of wires take care the end removed does not fly across the room as it is clipped.

Occasionally you will wish to hold a bare wire in place as it is being soldered. A handy device for this purpose is a short length of wooden dowel, with one end shaped as shown in Fig. 4-5. In soldering to terminal pins mounted in plastic rods it is necessary to use some form of “heat sink” to avoid melting the plastic. A pair of log-nosed pliers (see Fig 4-6) makes a convenient tool for this purpose.

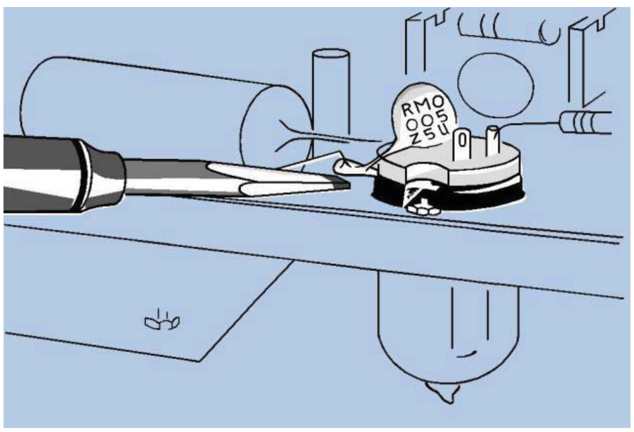


Fig. 4-4. Soldering to metal terminals.

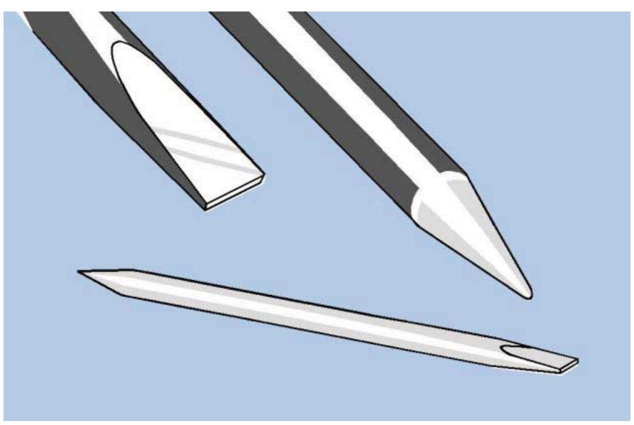


Fig. 4-5. Wooden dowel.

Ceramic Strips

Two distinct types of ceramic strips have been used in Tektronix instruments. The earlier type mounted on the chassis by means of #4-40 bolts and nuts. The later type is mounted with snap-in plastic fittings. Both styles are shown in Fig. 4-7.

To replace ceramic strips which bolt to the chassis, screw a #4-40 nut onto each mounting bolt, positioning the bolt so that the distance between the bottom of the bolt and the

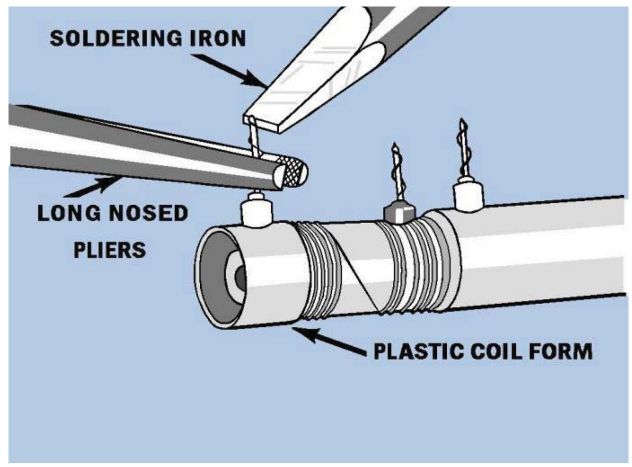


Fig. 4-6. Long-nosed pliers as “heat sink”.

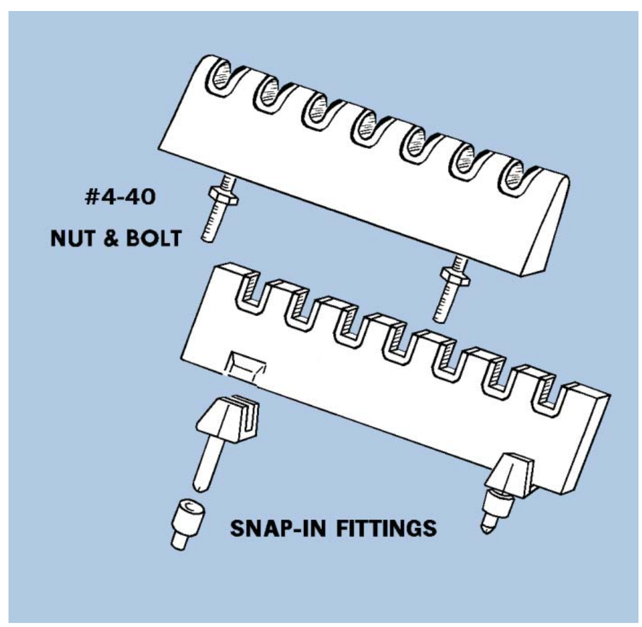


Fig. 4-7. Ceramic strips and fittings.

bottom of the ceramic strip equals the height at which you wish to mount the strip above the chassis. Secure the nuts to the bolts with a drop of red glyptal. Insert the bolts through the holes in the chassis where the original strip was mounted, placing a #4-40 lockwasher between each nut and the chassis. Place a second set of #4040 lockwashers on the protruding ends of the bolts, and fasten them firmly with another set of #4-40 nuts. Place a drop of red glyptal over each of the second set of nuts after fastening.

To replace ceramic strips which mount with snap-in plastic fittings, first remove the original fittings from the chassis. Assemble the mounting post on the ceramic strip. Insert the nylon collar into the mounting holes in the chassis. Carefully force the mounting posts into the nylon collars. Snip off the portion of the mounting post which protrude below the nylon collar on the reverse side of the chassis.

Note: Considerable force may be necessary to push the mounting rods into the nylon collars. Be sure that you apply this force to the upper ends of the mounting rods rather than to the ceramic strip.

Cleaning

You will find that the time spent in properly cleaning an instrument will result in fewer calibration problems, a longer period between calibrations and greater operator satisfaction with both the instrument and the service centre.

Dry cleaning can be accomplished as follows. With the side, top, and bottom panels removed, compressed air and a small paint brush will remove most of the interior dust, unless the instrument has been in a greasy environment or been affected by cigarette smoke.

To clean the front panel you should reinstall the side, top, and bottom covers and lightly spray the front panel only, using a 5% Kelite solution and rinsing with water. Be careful not to get excess water in the instrument. Just a little spray applied on an angle works best.

Use a toothbrush and detergent to clean the knobs and connectors, and rinse with warm water. The side covers can be removed and, along with the bottom and top panels, be washed separately. They should be placed in an oven to dry. Compressed air is used to remove as much water as practicable from the front panel area, and the instrument is then placed in the oven for 15 to 20 minutes, or until you are ready to work on it.

Precautions against spraying detergent and water directly on the power transformer should be diligently observed. Cleaning agents such as trichloroethylene, Freon, and other containing halogens, should not be used. They can damage aluminium electrolytic capacitors and some other materials.

Lubrication

Anytime the instrument is cleaned, the components should be completely lubricated as outlined in this section.

At the time of recalibration, the instrument should be inspected for signs of components needing lubrication. It's usually good practice to lubricate exposed switch detent mechanisms at this time. Other components may also need attention, depending on the instrument's condition and use.

Components requiring lubrication often show up in the form of mechanical or electrical noise, such as unstable readings. This section covers the components that may require attention.

Figure 4-8 will acquaint you with some of the parts of a rotary switch. These will be referred to in describing the lubrication procedures.

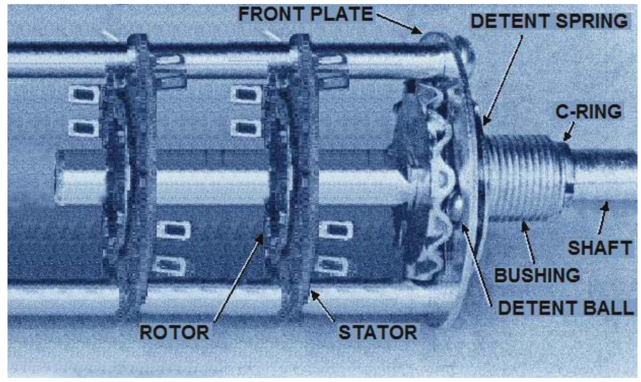


Fig. 4-8. Type F rotary switch components.

1. Lubricating Switch Mechanism

Apply DETENT LUBRICATING GREASE liberally between ball and index wheel.

Apply WD-40 to shaft at front of bushing. This is best done at the point where the ends of the "C" ring meet. Wipe away the excess.

2. Lubricating Switch Wafers

Contact lubrication will help to reduce electrical noise and extend switch life. However, care should be exercised not to over lubricate this part of the switch, as excess oil will tend to hold dust particles that can be detrimental to switch performance. If the interior of an instrument contains dust or other foreign material, it is desirable that it be cleaned as described in this manual prior to switch lubrication.

There are a half dozen or more insulating materials commonly used in rotary switches assembled in Tektronix instruments. All may be lubricated in the same manner without resulting detrimental effects, if the NO NOISE contact restorer-lubricant is used according to the following applicable suggestions and procedures.

The nozzle extension tube provided with each can of NO NOISE should be used to direct this fluid when applying it to rotary switches. To free switch contacting surfaces of resistive oxides and at the same time amply lubricate them, spray onto each switch wafer side having contact clips, a quantity of NO NOISE that will wet the rotor blade and ends of clips. Immediately rotate the switch from stop to stop, to distribute the volatile vehicle before it evaporates. By so doing, an invisible film of protective lubricating oil is left on the contacting surfaces after vehicle evaporation.

When applying NO NOISE as just described, direct the spray toward wafer from two opposite angles. Spraying should preferably be done from each side of the switch onto the same side of each wafer, to improve application to inner surfaces of rotor blades. When wetting the switch wafer with this contact restorer, spray surfaces until they appear wet, but not until they drip with excess fluid. Blot any excess immediately with clean soft cloth.

Detent Ball Replacement

Detent mechanisms of the “non-captive: type have, on occasion, “dropped the ball”. This usually occurs because of a dry or poorly lubricated mechanism. The Type F switch uses a 5/32 inch ball.

Missing detent balls should be replaced by removing the “C” ring at the front of the bushing. This relieves the tension on the spring, allowing the ballot be clipped in place. If you are extremely careful, you can, in many cases, replace the ball by prying the spring back with a soldering iron or scriber. Care must be taken or the detent spring will be bent, lessening the tension required for normal detent action.

Lubricating Potentiometers

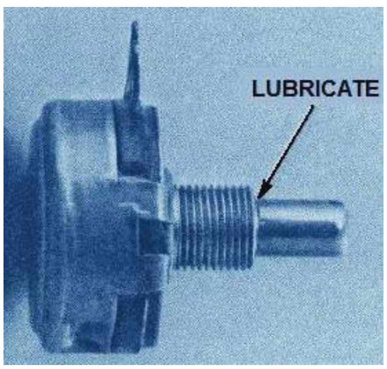
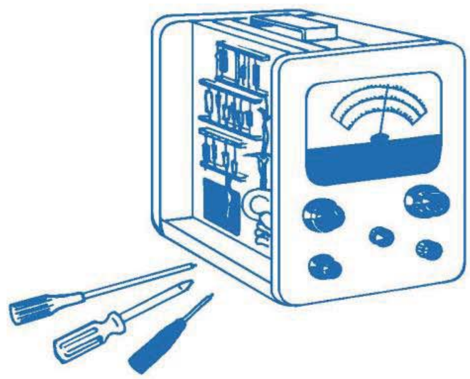


Fig. 4-9. Commercial Potentiometer Lubrication.

Lubricate the pot shaft at the front of the bushing, using WD-40.



SECTION 5

CALIBRATION PROCEDURE

Ordinarily you will not need to calibrate this instrument except after tube replacement, and then the calibration required will be less extensive than the calibration procedure which follows. If in doubt as to the effect of an adjustment you wish to make we suggest that you run through the complete calibration procedure.

Equipment Required

The following equipment is necessary for a complete calibration of the Type 130 L-C Meter:

(1.) Tektronix Type S-30 Delta Standards and connectors.

(2.) DC voltmeter.

(3.) Either an accurate frequency meter, such as a Type LM-13 or Type BC-221, or a local broadcasting station with an exact harmonic of 140 kc.

(4.) Low-Capacitance Calibration tools: See Figure 5.1.

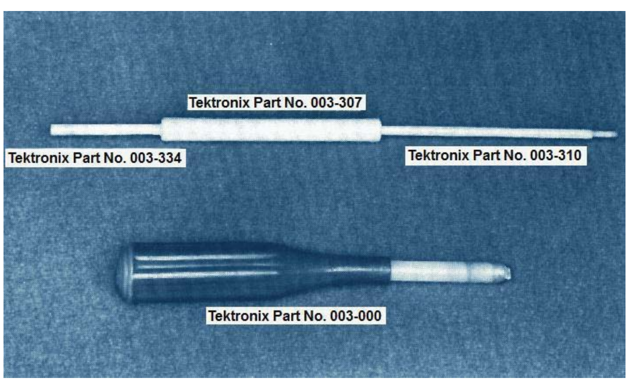


Fig. 5.1. Suggested Calibration Tools.

Adjustment Procedure

Remove side panels of L-C Meter. Zero adjust meter with screwdriver. Check power supply at check point (see Figure 5-3) for +150 volts ±5 volts. There is a 21 ma load plus 14 ma shunted through the regulator V402.

1. Fixed-Oscillator Frequency, T30 slug

The fixed oscillator should be set to a frequency of 140 kc ±½ kc by one of the following methods:

(a.) Measure the frequency by comparing a Type BC-221 or a Type LM-13 with the signal from the fixed oscillator at the FIXED OSCILLATOR CHECK POINT (R47), as shown in Fig. 5-3. Frequency adjustment is made with the slug in the top of the inductor T30 (see Figure 5-4).

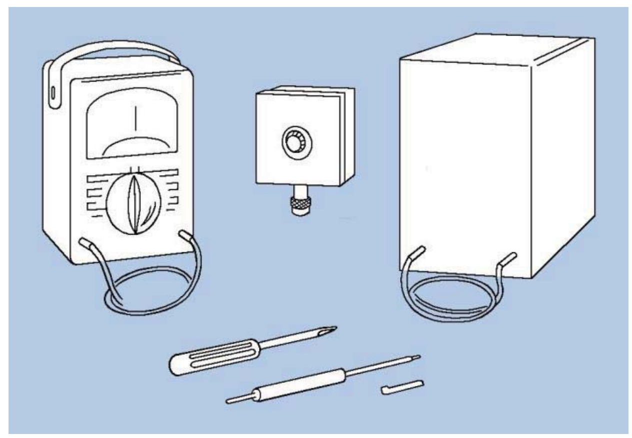


Fig. 5.2. Equipment needed for calibration of Type 130 L-C Meter.

(b.) An accurate source of 140-kc signal is connected to the UNKNOWN jack. The peak-to-peak value of the signal should be at least one-half volt. The internal impedance of the source should range between 100 ohm and 1000 ohm. Turn the RANGE SELECTOR switch to 300 $\mu\mu$f and note the deflection on the front panel meter. Adjust the slug on T30 until the deflection is zero. For more precise adjustment, turn the RANGE SELECTOR switch to 10 $\mu\mu$f or to the 3 $\mu\mu$f position and zero the meter deflection using T30.

(c.) If a local broadcast station has a harmonic of 140 kc, the fixed oscillator may be set to zero beat with a station frequency for the correct harmonic. For example, the fixed oscillator can be adjusted by checking the fifth harmonic against a station having a frequency of 700 kc.

2. Variable-Oscillator Frequency

Set the COARSE ZERO control about 10 degrees above right horizontal, and the FINE ZERO control at full capacitance index horizontal to the right. Set the internal screwdriver control, C2 (see Figure 503), at mid range, slot vertical. C2 is mounted on the FINE ZERO capacitor.

Set the variable oscillator also to 140 kc by adjusting the tuning slug in T1 (Figure 5-4). The variable –oscillator signal appears at the GUARD VOLTAGE terminal, and the VARIABLE OSCILLATOR CHECK POINT (C17), Fig. 5-3.

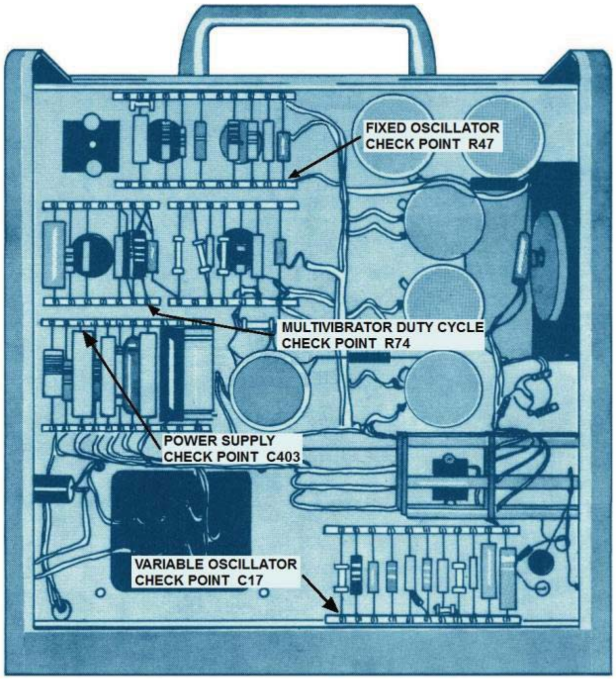


Fig. 5.3. Left side view showing test points.

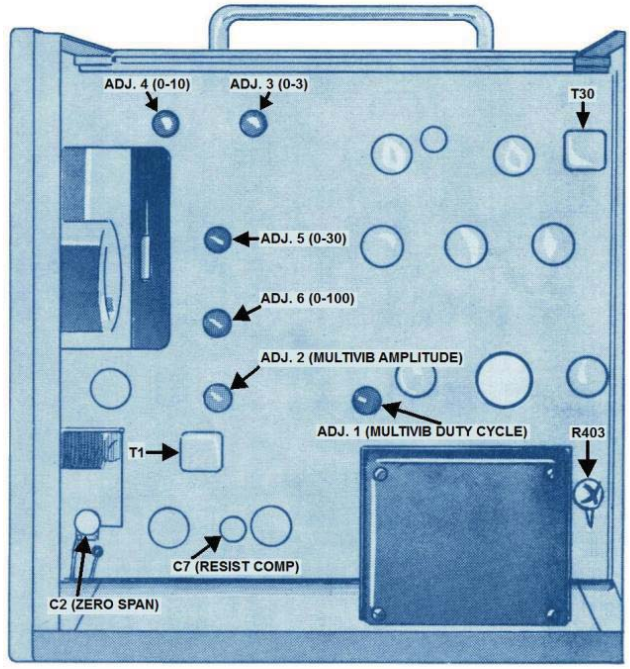


Fig. 5.4. Right side view showing calibration control points.

3. Multivibrator Duty Cycle, R68, ADJ. 1

Connect the Type S-30 Delta Standards to the UNKNOWN connector. Using the COARSE ZERO and Fine ZERO controls, set the L-C Meter accurately to zero indication with the S-30 at 0 $\mu\mu$f, and then switch both units to 300 $\mu\mu$F.

Without making any other changes, turn the ADJ. 1 control hard right and measure the voltage at the MULTIVIBRATOR DUTY CYCLE CHECK POINT (R74) with a DC voltmeter (see Figure 5-3). Carefully note the voltage reading, which should be around 155 volts.

Then, turn the ADJ. 1 control hard left and again measure the voltage at the MULTIVIBRATOR DUTY CYCLE CHECK POINT, and carefully note the reading, which should be around 105 volts.

Turn the ADJ. 1 control back until the voltage rises to midway between the two readings (i.e., around 130 volts). This will indicate that the duty cycle is 50%.

4. Multivibrator Amplitude, R78, ADJ. 2

With S-30 set to 0 $\mu\mu$f, recheck that the L-C Meter accurately reads zero.

Switch both units back to 300 $\mu\mu$f, and turn ADJ. 2 (see Figure 5-4) so that the indicating meter reads 300 $\mu\mu$f.

5. LC Balance, T1 slug

Set the S-30 to SHORT CIRCUIT and the L-C Meter to 3 μh. Now carefully adjust the L-C Meter to zero with the front panel controls.

Switch the S-30 to 300 μh and the L-C Meter to the 300 μh range. Carefully read the amount of error. Leaving all other controls as they are, adjust the tuning slug in T1 to increase the amount of error by a factor of three.

Repeat steps 4 and 5 until the L-C Meter reads both 300 $\mu\mu$f and 300 μH without error.

6. Resistance Compensator, C7

With the S-30 at 0 $\mu\mu$f, set the L-C Meter ZERO controls to get about a half-scale reading on the 10 $\mu\mu$f range. Set teh S-30 to 1 megohm and adjust the ZERO control so the meter deflection indicates an even scale division. Switch the S-30 to 100 kilohm and see if there is any change in teh deflection. If there is a change, adjust the RESIST. COMP. Control, (see Figure 5-3), so the deflection is the same as for the 1-megohm position and repeat a time or two.

If you cannot find a satisfactory adjustment, try a new tube for V4, and try the procedure again. Tubes that cannot be compensated by adjustment of C7 will drift in frequency when the line voltage changes.

7. 0-3 Range, ADJ. 3, R100

Set the S-30 to 0 $\mu\mu$f and the L-C Meter to 3 $\mu\mu$f. Carefully set the FINE ZERO control for zero deflection.

Then set the S-30 to +3 $\mu\mu$f and set the ADJ. 3 pot, R100, (see Figure 5-4), so that the indicating meter reads accurately at full scale.

Now set the S-30 to –3 $\mu\mu$f and check to see if the meter still reads full scale. If not, adjust the FINE ZERO so meter is at full scale.

Reset the S-30 to +3 $\mu\mu$f and reset ADJ. 3 if necessary for full scale reading.

This procedure minimizes a small error in zero setting that may occur in the case that the zero is off due to lock in of the two oscillators.

8. 0-10 Range, ADJ. 4, R99

Set the S-30 to 10 $\mu\mu$f and the L-C Meter to 10 $\mu\mu$f. Set the ADJ. 4 control so that the indicating meter reads full scale.

9. 0-30 Range, ADJ. 4, R98

Set the S-30 to 30 μμf and the L-C Meter to 30 μμf. Set the ADJ. 5 control (see Figure 5-4) so that the indicating meter reads full scale.

10. 0-100 Range, ADJ. 4, R97

Set the S-30 to 100 μμf and the L-C Meter to 100 μμf. Set the ADJ. 5 control (see Figure 5-4) so that the indicating meter reads full scale.

11. Zero Control Span, C2

Remove the S-30 and UHF coupling from the L-C Meter. Set the COARSE ZERO and FINE ZERO controls so that they are fully meshed. Check behind the panel to be positive that the meshing is absolutely completed. Set the RANGE SELECTOR to the 10 μμf position and adjust C2, (see Figure 5-3) so the meter reads 7.5.

Check whether the meter can be made to read zero with a small rotation to the left of the COARSE ZERO control.

12. Check the accuracy of the Guard Voltage

With no external devices or leads connected to the UNKNOWN connector, set the RANGE SELECTOR to the 3 μμf range.

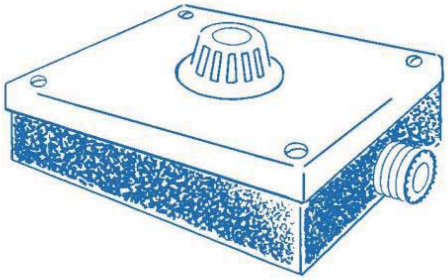
Adjust the ZERO control so the meter reads at mid scale of 1.5 μμf.

Now touch the centre of the UNKNOWN connector with the tip of the finger and note which way the meter deflects.

Next, hold a 100 μμf, ±5% capacitor in a pair of plastic tongs or other insulator, so as to avoid body capacity effects, touching one lead to the centre of the UNKNOWN connector, and the other lead to the GUARD VOLTAGE terminal. If the meter deflects in the same direction as when touched with the finger, GUARD VOLTAGE is low.

The deflection should be less than ½ μμf. If out of tolerance, try changing V110. If this does not correct it, change R112 to 2.7 or 3.3 meg. To bring it in. If the meter deflects in the opposite direction as when touched with the finger, teh guard voltage is high, however, the meter deflection tolerance on the high side is + 1 μμf.

NOTES



SECTION 6

DELTA STANDARD

Fig. 6.1. The S-30 Delta Standards.

The S-30 Delta Standards provides a means for calibrating the Type 130 L-C Meter. The accuracy of the S-30 is ±1% or better on all ranges.

The S-30 provides seven calibrated capacitance ranges, two precision resistors, and one standard inductance of 300 µH at 140 kc.

Equipment Required for Calibration of Delta Standards

A commercial impedance bridge with tolerances of ± one quarter of one percent for capacitance, and one per cent for inductance.

Inductance Standardizer, to be constructed from the following specification in the circuit diagram preceding all sections on the S-30 Delta Standards. The value of the capacitor and resistor must be within 2% of those shown. Figure 6-2 is a pictorial representation of the completed Inductance Standardizer.

Operation

Only the stray capacitance of the connector and switch assembly is in the circuit in the –3 *µµ*fd position. The actual capacitance of these strays is approximately 10 to 20 *µµ*fd. No effort is made to standardize this value. As the switch is rotated, capacitors are switched into the circuit to provide a change (or "Delta") of capacitance as indicated. In the 0 *µµ*fd position, an additional 3 *µµ*fd has been added in addition to the strays.

Calibration of Capacitance Ranges

Calibration of the capacitance ranges is possible with most commercial bridges. The procedure is to measure the capacitance of the S-30 in the –3 *µµ*fd position, then switch to the 0 *µµ*fd position and determine if the "Delta" change is 3 *µµ*fd ±1%. Adjustment of C-2 will be necessary if not within tolerance. Continue to switch to each range and measure the capacitance, adjusting the trimmer as indicated in Table I to give the correct "Delta" changes.

TABLE I

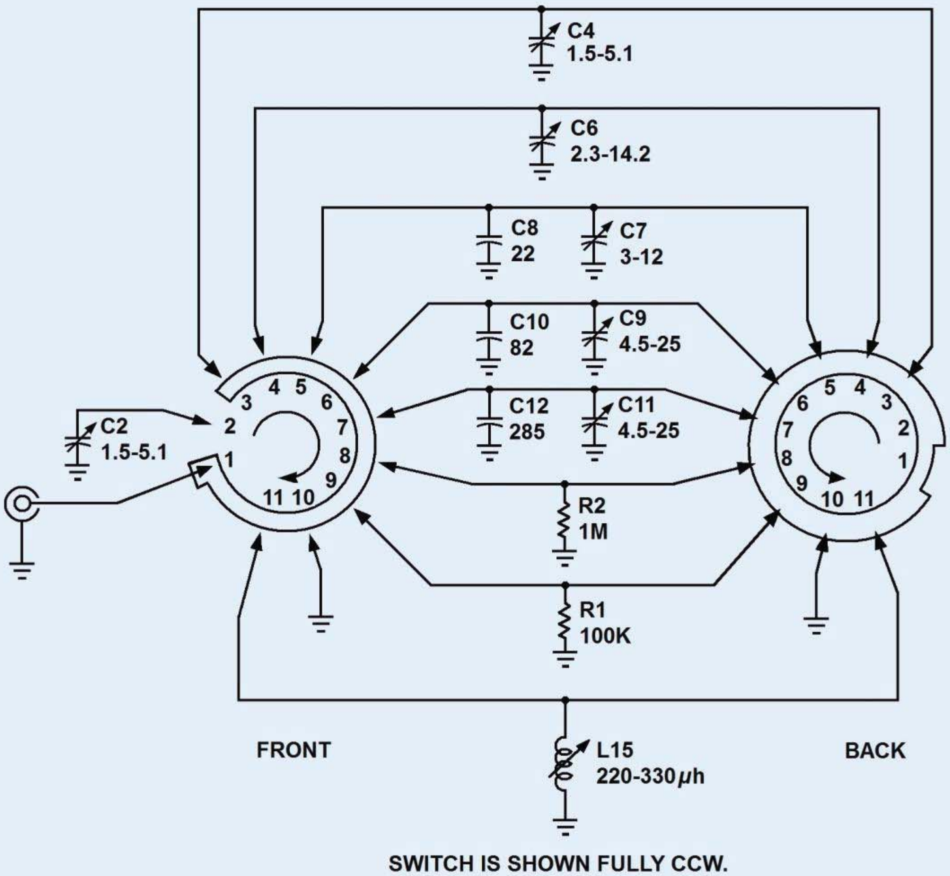
Switch position	Typical Value	Adjustment
–3 *µµ*fd	13 *µµ*fd	None
0 *µµ*fd	16 *µµ*fd	C-2
+3 *µµ*fd	19 *µµ*fd	C-4
+10 *µµ*fd	26 *µµ*fd	C-6
+30 *µµ*fd	46 *µµ*fd	C-7
+100 *µµ*fd	116 *µµ*fd	C-9
+300 *µµ*fd	316 *µµ*fd	C-11

Calibration of Resistance Ranges

Two precision resistors of identical manufacture are used ro standardize the resistance compensation. These can be checked for resistance value with any reliable bridge. If either resistor is out of tolerance, it is advisable to change both to maintain the balance of capacity, unless a resistor of similar manufacture is available.

Calibration of Inductance Range

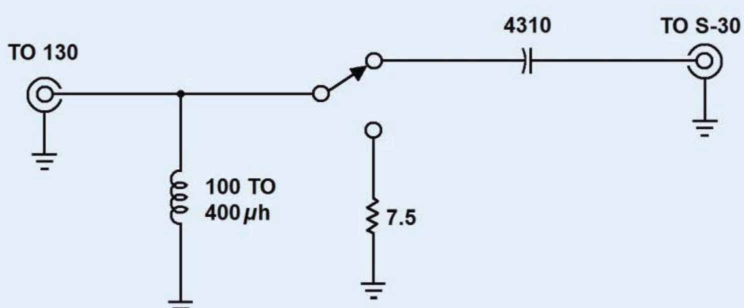
Standardization of the 300 *µ*H inductance is somewhat complicated since its value cannot be read directly with a "Bridge" type device, since these generally do not operate at 120–150 kc. Since L15 has a powdered iron core, its



SWITCH POSITIONS

1. −3 µµF
2. 0 µµF
3. +3 µµF
4. +10 µµF
5. +30 µµF
6. +100 µµF
7. +300 µµF
8. 1MEGΩ
9. 100KΩ
10. SHORT CIRCUIT
11. 300 µH

TYPE S-30 DELTA STANDARD



INDUCTANCE STANDARDIZER

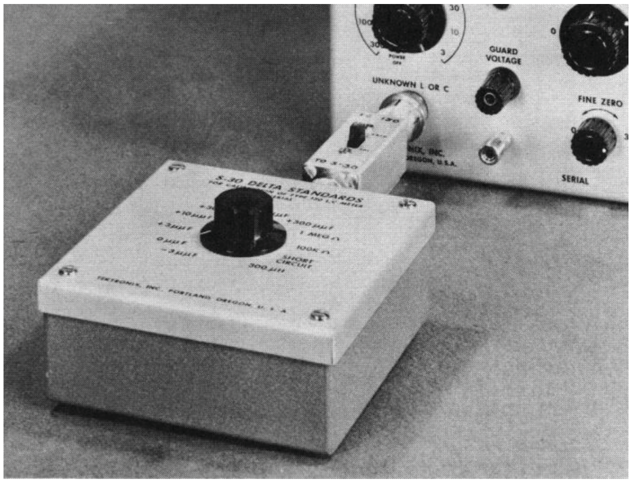


Fig. 6.2. The Type S-30 and the Type 130 L-C Meter connected with the Inductance Standardizer. .

inductance will not be the same at 1 kc or 1.59 kc. In addition, shunt capacitance across L15, representing about 1/3 or 1% of L15's admittance at 140 kc, will not have the same effect at typical bridge frequencies.

To calibrate the 300 μh range of the Type 130 construction of the Inductance Standardizer shown in Fig. 6-2 and in the circuit on page 6-2 is suggested. The value of the capacitor and resistor must be within 2% of those shown.

Connect the Type S-30, the Inductance Standardizer, and the Type 130 as shown in Fig. 6-2. Place the switch of the Type 130 in the 300 μh position. Depress the switch on the Inductance Standardizer. With the COARSE and FINE ZERO controls bring the meter reading of the Type 130 to 0.

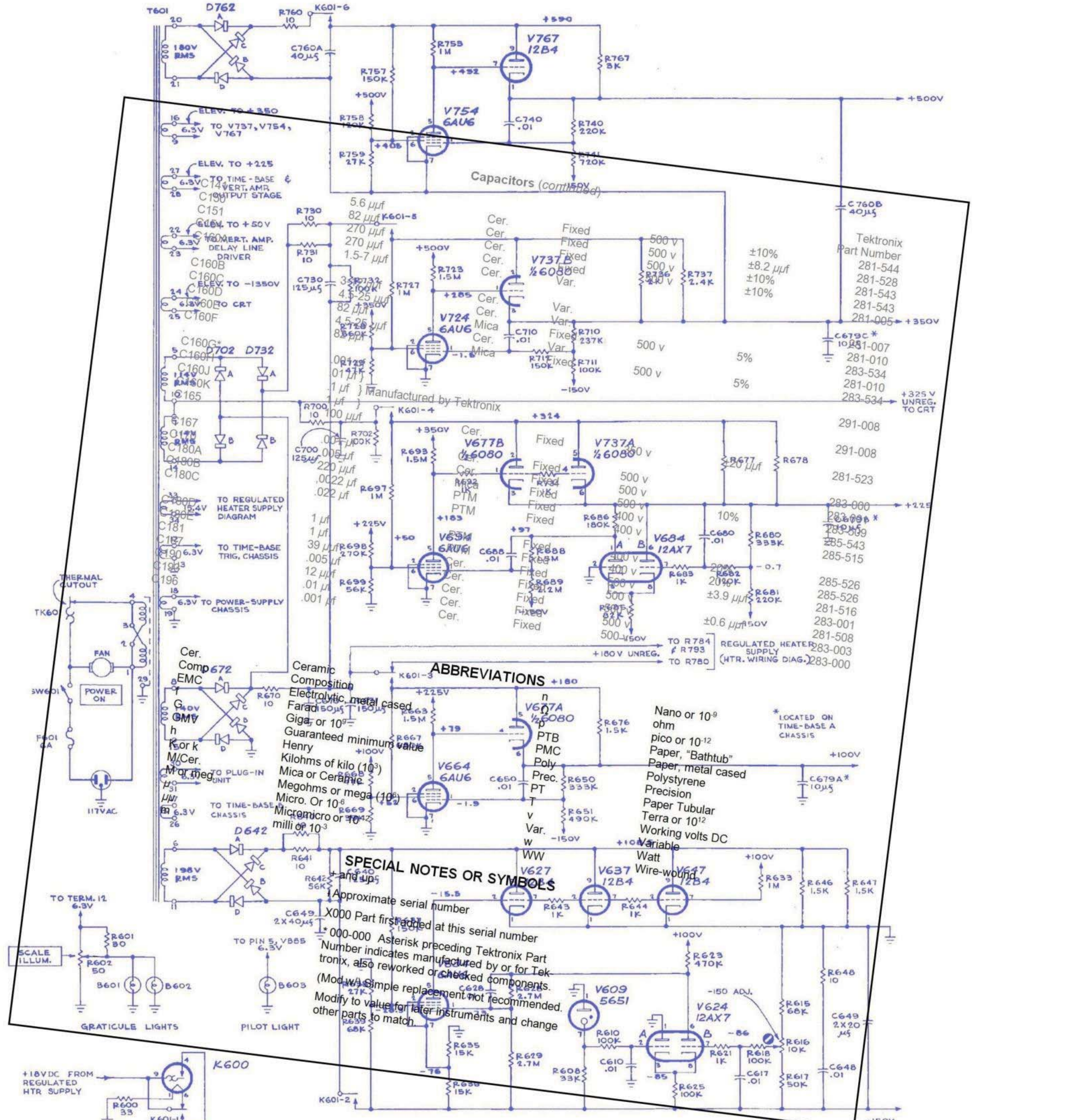
With the switch depressed, the 100-400 μh coil is parallel resonant with the internal capacity of the 130 LC Meter, and the 7.5 Ω resistor replaces the DC resistance of the 300 μh coil in the S-30.

Release the shorting switch on the Inductance Standardizer and adjust L15 in the S-30 until the Type 130 Meter reading is brought back to 0.

The 4310 μμF capacitor in the Inductance Standardizer is series resonant with the 300 μh coil in the S-30 at 140 kc, and the 130 sees only the 7.5 Ω resistance of the coil.

Replace the outer case of the Type S-30.

PARTS LIST *and* DIAGRAMS



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POWER SUPPLY

MANUFACTURERS OF CATHODE-RAY OSCILLOSCOPES

HOW TO ORDER PARTS

Replacement parts may be purchased at current net prices from your local Tektronix Field Office or from the factory. Most of the parts can be obtained locally. All of the structural parts, and those parts noted in the parts list "Manufactured by Tektronix", should be ordered from Tektronix.

When ordering from Tektronix include a complete description of the part, and its 6-digit part number. Give the type, serial number, and modification number (if any) of the instrument for which it is ordered.

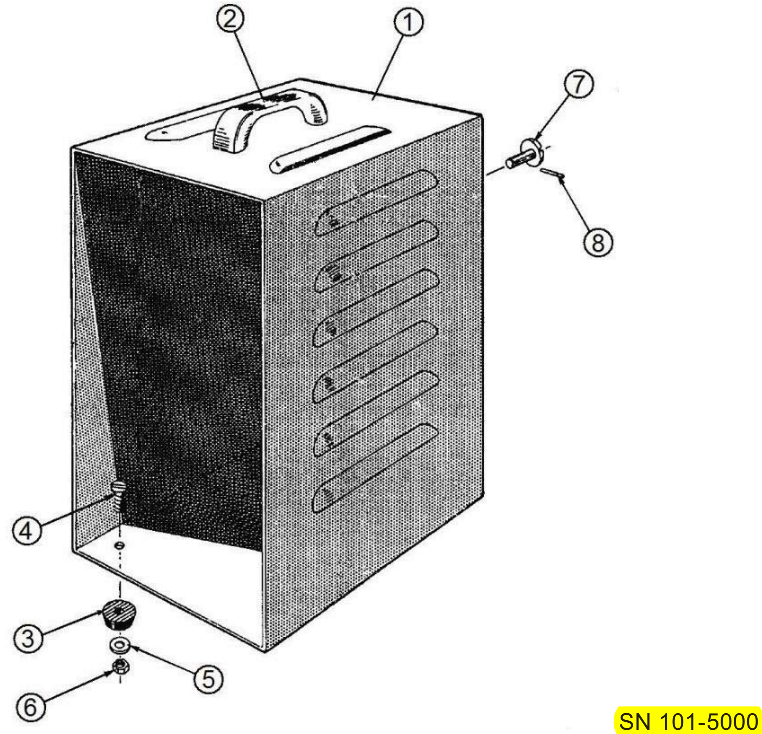
If the part which you have ordered has been replaced by a new or improved part, the new part will be shipped instead. Tektronix Field Engineers are informed of such changes. Where necessary replacement information comes with new parts.

PARTS LIST ABBREVIATIONS

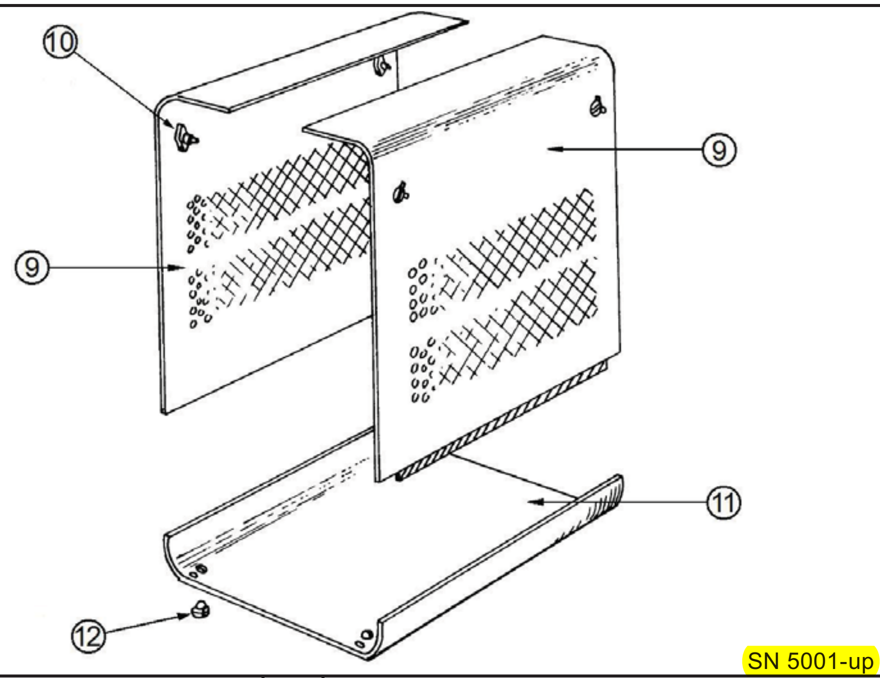
BHB	binding head brass	keps	shaKEProof (nut w/- free-spinning washer)
BHS	binding head steel	lg	length or long
cap.	capacitor	met.	Metal
cer.	Ceramic	mtg hdw	mounting hardware
comp.	Composition	OD	outside diameter
conn	connector	OHB	oval head brass
CRT	cathode-ray tube	OHS	oval head screw
csk	countersunk	P/O	part of
DE	double end	PHB	pan head brass
dia	diameter	PHS	pan head steel
div	division	plstc	plastic
elect.	electrolytic	PMC	paper, metal cased
EMC	electrolytic, metal cased	poly	polystyrene
EMT	electrolytic, metal tubular	prec	precision
ext	external	PT	paper, tubular
F & I	focus and intensity	PTM	paper or plastic, tubular, molded
FHB	flat head brass	RHB	round head brass
FHS	flat head steel	RHS	round head steel
Fil HB	fillister head brass	SE	single end
Fil HS	fillister head steel	sems	screw pre-asSEMbled with Star washer
GMV	guaranteed minimum value	SN or S/N	serial number
h	height or high	S or SW	switch
hex.	Hexagonal	TC	temperature compensated
HHB	hex head brass	THB	truss head brass
HHS	hex head steel	thk	thick
HSB	hex socket brass	THS	truss head steel
HSS	hex socket steel	tub.	Tubular
ID	inside diameter	var	variable
Inc	incandescent	w	wide or width
int	interna	WW	wire-wound l

MECHANICAL PARTS LIST

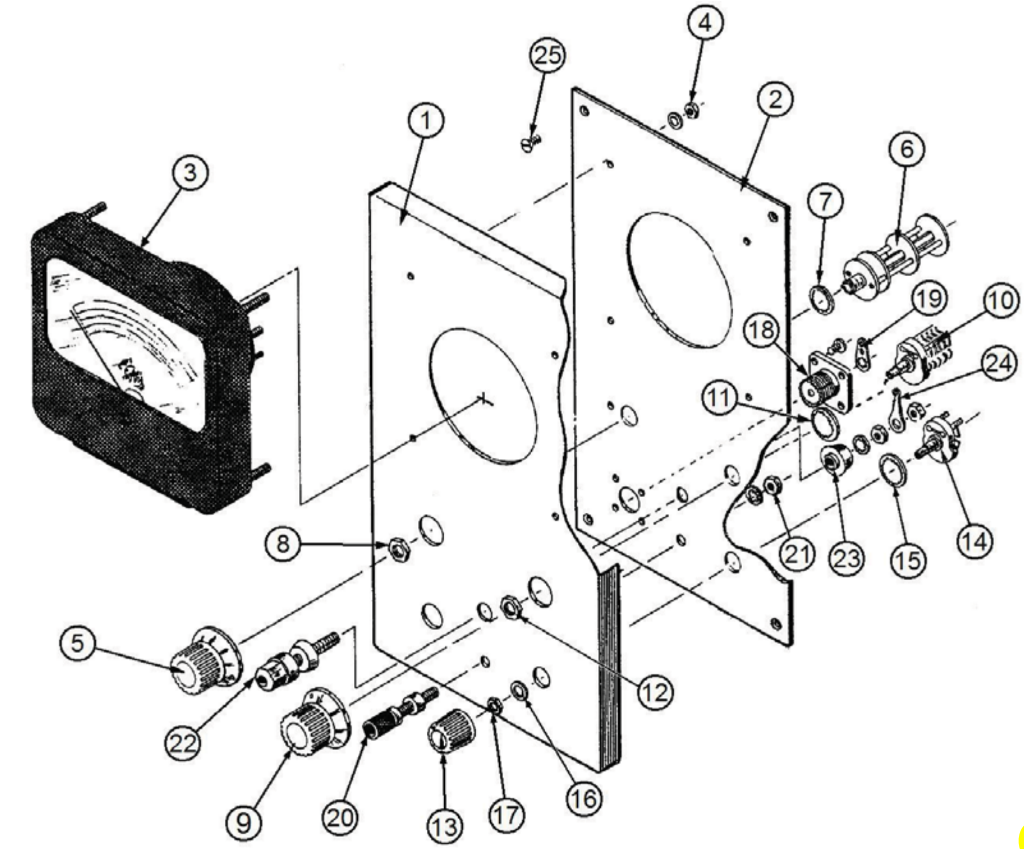
CABINET



REF NO.	PART NO.	Serial/Model No.		QTY.	DESCRIPTION
		Start	End		
1	437-021	101	5000	1	ASSEMBLY, cabinet
	- - - - - -				Assembly includes:
2	367-007	101	5000	1	HANDLE, 4 inches
	- - - - -				Mounting hardware: (not included w/handle)
	210-008	101	5000	2	LOCKWASHER, internal, #8
	212-001	101	5000	2	SCREW, #8-32 x ¼ inch, PHS
3	348-001	101	5000	4	FOOT, rubber, 1 inch
	- - - - - -				Mounting hardware for each: (not included w/foot)
4	211-507	101	5000	1	SCREW, #6-32 x $^{5}/_{16}$ inch, PHS
5	210-006	101	5000	1	LOCKWASHER, internal, #6
6	210-407	101	5000	1	NUT, he., #6-32 x ¼ inch
7	355-014	101	5000	1	STUD, cowl fastener, #5
8	384-507	101	5000	1	ROD, pin



REF NO.	PART NO.	Serial/Model No. Start	End	QTY.	DESCRIPTION
9	386-539	5001	6213	2	PLATE, cabinet side, blue wrinkle
	387-027	6214			PLATE, cabinet side, blue vinyl
	- - - - - -				Each plate includes:
10	105-009	5001		2	STOP
	210-047	5001		2	NUT, special, plastic
	210-087	5001		2	WASHER, flat, $^{9}/_{64}$ ID x $^{5}/_{16}$ inch OD
	213-040	5001		2	SCREW, #8-32 x ½ inch, THS
11	386-538	5001	6213	1	PLATE, cabinet bottom, blue wrinkle
	386-028	6214		1	PLATE, cabinet bottom, blue vinyl
	- - - - - -				Plate includes:
12	348-013	5001		4	FOOT, rubber, ½ inch
	- - - - - -				Plate mounting hardare: (not included w/plate)
	211-537	5001		4	SCREW, #6-32 x $^{3}/_{8}$ inch, THS (not shown)
	210-457	5001		4	NUT, keps, #6-32 x $^{5}/_{16}$ inch (not shown)

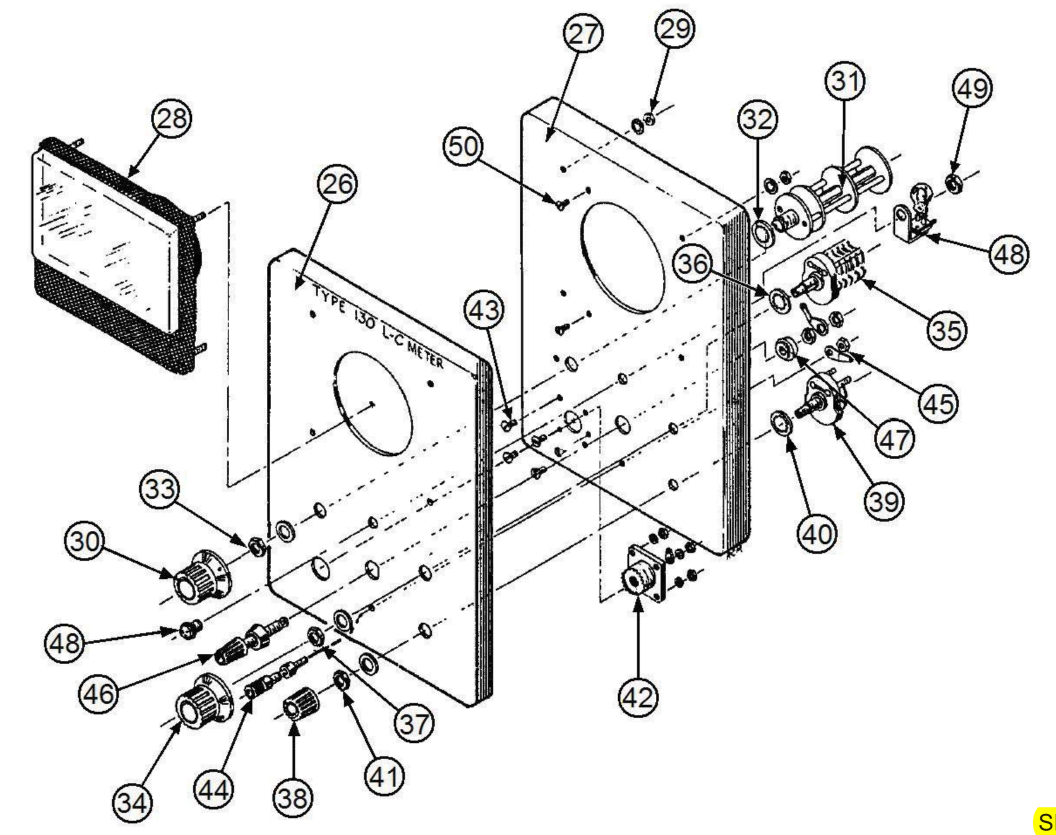


SN 101-5000

REF NO.	PART NO.	Serial/Model No. Start	Serial/Model No. End	QTY.	DESCRIPTION
1	333-023	101	5000	1	PANEL, front
2	386-354	101	5000	1	PLATE, sub-panel
3	- - - - - -				METER, 4700 Ω
	- - - - - -				mounting hardware: (not included w/meter)
	210-006	101	5000	4	LOCKWASHER, internal, #6
4	210-407	101	5000	4	NUT, hex., #6-32 x ¼ inch
5	366-011	101	535	1	KNOB, large black—RANGE SELECTOR
	366-042	536		1	KNOB, large black—RANGE SELECTOR
	- - - - - -				Knob includes:
	213-004	101	5000		SCREW, set, #6-32 x $^{3}/_{16}$ inch, HSS
6	260-072			1	SWITCH, unwired—RANGE SELECTOR
	- - - - - -				mounting hardware: (not included w/switch)
7	210-012	101		1	LOCKWASHER, internal, $^{3}/_{8}$ ID x ½ inch OD
8	210-413	101		`1	NUT, hex., $^{3}/_{8}$-32 x ½ inch
5	366-011	101	535	1	KNOB, large black—COARSE ZERO
	366-042	536		1	KNOB, large black—COARSE ZERO
	- - - - - -				Knob includes:
	213-004	101	5000		SCREW, set, #6-32 x $^{3}/_{16}$ inch, HSS
10	281-016			1	CAPACITOR, variable, 5-80 $\mu\mu$F
	- - - - - -				mounting hardware: (not included w/capacitor)
11	210-012	101	5000	1	LOCKWASHER, internal, $^{3}/_{8}$ ID x ½ inch OD
12	210-413	101	5000	1	NUT, hex., $^{3}/_{8}$-32 x ½ inch
13	366-014	101	535	1	KNOB, small black—FINE ZERO
	366-033	536		1	KNOB, small black—FINE ZERO
	- - - - - -				Knob includes:
	213-004	101	5000		SCREW, set, #6-32 x $^{3}/_{16}$ inch, HSS

FRONT (continued)

REF NO.	PART NO.	Serial/Model No. Start	End	QTY.	DESCRIPTION
14	281-015				CAPACITOR, variable, 1-4 μμF
	- - - - - -				mounting hardware: (not included w/capacitor)
15	210-012	101	5000	1	LOCKWASHER, internal, $^3/_8$ ID x ½ inch OD
16	210-840	101		1	WASHER, flat, 0.390 ID x $^9/_{16}$ OD
17	210-413	101		1	NUT, hex., $^3/_8$-32 x ½ inch
18	131-012	101		1	Connector, coaxial, 2-contact, female (SO239)
	- - - - - -				mounting hardware: (not included w/connector)
19	210-202	101	5000	1	LUG, solder, SE #6
	211-007	101	5000	4	SCREW, #4-40 x $^3/_{16}$ inch, PHS
20	129-020	101		1	ASSEMBLY, binding post
	- - - - - -				assembly includes:
	355-503	101		1	STEM
	200-072	101		1	CAP
	- - - - - -				mounting hardware: (not included w/assembly)
	210-223	101	5000	1	LUG, solder, ¼ ID x $^7/_{16}$ inch OD, SE
21	210-455	101	5000	1	NUT, hex., ¼-28 x $^3/_8$ inch
22	129-030	101	5000	1	POST, binding, black
	- - - - - -				mounting hardware: (not included w/post)
23	358-036	101	5000	1	BUSHING, nylon, black
	210-010	101	5000	1	LOCKWASHER, internal, #10
24	210-206	101	5000	1	LUG, solder, SE #10
	210-445	101	5000	2	NUT, hex., 10-32 x 3/8 inch
25	211-538	101	5000	4	SCREW, #6-32 x 5/16 inch, 100º csk, FHS

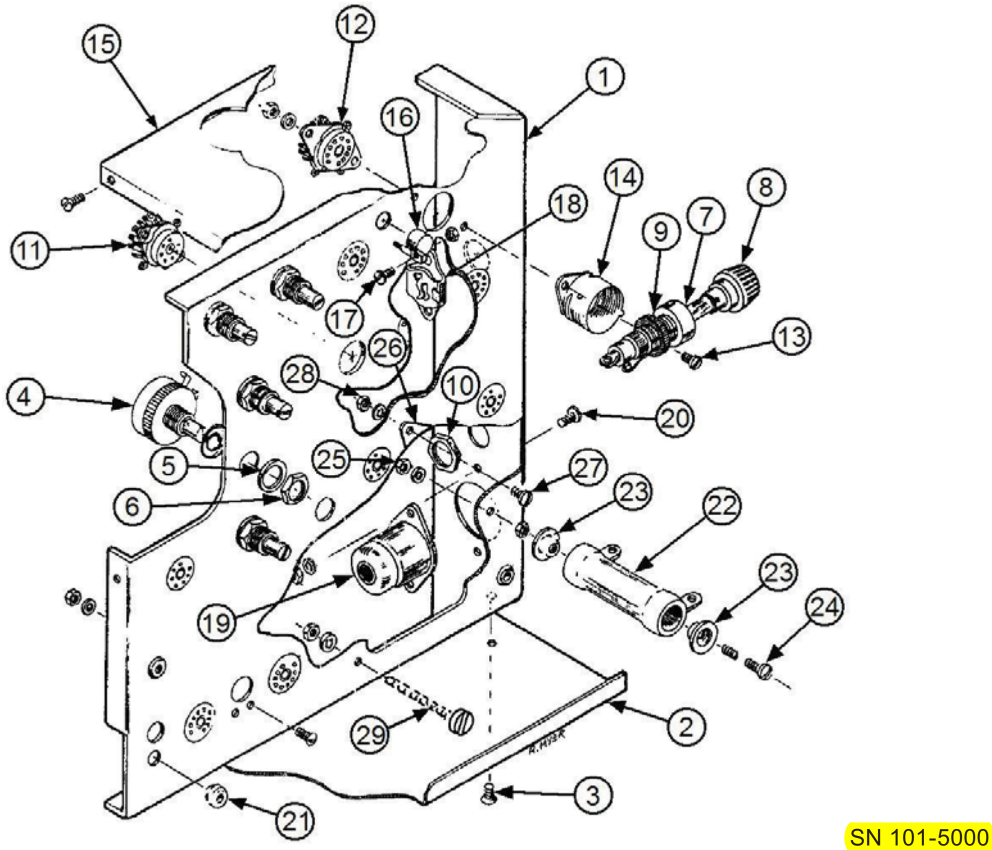


SN 5001-up

REF NO.	PART NO.	Serial/Model No. Start	End	QTY.	DESCRIPTION
26	333-334	5001	5167	1	PANEL, front
	333-427	5168		1	PANEL, front
27	386-604	5001	5167		PLATE, sub-panel
	386-763	5168			PLATE, sub-panel
28	149-010	5001		1	Meter, 200 μa
	- - - - - -				mounting hardware: (not included w/meter)
	210-085	5001		4	WASHER, flat, 0.204 ID x 0.438 inch OD
29	210-458	5001		4	NUT, keps, 8-32 x $^{11}/_{32}$ inch
30	366-042	536	8749	1	KNOB, large black—RANGE SELECTOR
	366-117	8750		1	KNOB, large charcoal—RANGE SELECTOR
	- - - - - -				Knob includes:
	213-004	101	5000		SCREW, set, #6-32 x $^{3}/_{16}$ inch, HSS
31	260-072			1	SWITCH, unwired—RANGE SELECTOR
	- - - - - -				mounting hardware: (not included w/switch)
32	210-012	101		1	LOCKWASHER, internal, $^{3}/_{8}$ ID x ½ inch OD
33	210-413	101		1	NUT, hex., $^{3}/_{8}$-32 x ½ inch
34	366-042	536	8749	1	KNOB, large black—COARSE ZERO
	366-117	8750		1	KNOB, large charcoal—COARSE ZERO
	- - - - - -				Knob includes:
	213-004	101	5000		SCREW, set, #6-32 x $^{3}/_{16}$ inch, HSS
35	281-016			1	CAPACITOR, variable, 5-80 $\mu\mu$F
	- - - - - -				mounting hardware: (not included w/capacitor)
36	210-013	5001		1	LOCKWASHER, internal, $^{3}/_{8}$ ID x $^{11}/_{64}$ inch OD
	210-840	5001		1	WASHER, flat, 0.390 ID x $^{9}/_{16}$ inch OD
37	210-413	101		1	NUT, hex., $^{3}/_{8}$-32 x ½ inch
38	366-033	536	8749	1	KNOB, small black—FINE ZERO
	366-148	8750		1	KNOB, small charcoal—FINE ZERO
	- - - - - -				Knob includes:

FRONT (continued)

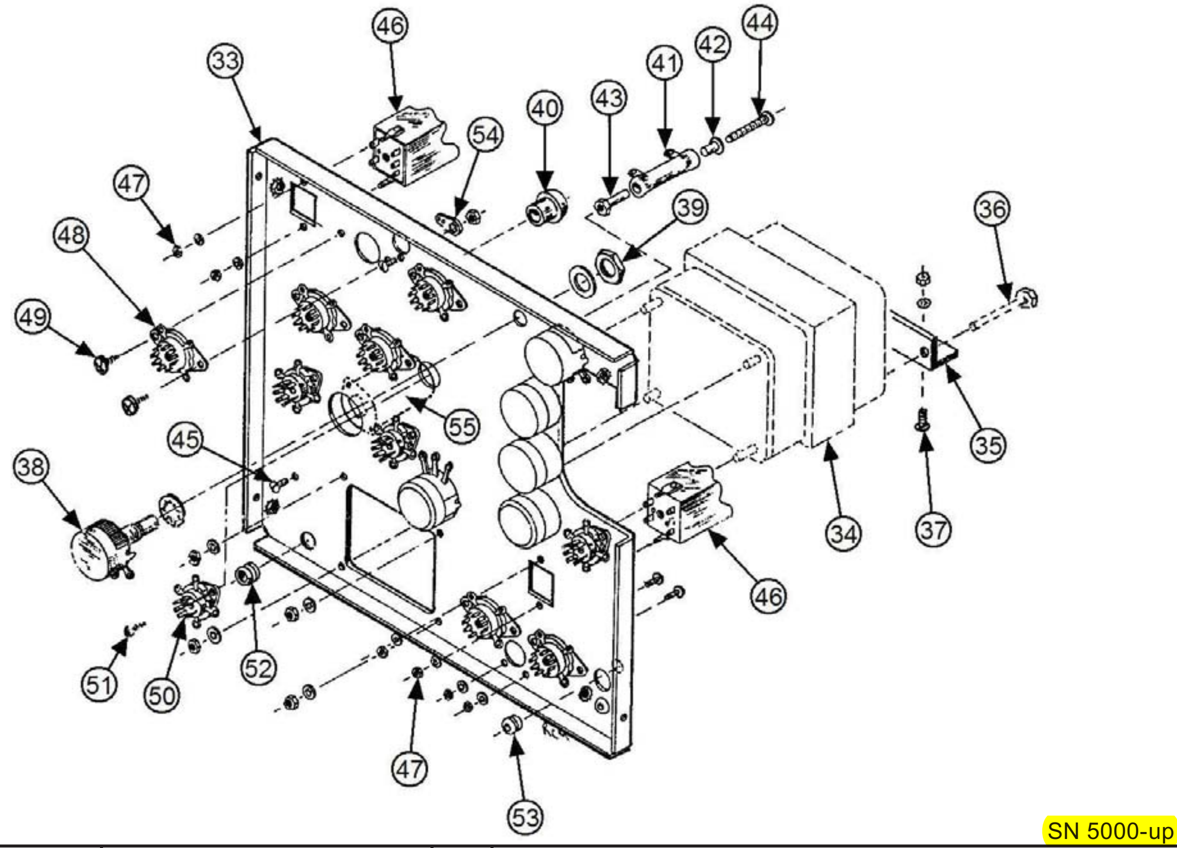
REF NO.	PART NO.	Serial/Model No. Start	End	QTY.	DESCRIPTION
	213-004	101	5000		SCREW, set, #6-32 x $^{3}/_{16}$ inch, HSS
39	281-015				CAPACITOR, variable, 1-4 $\mu\mu$F
	- - - - - -				mounting hardware: (not included w/capacitor)
40	210-013	5001		1	LOCKWASHER, internal, $^{3}/_{8}$ ID x $^{11}/_{64}$ inch OD
	210-840	101		1	WASHER, flat, 0.390 ID x $^{9}/_{16}$ OD
41	210-413	101		1	NUT, hex., $^{3}/_{8}$-32 x ½ inch
42	131-012	101		1	Connector, coaxial, 2-contact, female (SO239)
	- - - - - -				mounting hardware: (not included w/connector)
43	211-101	5001	10439	4	SCREW, #4-40 x ¼ inch, 100º csk, FHS
	211-038	10440		4	SCREW, #4-40 x 5/16 inch, 100º csk, FHS
	210-001	X10440		1	LOCKWASGER, internal, #4
	210-201	5001		1	LUG, solder, SE #4
	210-586	5001		4	NUT, keps, 4-40 x ¼ inch
44	129-020	101		1	ASSEMBLY, binding post
	- - - - - -				assembly includes:
	355-503	101		1	STEM
	200-072	101		1	CAP
	- - - - - -				mounting hardware: (not included w/assembly)
	210-223	101		1	LUG, solder, ¼ ID x $^{7}/_{16}$ inch OD, SE
45	210-455	101		1	NUT, hex., ¼-28 x $^{3}/_{8}$ inch
46	129-030	101	5616	1	POST, binding, black
	129-036	5167	8749	1	POST, binding, black
	129-063	8750		1	POST, binding, black
	- - - - - -				mounting hardware: (not included w/post)
47	358-036	101	8749	1	BUSHING, nylon, black
	358-169	8750		1	BUSHING, nylon, charcoal
	210-010	101	8069	1	LOCKWASHER, internal, #10
	210-206	101	8069	1	LUG, solder, SE #10
	210-445	101	8069	2	NUT, hex., 10-32 x $^{3}/_{8}$ inch
	220-410	8070		1	NUT, keps, 10-32 x $^{3}/_{8}$ inch
48	136-047	5168	9829	1	ASSEMBLY, pilot light mounting, w/red jewel
	136-079	9830		1	ASSEMBLY, pilot light mounting, w/green jewel
	- - - - - -				assembly includes:
49	- - - - - -	5168		1	NUT
50	211-538	101		4	SCREW, #6-32 x 5/16 inch, 100º csk, FHS



REF NO.	PART NO.	Serial/Model No. Start	End	QTY.	DESCRIPTION
1	441-074	101	5000	1	CHASSIS
2	387-533	101	5000	1	PLATE, bottom
3	211-538	101	5000	4	SCREW, #6-32 x $^5/_{16}$ inch, 100º csk, FHS
4	311-015	101		4	RESISTOR, variable 10 kohm
	311-023	101		1	RESISTOR, variable 50 kohm
	311-026	101		1	RESISTOR, variable 100 kohm
	- - - - - -				mounting hardware for each: (not included w/resistor)
	210-012	101		1	LOCKWASHER, internal, $^3/_8$ ID x $^1/_2$ inch OD
5	210-840	101		1	WASHER, flat, 0.390 ID x $^9/_{16}$ OD
6	210-413	101		1	NUT, hex., $^3/8$-32 x $^1/_2$ inch
7	352-002	101		1	ASSEMBLY, fuse holder
	- - - - - -				Assembly includes:
	352-010	101		1	HOLDER, fuse 3AG
8	200-582	101		1	CAP, fuse
9	210-873	101		1	WASHER, rubber, ½ ID x $^{11}/_{16}$ inch OD
10	- - - - - -	101		1	NUT, $^1/_2$-24 x $^1/_8$ inch
11	136-008	101		4	SOCKET, tube, 7-pin, w/ground lugs
	- - - - - -				mounting hardware for each: (not included w/socket)
	211-033	101		2	SCREW, sems, #4-40 x $^5/_{16}$ inch, PHS
	210-004	101		2	LOCKWASHER, internal, #4
	210-406	101		2	NUT, hex., 4-40 x $^3/_{16}$ inch
12	136-015	101		6	SOCKET, tube, 9-pin, w/ground lugs
	- - - - - -				mounting hardware for each: (not included w/socket)
13	211-033	101		2	SCREW, sems, #4-40 x $^5/_{16}$ inch, PHS
	210-004	101		2	LOCKWASHER, internal, #4
	210-406	101		2	NUT, hex., 4-40 x $^3/_{16}$ inch
14	337-005	101	5000	1	SHIELD, socket, $^{29}/_{32}$ inch ID

CHASSIS (continued)

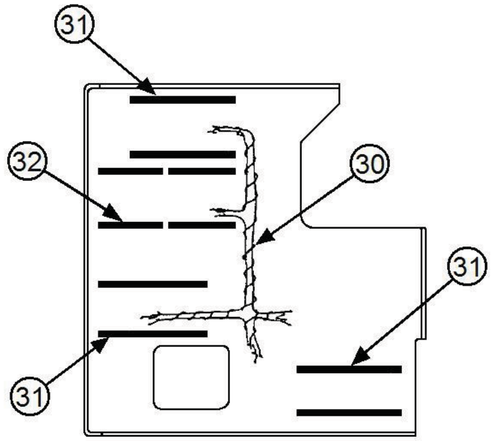
REF NO.	PART NO.	Serial/Model No. Start	End	QTY.	DESCRIPTION
15	387-534	101		1	PLATE, top
16	343-015	101		1	CLAMP, stainless steel, ½ inch
	- - - - - -				mounting hardware: (not included w/clamp)
17	211-504	101		1	SCREW, #6-32 x ¼ inch, PHS
	210-407	101		2	NUT, hex., 6-32 x ¼ inch
	214-012	101		1	BOLT, spade, #6-32 x $^3/_8$ inch
	210-006	101		2	LOCKWASHER, internal, #6
18	214-024	101		1	FASTENER, spring
19	131-010	101		1	CONNECTOR, 2-contact, male recessed NEMA
	- - - - - -				mounting hardware: (not included w/connector)
20	211-507	101		2	SCREW, #6-32 x $^5/_{16}$ inch, PHS
	210-006	101		2	LOCKWASHER, internal, #6
	210-407	101		2	NUT, hex., #6-32 x ¼ inch
21	348-002	101	5000	2	GROMMET, rubber, ¼ inch diameter
22	308-032	101	753	1	RESISTOR, 3.5 k 20 w
	308-020	754		1	RESISTOR, 3 k 10 w
	- - - - - -				mounting hardware: (not included w/resistor)
23	210-808	101	753	2	WASHER, centering
	210-601	754		1	EYELET, 0190 ID x 0.323 inch OD
24	212-037	101	753	1	SCREW, #8-32 x 1$^3/_4$ inches, Fil HS
	211-553	754		1	SCREW, #6-32 x 1½ inches, RHS
25	210-409	101	753	2	NUT, hex., 8-32 x $^5/_{16}$ inch
	210-008	101	753	1	LOCKWASHER, internal, #8
	210-478	754		1	NUT, hex., resistor mounting
26	290-034	101		1	CAPACITOR, 2 x 15 μf 350 v
	- - - - - -				mounting hardware: (not included w/capacitor)
	386-253	101		1	PLATE, capacitor flange, metal
27	211-534	101		2	SCREW, sems, #6-32 x $^5/_{16}$ inch, PHS
	210-006	101		2	LOCKWASHER, external, #6
28	210-407	101		2	NUT, hex., 6-32 x ¼ inch
29	120-038	101		1	TRANSFORMER, power 240-0-240 v & 6.5 v
	- - - - - -				mounting hardware: (not included w/transformer)
	212-039	101	5000	4	SCREW, #8-32 x 3 inches, RHS
	210-008	101	5000	4	LOCKWASHER, internal, #8
	210-409	101	5000	4	NUT, hex., 8-32 x $^5/_{16}$ inch
	120-053	101		2	TRANSFORMER, oscillator adjustable
	- - - - - -				mounting hardware for each: (not included w/transformer)
	210-457	101		2	NUT, keps, 6-32 x $^5/_{16}$ inch



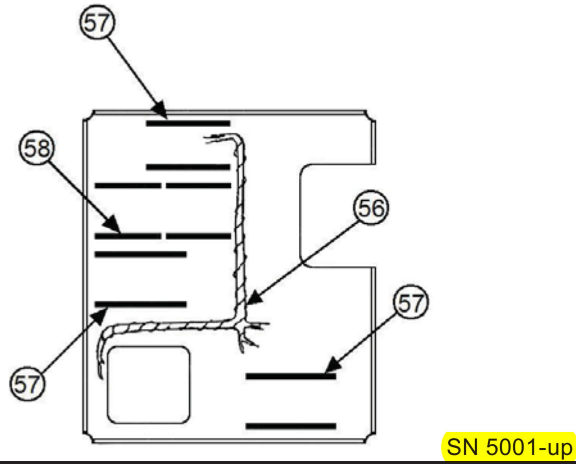
REF NO.	PART NO.	Serial/Model No.		QTY.	DESCRIPTION
		Start	End		
33	441-153	5001		1	CHASSIS
	- - - - - -				mounting hardware: (not included w/chassis)
	210-457	5001		6	NUT, keps, 6-32 x 5/16 inch
34	120-038	101		1	TRANSFORMER, power 240-0-240 v & 6.5 v
	- - - - - -				Transformer includes:
35	406-872	7580		1	BRACKET, transformer support
36	212-029	5001		4	SCREW, #8-32 x 3 inches, HHS
	- - - - - -				mounting hardware: (not included w/transformer)
	210-008	101	5000	4	LOCKWASHER, internal, #8
	210-409	101	5000	4	NUT, hex., 8-32 x 5/16 inch
37	211-537	7580		3	SCREW, #6-32 x 3/8 inch, THS
	210-803	7580		3	WASHER, flat, 0.150 ID x 0.375 inch OD
	210-457	7580		3	NUT, keps, 6-32 x 5/16 inch
38	311-015	101		4	RESISTOR, variable 10 kohm
	311-023	101		1	RESISTOR, variable 50 kohm
	311-026	101		1	RESISTOR, variable 100 kohm
	- - - - - -				mounting hardware for each: (not included w/resistor)
	210-012	101		1	LOCKWASHER, internal, 3/8 ID x 1/2 inch OD
	210-840	101		1	WASHER, flat, 0.390 ID x 9/16 OD
39	210-413	101		1	NUT, hex., 3/8-32 x 1/2 inch
40	343-015	5001	5453	1	CLAMP, stainless steel, ½ inch
	- - - - - -				mounting hardware: (not included w/clamp)
	211-504	5001	5453	1	SCREW, #6-32 x ¼ inch, PHS
	210-006	5001		2	LOCKWASHER, internal, #6
	210-407	5001	5453	2	NUT, hex., 6-32 x ¼ inch
	214-012	5001	5453	1	BOLT, spade, #6-32 x 3/8 inch
	354-068	5454		1	RING, securing

CHASSIS (continued)

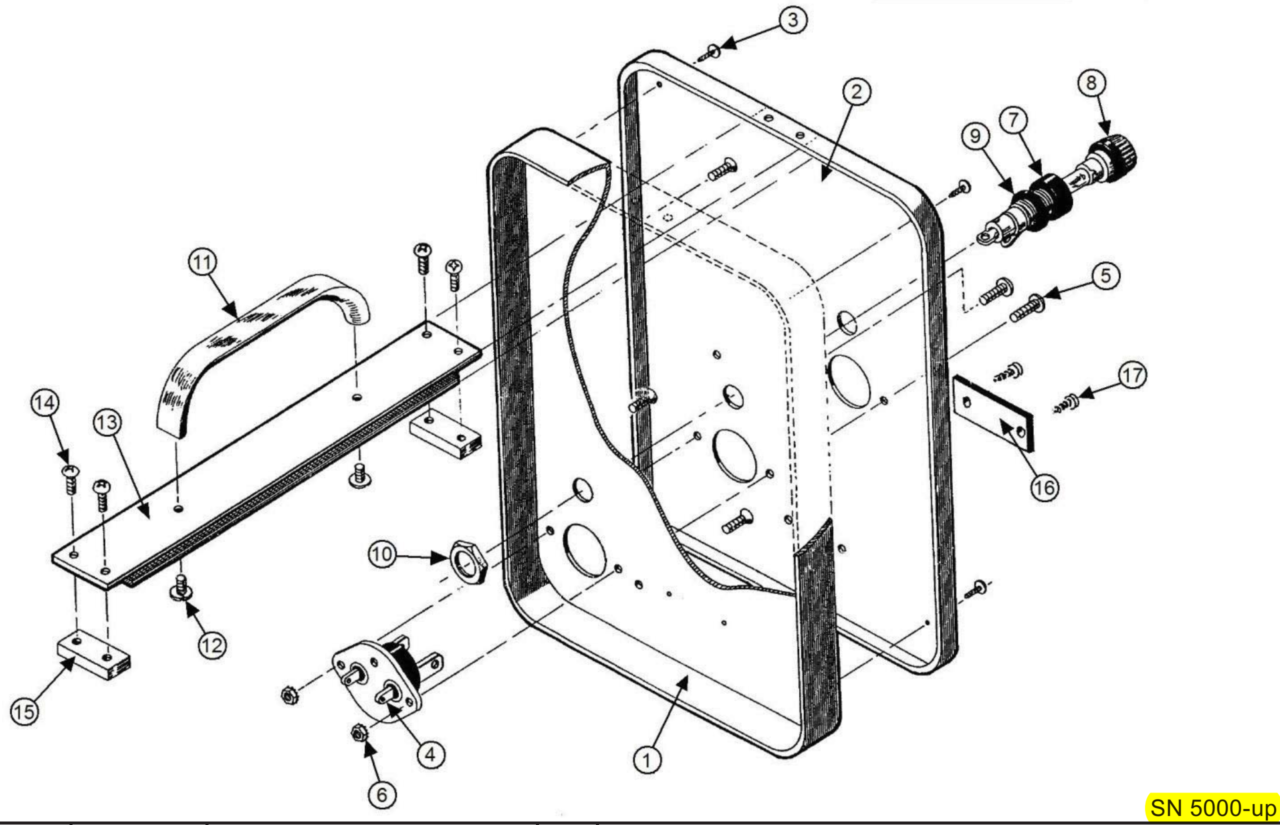
REF NO.	PART NO.	Serial/Model No. Start	End	QTY.	DESCRIPTION
41	308-020	754		1	RESISTOR, 3 k 10 w
	------				mounting hardware: (not included w/resistor)
42	210-601	754		1	EYELET, 0190 ID x 0.323 inch OD
43	210-478	754		1	NUT, hex., resistor mounting
44	211-553	754		1	SCREW, #6-32 x 1½ inches, RHS
45	211-507	5001		1	SCREW, #6-32 x $^{5}/_{16}$ inch, PHS
46	120-053	101		2	TRANSFORMER, oscillator adjustable
	------				mounting hardware for each: (not included w/transformer)
47	210-457	101		2	NUT, keps, 6-32 x $^{5}/_{16}$ inch
48	136-015	101		6	SOCKET, tube, 9-pin, w/ground lugs
	------				mounting hardware for each: (not included w/socket)
49	211-033	101		2	SCREW, sems, #4-40 x $^{5}/_{16}$ inch, PHS
	210-004	101		2	LOCKWASHER, internal, #4
	210-406	101		2	NUT, hex., 4-40 x $^{3}/_{16}$ inch
50	136-008	101		4	SOCKET, tube, 7-pin, w/ground lugs
	------				mounting hardware for each: (not included w/socket)
51	211-033	101		2	SCREW, sems, #4-40 x $^{5}/_{16}$ inch, PHS
	210-004	101		2	LOCKWASHER, internal, #4
	210-406	101		2	NUT, hex., 4-40 x $^{3}/_{16}$ inch
52	348-003	5001		1	GROMMET, rubber, $^{5}/_{16}$ inch diameter
53	348-002	5001		3	GROMMET, rubber, ¼ inch diameter
54	210-202	5454		1	LUG, solder, SE #6
	------				mounting hardware: (not included w/lug)
	211-504	5454		1	SCREW, #6-32 x ¼ inch, PHS
	210-407	5454		1	NUT, hex., 6-32 x ¼ inch
55	290-034	101		1	CAPACITOR, 2 x 15 μf 350 v
	------				mounting hardware: (not included w/capacitor)
	386-253	101		1	PLATE, capacitor flange, metal
	211-534	101		2	SCREW, sems, #6-32 x $^{5}/_{16}$ inch, PHS
	210-006	101		2	LOCKWASHER, external, #6
	210-407	101		2	NUT, hex., 6-32 x ¼ inch



REF NO.	PART NO.	Serial/Model No. Start	Serial/Model No. End	QTY.	DESCRIPTION
30	179-051	101		1	CABLE HARNESS
31	124-016	101	5689	6	STRIP, ceramic, ¾ inch h, w/11 notches
	- - - - - -				mounting hardware for each: (not included w/strip)
	210-085	101	5689	2	WASHER, flat, 0.093 ID x $^{9}/_{32}$ inch OD
	210-002	101	5689	2	LOCKWASHER, external, #2
	210-045	101	5689	4	NUT, hex., 2-56 x $^{3}/_{16}$ inch
32	124-014	101	5689	4	STRIP, ceramic, ¾ inch h, w/7 notches
	- - - - - -				mounting hardware for each: (not included w/strip)
	210-085	101	5689	2	WASHER, flat, 0.093 ID x $^{9}/_{32}$ inch OD
	210-002	101	5689	2	LOCKWASHER, external, #2
	210-045	101	5689	4	NUT, hex., 2-56 x $^{3}/_{16}$ inch



REF NO.	PART NO.	Serial/Model No. Start	End	QTY.	DESCRIPTION
56	179-051	101		1	CABLE HARNESS
57	124-016	101	5689	6	STRIP, ceramic, ¾ inch h, w/11 notches
	- - - - - -				mounting hardware for each: (not included w/strip)
	210-085	101	5689	2	WASHER, flat, 0.093 ID x $^{9}/_{32}$ inch OD
	210-002	101	5689	2	LOCKWASHER, external, #2
	210-045	101	5689	4	NUT, hex., 2-56 x $^{3}/_{16}$ inch
	124-091	5690		6	STRIP, ceramic, ¾ inch h, w/11 notches
	- - - - - -				Each strip includes:
	355-046	5690		2	STUD, plastic, clip-on
	- - - - - -				mounting hardware for each: (not included w/strip)
	361-009	5690		2	SPACER, plastic, 0.406 inch long
58	124-014	101	5689	4	STRIP, ceramic, ¾ inch h, w/7 notches
	- - - - - -				mounting hardware for each: (not included w/strip)
	210-085	101	5689	2	WASHER, flat, 0.093 ID x $^{9}/_{32}$ inch OD
	210-002	101	5689	2	LOCKWASHER, external, #2
	210-045	101	5689	4	NUT, hex., 2-56 x $^{3}/_{16}$ inch
	124-089	5690		6	STRIP, ceramic, ¾ inch h, w/7 notches
	- - - - - -				Each strip includes:
	355-046	5690		2	STUD, plastic, clip-on
	- - - - - -				mounting hardware for each: (not included w/strip)
	361-009	5690		2	SPACER, plastic, 0.406 inch long



REF NO.	PART NO.	Serial/Model No. Start	Serial/Model No. End	QTY.	DESCRIPTION
1	386-603	5001		1	PLATE, rear sub-panel
2	386-643	5001	6213	1	PLATE, rear overlay, blue wrinkle
	387-035	6214		1	PLATE, rear overlay, blue vinyl
	- - - - - -				mounting hardware for each: (not included w/plate)
3	213-088	5001		3	SCREW, thread forming, #4-40 x ¼ inch, PHS
4	131-010	5001	5496	1	CONNECTOR, 2-contact, male recessed NEMA
	- - - - - -				mounting hardware for each: (not included w/connector)
	213-041	5001	5496	2	SCREW, thread cutting, #6-32 x $^3/_8$ inch, PHS
	131-102	5497		1	CONNECTOR, 3-contact, male projecting
	- - - - - -				Connector includes
	129--041	5497		1	POST, ground
	121-003	5497		2	LOCKWASHER, external, #4
	210-551	5497		2	NUT, hex., 4-40 x ¼ inch
	- - - - - -				mounting hardware: (not included w/connector)
5	211-537	5497		2	SCREW, #6-32 x $^3/_8$ inch, THS
6	210-457	5497		2	NUT, keps, 6-32 x $^5/_{16}$ inch
7	352-010	101		1	ASSEMBLY, fusheholder
	- - - - - -				assembly includes
	352-010	101		1	HOLDER, fuse 3AG
8	200-582	101		1	CAP, fuse
9	210-873	101		1	WASHER, rubber, ½ ID x $^{11}/_{16}$ inch OD
10	- - - - - -	101		1	NUT, $^1/_2$-24 x $^1/_8$ inch
11	367-007	5001		1	HANDLE, 4 inches
	- - - - - -				mounting hardware: (not included w/handle)
12	212-004	5001		2	SCREW, 8-32 x $^5/_{16}$ imnch, PHS
13	381-062	5001	6213	1	BAR, chrome
	381-159	6214		1	BAR, blue painted
	- - - - - -				mounting hardware: (not included w/bar)

REAR (continued)

REF NO.	PART NO.	Serial/Model No. Start	End	QTY.	DESCRIPTION
14	211-537	5001		4	SCREW, #6-32 x 3/8 inch, THS
15	381-084	5001		2	BAR, w/2 #6-32 holes
16	334-0649	5001		1	TAG, voltage rating 117 v 50-60 c/s
	- - - - - -				mounting hardware: (not included w/bar)
17	213-088	5001		2	SCREW, thread forming, #4 x ¼ inch, PHS

ELECTRICAL PARTS LIST

***000-000 Asterisk preceding Tektronix Part Number indicates manufactured by or for Tektronix, also reworked or checked components.**

Bulb

				Tektronix Part Number
B401	5168-up	Incandescent	Pilot Light	150-018

Capacitors

C1		.1 μF	PT	Fixed	400V	20%	285-526
C2		5-25 μμF	Cer.	Var.	500 v		281-011
C3		1-4 μμF	Air	Var.			281-015
C4		5-80 μμF	Air	Var.			281-016
C5		.001 μF	Mica	Fixed	500 v	1%	283-526
C6		470 μμF	Cer.	Fixed	500 v	20%	281-525
C7	101-5108	5-25 μμF	Cer.	Var.			281-011
	5109-up	8-50 μμF	Cer.	Var.			281-013
C9		0.01 μF	PT	Fixed	400 v	20%	285-510
C10		22 μμF	Cer.	Fixed	500 v	10%	281-511
C11		.001 μF	Cer.	Fixed	500 v	GMV	283-000
C15		22 μμF	Cer.	Fixed	500 v	10%	281-511
C17		100 μμF	Cer.	Fixed	350 v	20%	281-523
C18		.005 μF	Cer.	Fixed	500 v	GMV	283-001
C30		.001 μF	Mica	Fixed	500 v	1%	283-526
C31		470 μμF	Cer.	Fixed	500 v	20%	281-525
C33		0.01 μF	PT	Fixed	400 v	20%	285-510
C35		.001 μF	Cer.	Fixed	500 v	GMV	283-000
C36		22 μμF	Cer.	Fixed	500 v	10%	281-511
C45		22 μμF	Cer.	Fixed	500 v	20%	281-510
C47		100 μμF	Cer.	Fixed	350 v	20%	281-523
C48		.005 μF	Cer.	Fixed	500 v	GMV	283-001
C60		.02 μF	Cer.	Fixed	150 v	GMV	283-004
C61		150 μμF	Cer.	Fixed	500 v	20%	281-524
C62		100 μμF	Cer.	Fixed	350 v	20%	281-523
C63		470 μμF	Cer.	Fixed	500 v	20%	281-525
C64		47 μμF	Cer.	Fixed	500 v	10%	281-519
C65		47 μμF	Cer.	Fixed	500 v	10%	281-519
C73		4.7 47 μμF	Cer.	Fixed	500 v	±0.1 μμF	281-519
C90		250 μμF	Mica	Fixed	500 v	5%	283-543
C91		.0015 μF	PT	Fixed	400 v	20%	285-504
C92		.0047 μμF	PT	Fixed	400 v	20%	285-506
C93		.015 μF	PT	Fixed	400 v	20%	285-512
C94		.047 μF	PT	Fixed	400 v	20%	285-519
C97	X259-up	470 μμF	Cer.	Fixed	500 v	20%	281-525
C99	X6040-up	5 μF	EMT	Fixed	6 v		290-125
C100	X6040-up	25 μF	EMT	Fixed	6 v		290-124
C110		.022 μF	PT	Fixed	400 v	20%	285-515
C112		.001 μF	Cer.	Fixed	500 v	GMV	283-000
C401		2x15 μF	EMC	Fixed	350 v	–20+50%	290-034
C402		6.25 μF	EMC	Fixed	300 v	–20+50%	285-515
C403		.022 μF	PT	Fixed	400 v	20%	285-515

Fuses

		Tektronix Part Number
Fuse	0.8 amp 3 AG Slo-Blo for 117 v operation	159-018
Fuse	0.4 amp 3 AG Slo-Blo for 234 v operation	159-031

Meters

Meter	101-5167	4700Ω	*149-003
	5168-up	0-200 μa	*149-010

Resistors

R1		10 meg	½ w	Fixed	Comp.	10%	302-106
R6		1.5 meg	½ w	Fixed	Comp.	10%	302-155
R7		100 k	½ w	Fixed	Comp.	10%	302-104
R8		1 meg	½ w	Fixed	Comp.	10%	302-105
R9		56 k	½ w	Fixed	Comp.	10%	302-563
R10		470 k	½ w	Fixed	Comp.	10%	302-474
R14		10 meg	½ w	Fixed	Comp.	10%	302-106
R15		1.5 meg	½ w	Fixed	Comp.	10%	302-155
R16		47 Ω	½ w	Fixed	Comp.	10%	302-470
R17		1 meg	½ w	Fixed	Comp.	10%	302-105
R18		1 meg	½ w	Fixed	Comp.	10%	302-105
R19		1.5 meg	½ w	Fixed	Comp.	10%	302-155
R31		1.5 meg	½ w	Fixed	Comp.	10%	302-155
R32		100 k	½ w	Fixed	Comp.	10%	302-104
R33		56 k	½ w	Fixed	Comp.	10%	302-563
R35		470 k	½ w	Fixed	Comp.	10%	302-474
R45		1.5 meg	½ w	Fixed	Comp.	10%	302-155
R46		47 Ω	½ w	Fixed	Comp.	10%	302-470
R47		1 meg	½ w	Fixed	Comp.	10%	302-105
R48		1 meg	½ w	Fixed	Comp.	10%	302-105
R49		1.5 meg	½ w	Fixed	Comp.	10%	302-155
R60		47 k	½ w	Fixed	Comp.	10%	302-473
R61		22 k	½ w	Fixed	Comp.	5%	302-223
R62		22 k	½ w	Fixed	Comp.	5%	302-223
R64		11 k	½ w	Fixed	Comp.	5%	302-113
R67		100 k	½ w	Fixed	Comp.	10%	302-104
R68		50 k	2 w	Var.	Comp.	20%	311-023
R69	X435-up	10k	½ w	Fixed	Comp.	10%	302-103
R70		6.8 k	½ w	Fixed	Comp.	10%	302-682
R71		5.6 k	1 w	Fixed	Comp.	5%	304-562
R72		180 k	½ w	Fixed	Comp.	5%	302-184
R73		470 k	½ w	Fixed	Comp.	5%	302-474
R74		15 k	1 w	Fixed	Comp.	10%	304-153
R75		330 k	½ w	Fixed	Comp.	10%	302-334
R76		47 Ω	½ w	Fixed	Comp.	10%	302-470
R77		4.7 meg	½ w	Fixed	Comp.	10%	302-475
R78		100 k	2 w	Var.	Comp.	20%	311-026
R79		82 k	½ w	Fixed	Comp.	10%	302-823
R80		47 Ω	½ w	Fixed	Comp.	10%	302-470
R81		47 Ω	½ w	Fixed	Comp.	10%	302-470

Resistors *(continued)*

								Tektronix Part Number
R95		33 k	2 w	Fixed	Comp.	10%		306-333
R96		470 Ω	½ w	Fixed	Comp.	10%		302-471
R97		10 k	2 w	Var.	WW	20%		311-015
R98		10 k	2 w	Var.	WW	20%		311-015
R99		10 k	2 w	Var.	WW	20%		311-015
R100		10 k	2 w	Var.	WW	20%		311-015
R110		1 meg	½ w	Fixed	Comp.	10%		302-105
R111		10 k	½ w	Fixed	Comp.	10%		302-103
R112		2.2 meg	½ w	Fixed	Comp.	10%		302-225
R113		4.7 meg	½ w	Fixed	Comp.	10%		302-475
R116		47 Ω	½ w	Fixed	Comp.	10%		302-470
R401		100 k	½ w	Fixed	Comp.	10%		302-104
R402		100 k	½ w	Fixed	Comp.	10%		302-104
R403	101-753	3.5 k	20 w	Fixed	WW	5%		308-032
R403	754-up	3 k	10 w	Fixed	WW	5%		308-020
R405		1.5 Ω	1 w	Fixed	WW	10%		308-058

Switches

SW1	3 wafer, 11 position, rotary RANGE SELECTOR	*260-072

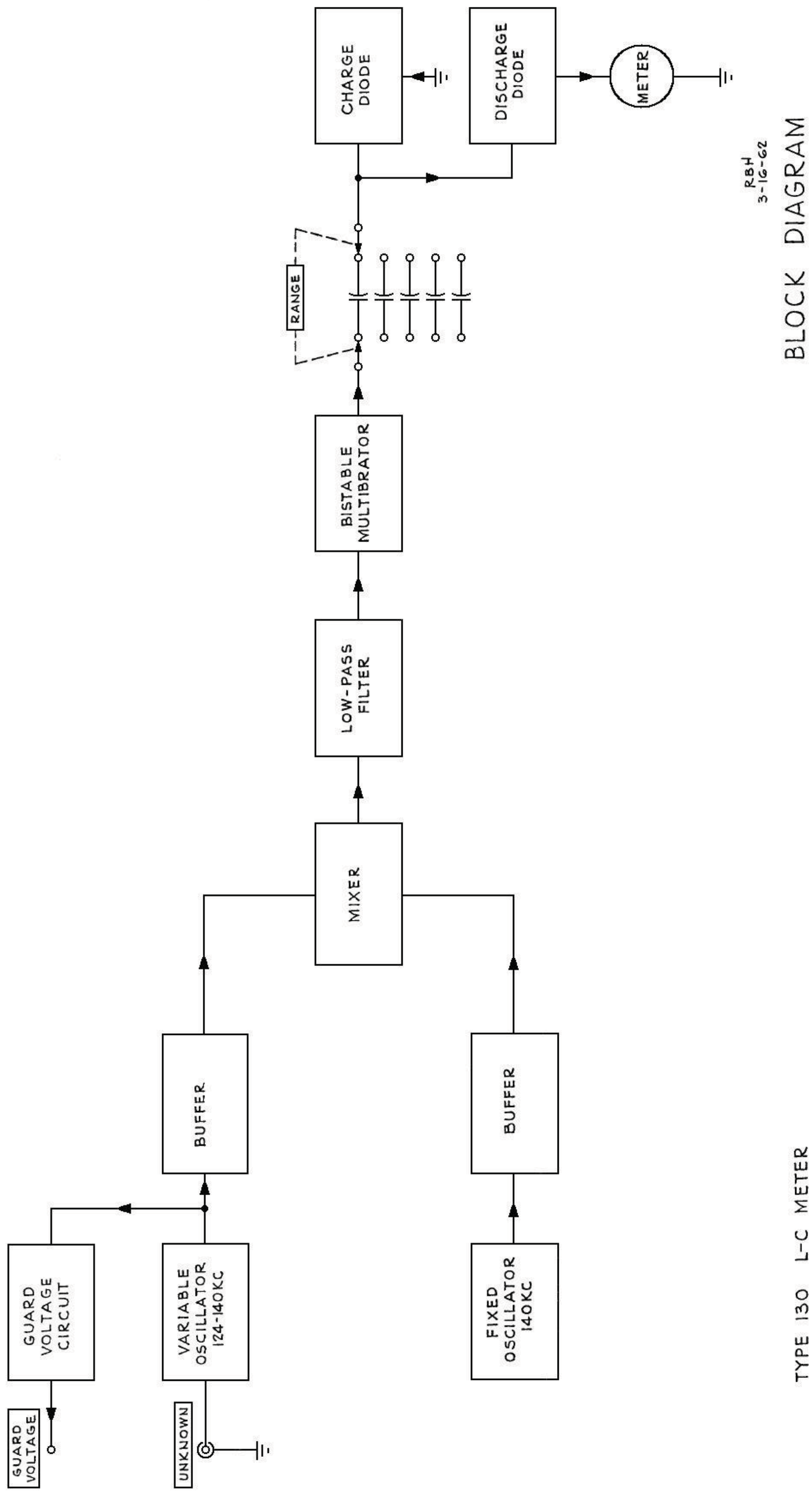
Transformers

T1	Oscillator Transformer	*120-053
T30	Oscillator Transformer	*120-053
T400	Plate and Heater Supply T130 PA 1 Primary: 117-234 vac, 60 cycles Secondary 240-0-240 vac at 40 ma 6.5 vac at 4 amp	*120-038

Vacuum Tubes

V4	6U8	154-033
V15	6U8	154-033
V30	6U8	154-033
V45	6U8	154-033
V60	6BE6	154-025
V70	6U8	154-033
V76	6BW7A	154-028
V110	6BH6	154-026
V400	6X4	154-035
V403	OA2	154-001

DIAGRAMS


GUARD VOLTAGE
GUARD VOLTAGE CIRCUIT
UNKNOWN
VARIABLE OSCILLATOR 124-140KC
BUFFER
FIXED OSCILLATOR 140KC
BUFFER
MIXER
LOW-PASS FILTER
BISTABLE MULTIBRATOR
RANGE
CHARGE DIODE
DISCHARGE DIODE
METER
RBH 3-16-62
BLOCK DIAGRAM
TYPE 130 L-C METER

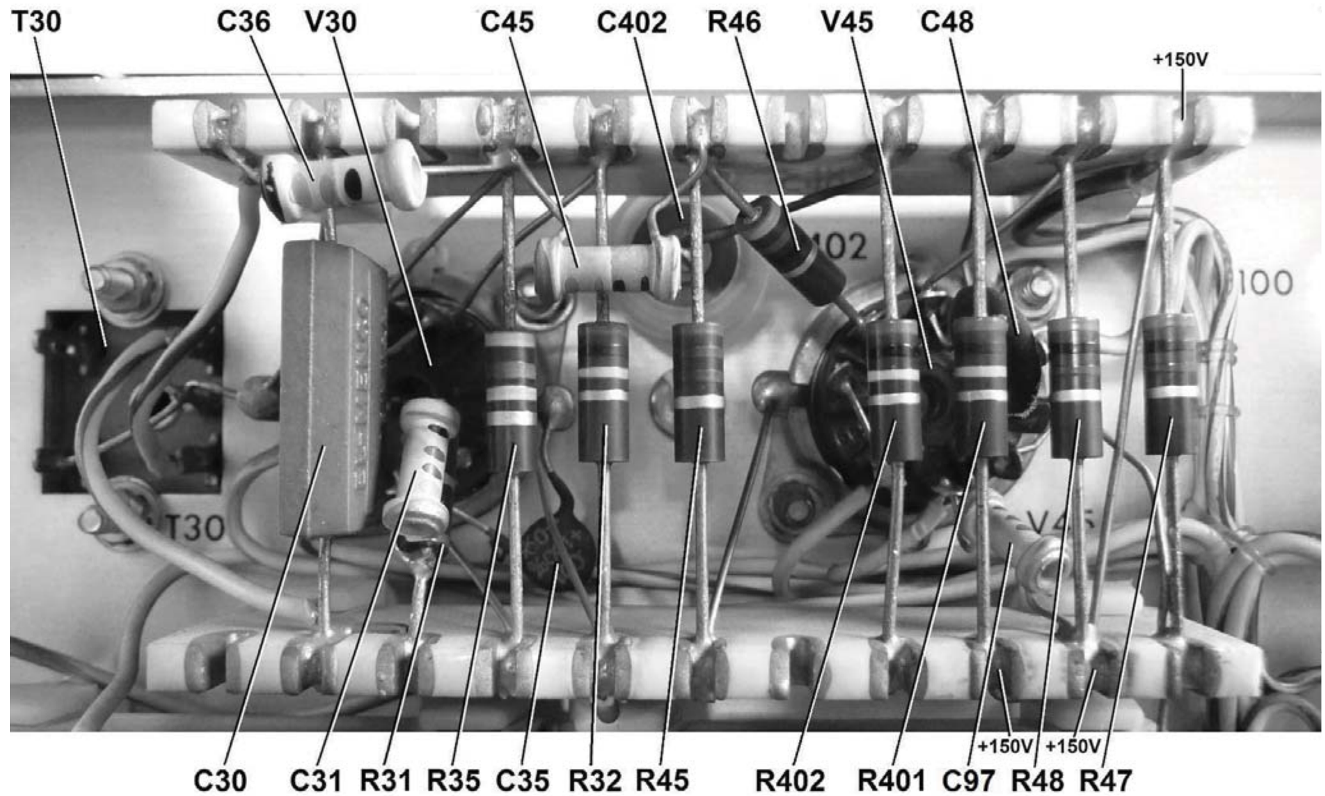


Figure 7.1 Fixed Oscillator, Buffer, and Discharge Diode

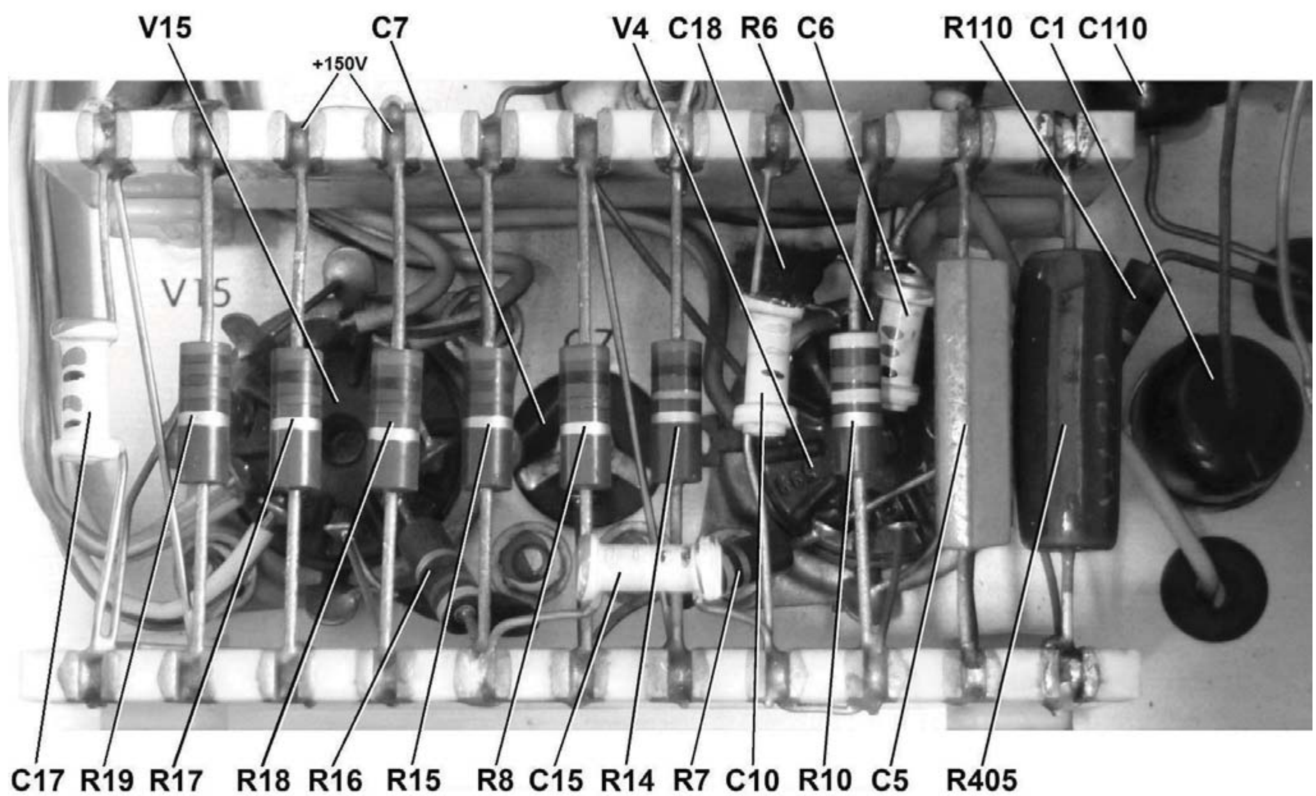


Figure 7.2 Variable Oscillator, Buffer, and Charge Diode

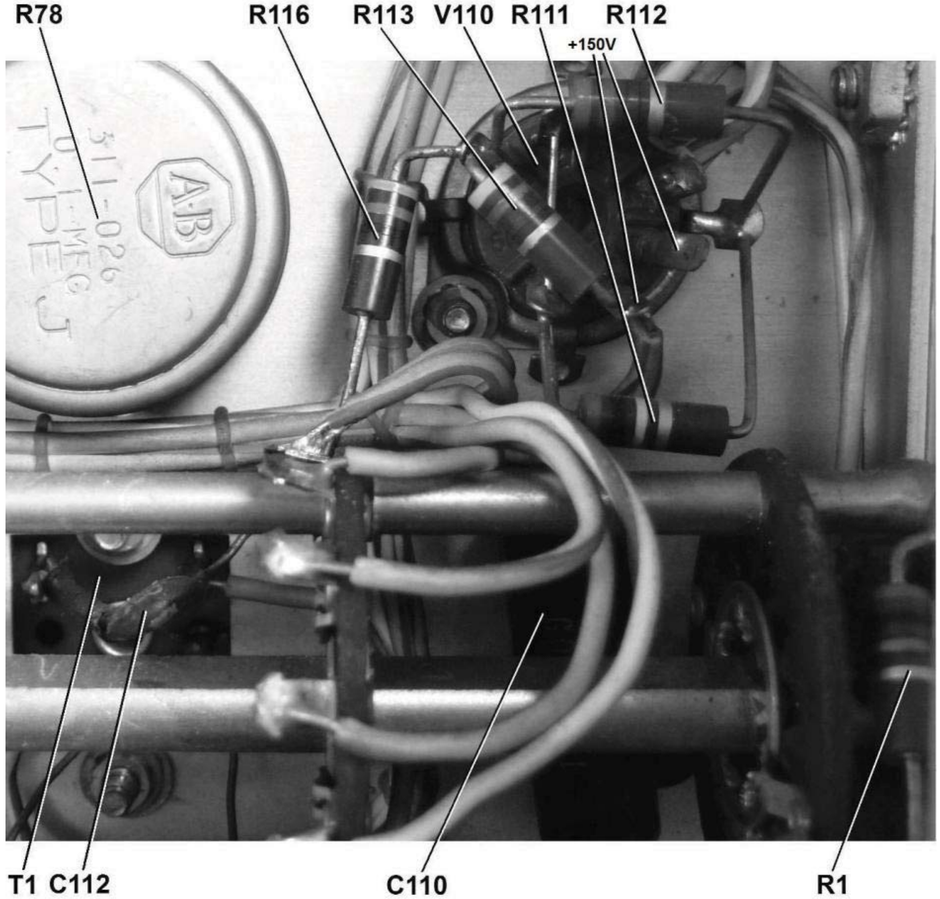


Figure 7.3 Cathode Follower

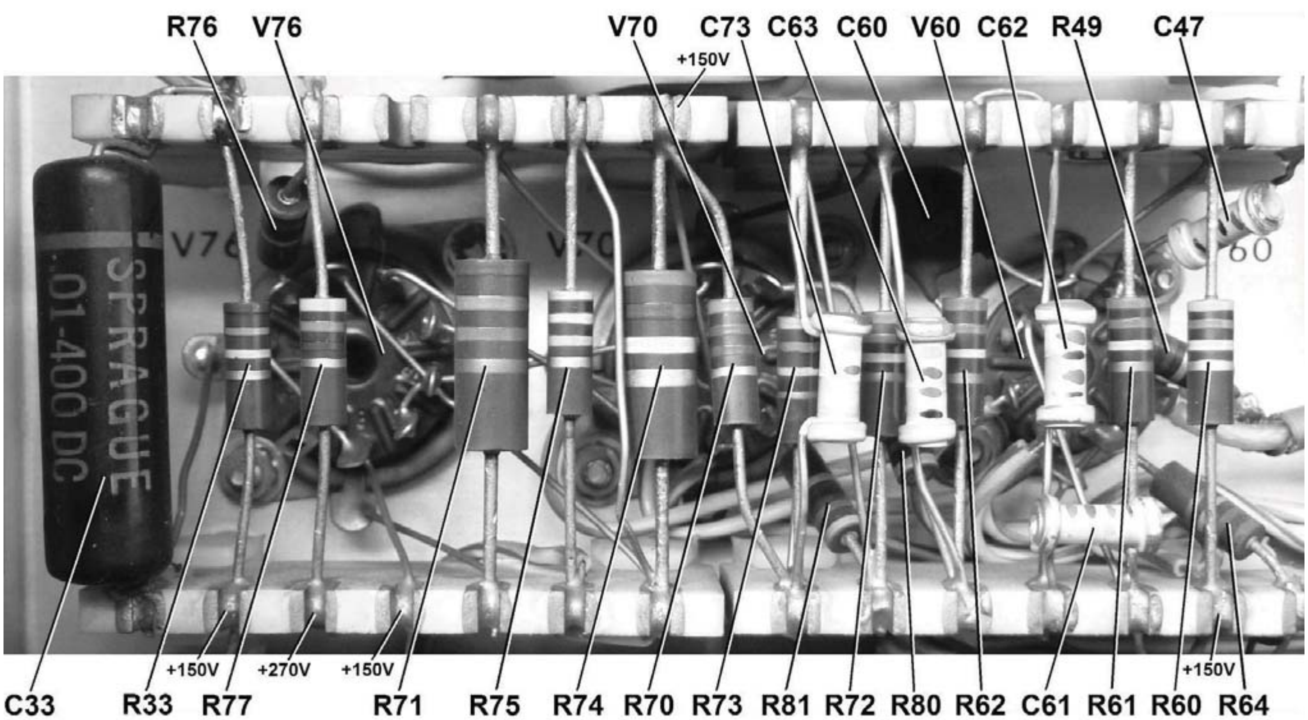


Figure 7.4 Mixer, Multivibrator and Clamp

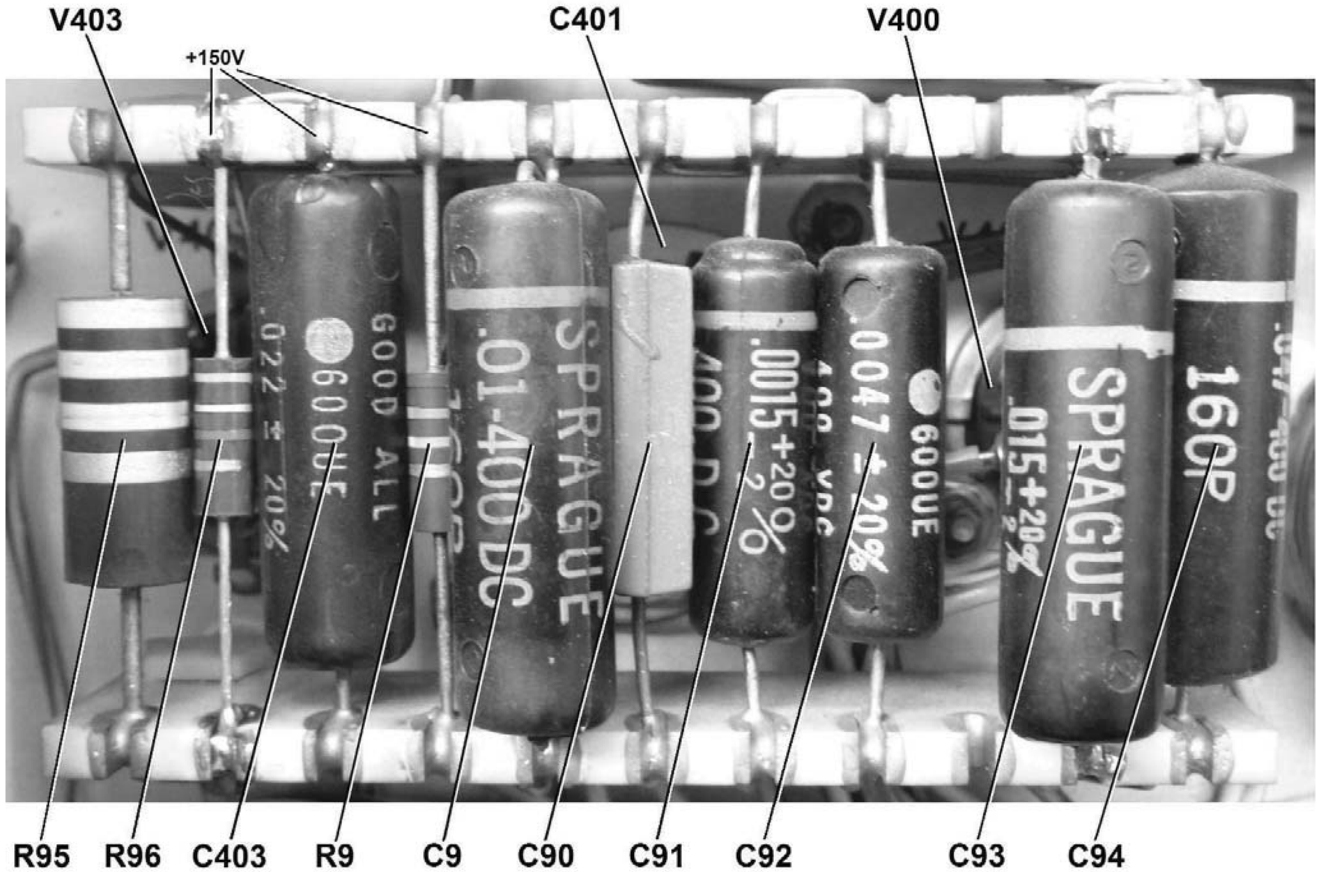
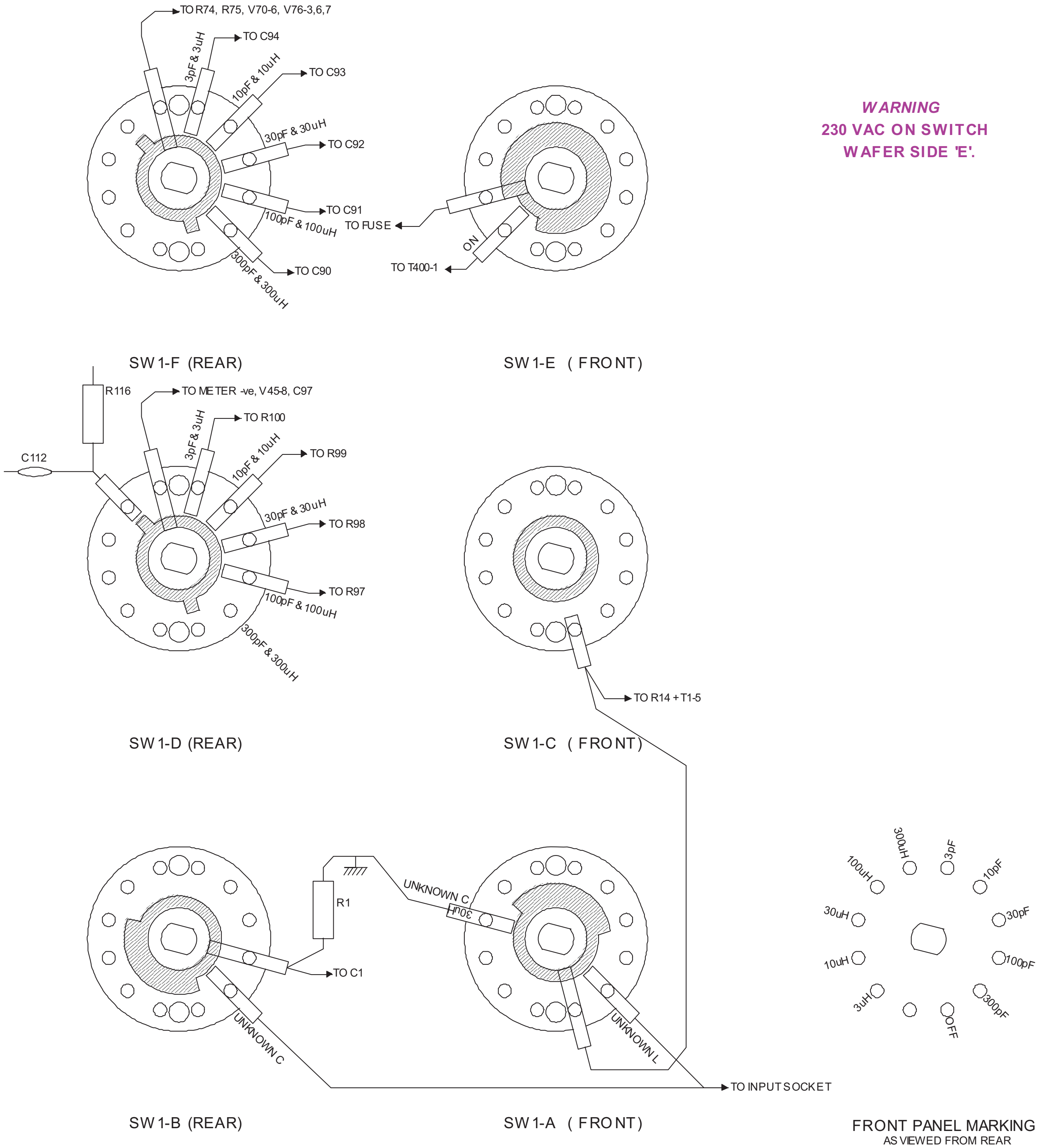
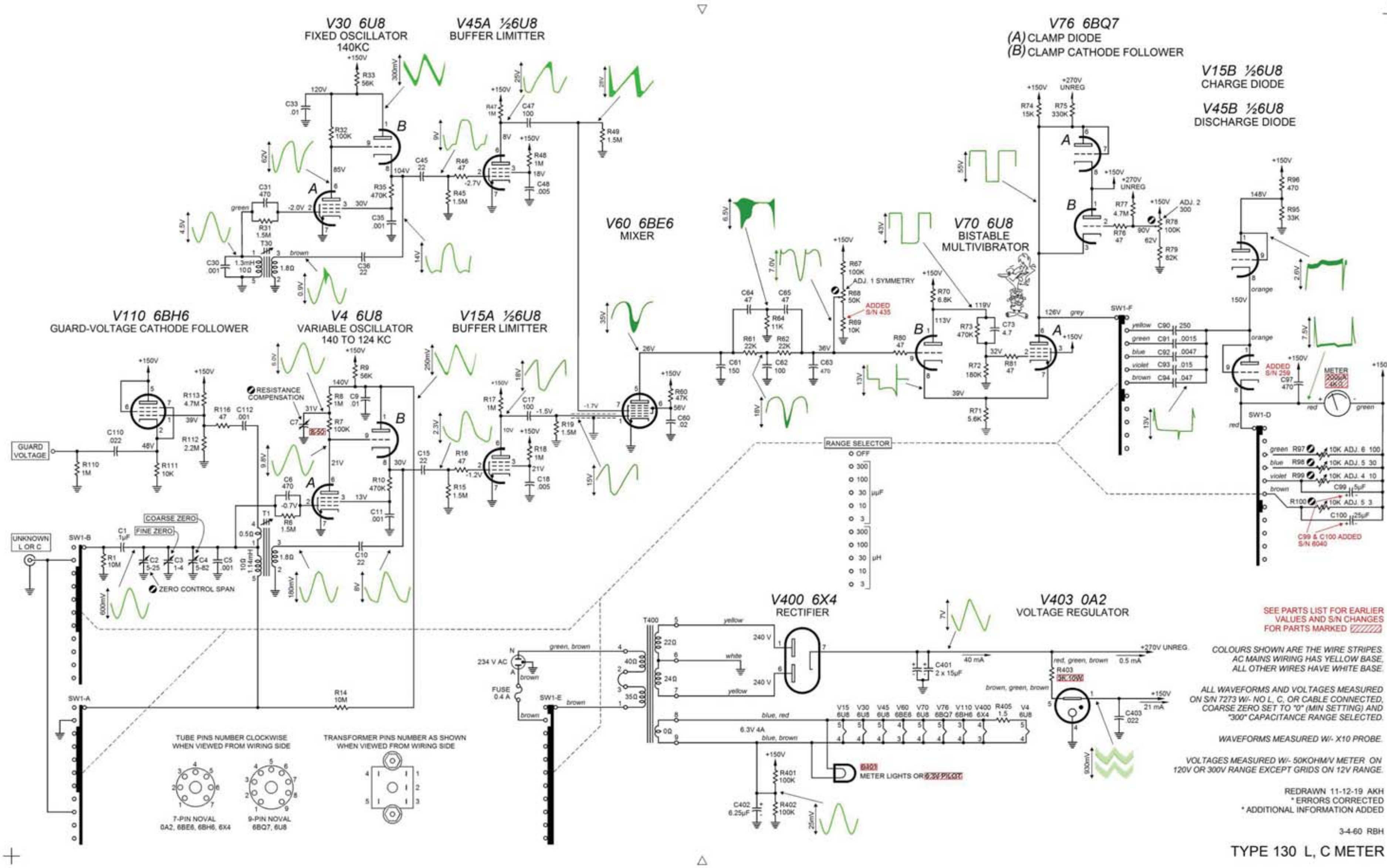


Figure 7.5 Range Capacitors and Power Supply

WARNING
230 VAC ON SWITCH WAFER SIDE 'E'.



TYPE 130 RANGE SWITCH SHOWN IN OFF POSITION
EACH DECK SHOWN AS VIEWED FROM REAR



V30 6U8
FIXED OSCILLATOR
140KC
V45A ½6U8
BUFFER LIMITTER
V76 6BQ7
(A) CLAMP DIODE
(B) CLAMP CATHODE FOLLOWER
V15B ½6U8
CHARGE DIODE
V45B ½6U8
DISCHARGE DIODE
V60 6BE6
MIXER
V70 6U8
BISTABLE
MULTIVIBRATOR
V110 6BH6
GUARD-VOLTAGE CATHODE FOLLOWER
V4 6U8
VARIABLE OSCILLATOR
140 TO 124 KC
V15A ½6U8
BUFFER LIMITTER
GUARD VOLTAGE
UNKNOWN L OR C
COARSE ZERO
FINE ZERO
ZERO CONTROL SPAN
RESISTANCE COMPENSATION
ADJ. 1 SYMMETRY
ADDED S/N 435
ADDED S/N 259
RANGE SELECTOR
OFF
µµF
µH
METER
C99 & C100 ADDED S/N 6040
V400 6X4
RECTIFIER
V403 0A2
VOLTAGE REGULATOR
234 V AC
FUSE 0.4 A
+270V UNREG.
+150V
METER LIGHTS OR 6.3V PILOT
TUBE PINS NUMBER CLOCKWISE WHEN VIEWED FROM WIRING SIDE
TRANSFORMER PINS NUMBER AS SHOWN WHEN VIEWED FROM WIRING SIDE
7-PIN NOVAL 0A2, 6BE6, 6BH6, 6X4
9-PIN NOVAL 6BQ7, 6U8
SEE PARTS LIST FOR EARLIER VALUES AND S/N CHANGES FOR PARTS MARKED
COLOURS SHOWN ARE THE WIRE STRIPES. AC MAINS WIRING HAS YELLOW BASE, ALL OTHER WIRES HAVE WHITE BASE.
ALL WAVEFORMS AND VOLTAGES MEASURED ON S/N 7273 W/- NO L, C, OR CABLE CONNECTED, COARSE ZERO SET TO "0" (MIN SETTING) AND "300" CAPACITANCE RANGE SELECTED.
WAVEFORMS MEASURED W/- X10 PROBE.
VOLTAGES MEASURED W/- 50KOHM/V METER ON 120V OR 300V RANGE EXCEPT GRIDS ON 12V RANGE.
REDRAWN 11-12-19 AKH
* ERRORS CORRECTED
* ADDITIONAL INFORMATION ADDED
3-4-60 RBH
TYPE 130 L, C METER

TYPE 130

FACTORY CALIBRATION PROCEDURE
S/N 5001-up

RECOMMENDED EQUIPMENT

500 series Tektronix scope. "L" or "B"
10X probe.
180 Time Mark Generator.
S30 Delta Standard.

PRELIMINARY INSPECTION

Check for unsoldered joints, rosin joints, wire dress, loose hardware, and check resistance to ground of transformer primaries and power supplies. (approximately 15 K for both +270 and +150) Fuse 0.8 amp slo. Preset all internal adjustments (potentiometers and capacitors) to mid-scale.

1. ZERO SET FRONT PANEL METER

Set the slotted adjustment on the front-panel meter so that the pointer indicates zero.

2. CHECK POWER SUPPLY OPERATION

Turn the <u>RANGE SELECTOR</u> switch away from the off position. Check the +150 volt for its rated voltage ±5 volts. If this falls outside of tolerance, try a different OA2 regulator tube.

Check the +270 volt supply for approximate voltage. The +150 volt supply will have approximately 0.3 volts of ripple and the +270 will be about 8 volts. The +150 should regulate from 105 to 125 line volts.

3. ADJUST THE FREQUENCY OF THE FIXED OSCILLATOR

Connect the 10X probe to either end of C47 and set the scope Time/CM switch to 5 µsec/CM. Adjust the frequency of the fixed oscillator for 7 cycles across the 10 division graticule. Now sync the scope externally from a 180 at a 100 µsec rate. Adjust the frequency of the fixed oscillator for the same presentation as obtained on internal sync except that it will not probably be possible to stop the slow drift one direction or the other. The frequency will, however, be well within tolerance. Switch the output of the 180 from 50 µsec through 1 millisecond. If the frequency is correct, the presentation will stay the same except for the brilliance of the trace due to the changing trigger rate. Now re-check with internal sync to see that there are exactly 7 cycles across the 10 divisions of graticule. It is possible to set the frequency incorrectly --- but checking with the other trigger speeds and with the scope calibration will eliminate this. The 140 kc fixed oscillator can also be set by comparison with an LM, an LR or any accurate frequency meter.

4. SET ADJ. 1 and ADJ. 2

Turn ADJ. 1 until a meter reading is obtained. Set coarse zero to about 20 degrees from CW end. Adjust T1 for minimum reading. Connect the S-30 to the unknown jack on the 130. Set the S-30 to 0 µµfd. Turn the 130 to the 3 µµfd range and use the <u>COARSE</u> and <u>FINE ZERO</u> on the 130 to zero the meter. Switch to the 300 µµf range on the 130 and the S-30. Set ADJ. 2 for full scale (300 µµf) reading. If the meter is erratic, generally a slight adjustment of ADJ. 1 will remedy this. Connect a voltmeter across R74. (20,000 Ω/volt or more) Adjust ADJ 1 to one extreme. The voltage will read in the vicinity of 50 volts. Note this reading and set ADJ. 1 for one half of this reading, approximately 25 volts. This sets the symmetry of the multivibrator. Now reset ADJ. 2 for full scale (300 µµf) reading if it has drifted.

5. ADJUST FREQUENCY OF T1 FOR CORRECT RANGE

Set the RANGE SELECTOR to the 30-μh range and set the type S-30 to the short-circuit position. Adjust the COARSE ZERO and the FINE ZERO controls for zero deflection of the meter. Now set the RANGE SELECTOR to the 300 μh position and the Type S-30 to the +300 μh position. Observe the error in the reading of the meter---the difference between the meter reading and 300 μh. Adjust T1 for an error three times as great as that just observed in the meter reading. Next set the S-30 to 0 μμf and the RANGE SELECTOR to the 3 μμf position. Reset the COARSE ZERO and the FINE ZERO controls for a meter reading of zero. Set both the S-30 and the 130 to 300 μμf. If there is any error here, reset ADJ. 2. Now switch the S-30 to short circuit and zero the meter on the 10 μh range. Switch the S-30 and the 130 to 300 μh. If there is any error here, adjust for three times the error again and re-check on the μμf ranges again. It may be necessary to go through these adjustments three or four times to get both the 300 μh and 300 μμf ranges on.

6. SET ADJ. 3, 4, 5, and 6

Set the type S-30 to 0 μμf. Adjust COARSE ZERO and FINE ZERO controls for zero reading on the meter. (130 on 3 μμf range.) Now adjust ADJ. 3 so that turning of the S-30 control to either the +3 μμf or the -3 μμf position results in a deflection of 3 on the 3 μμf range of the meter. If the two deflections are not identical, they can be made so by a small adjustment of the FINE ZERO control. (The average of deflections can be made zero, if preferred.)

Now set the S-30 to 10 μμf and the 130 to 10 μμf. Set ADJ. 4 to obtain a meter reading of 10 μμf. Next set both S-30 and 130 to 30 μμf. Set ADJ. 5 for 30 μμf. Set both to 100 μμf. Set ADJ. 6 for 100 μμf reading. Check all μh ranges for operation.

7. CHECK LINEARITY OF METER

Zero meter on 3 μμf range and then switch the S-30 to 100 μμf and the 130 to 300 μμf. The meter error must be less than 3% of full scale.

8. SET RESIST. COMP.

Switch the S-30 to 100k. Set the 130 for mid scale deflection on the 10 μμf range. Switch the S-30 to 1 meg. Adjust the RESIST. COMP. for minimum deflection while switching between 100k and 1 meg. If the adjustment is at the end of the range of the capacitor, it may be necessary to change V4.

9. SET THE RANGE OF THE ZERO CONTROLS

Turn the COARSE ZERO and FINE ZERO controls to maximum capacitance settings. (The maximum setting of the Coarse Zero control may not occur at the maximum CW position.) Set the RANGE SELECTOR to 10 μμf. Disconnect the S-30 from the Unknown jack. Set C2 for a meter indication of 7.5 μμf. Check to see that it is still possible to zero the meter by turning the COARSE ZERO in a CCW direction.

10. CHECK THE ACCURACY OF THE GUARD VOLTAGE

With no external devices or leads connected to the UNKNOWN connector, set the RANGE SELECTOR to 3 μμf. Adjust the COARSE and FINE ZERO controls for a meter indication of 1½ μμf. Touch the UNKNOWN connector with the finger, and note the direction of the meter deflection. Connect a capacitor of 100 μμf ±5% between the UNKNOWN connector and the GUARD VOLTAGE terminal. (To avoid disturbing capacitance value, hold capacitor in plastic tongs or other suitable device.) If the meter deflection is in the same direction as that obtained in the operation above, the guard voltage is low. If the change is in the opposite direction, the guard voltage is high. The percentage error in the guard voltage is indicated by the change in meter indication in μμf.

10. (continued)

The guard voltage tolerance is from -0.5% to +1.0%. If the guard voltage is out of tolerance, try replacing V110 (6BH6), check the values of R112 and R113, and consider replacing T1.

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 18

FEBRUARY 1963

THE TYPE 130 L-C METER AND THE S-30 DELTA STANDARDS

Some *Questions and Answers*

Question: In measuring the inductance of a coil with a Type 130 L-C Meter, I can increase inductance by inserting a core into the coil, but only up to a point, then the meter indication suddenly drops to zero. What is wrong?

Answer: Core losses. Many types of cores are suitable only for low frequency use, and show considerable loss (low Q) at the 120-140 kc measurement frequency of the Type 130 L-C. Core loss shows up as effective series resistance. The Type 130 L-C manual (Tektronix part number 070-231, page 2-4) provides correction tables for L measurements with *known* series resistance up to 40 ohms. When series resistance reaches about 75 ohms, the Q of the entire variable oscillator tank circuit has dropped to a level beneath that required to sustain oscillation, and the meter circuit—unable to follow a "difference" frequency of 140 kc—ceases to function. Therefore, do not rely on the Type 130 to measure coils which owe most of their inductance to their cores, particularly where the core material is intended for low-frequency use. The Type 130 is intended primarily for measuring coils having high Q at 120-140 kc.

Question: I understand that a S-30 Delta Standards can be "certified," traceable to N.B.S. Is this right?

Answer: Yes. On an order for a new S-30, simply request a certificate of traceable calibration. There is no extra charge; but, allow extra time.

Question: Why can't L15 (300 μh) in the S-30 be measured on a bridge?

Answer: Actually, L15 could be calibrated on a bridge *if* you had a bridge which operated at 120-140 kc. Most bridges at 1 kc, however, and most "Q" meters don't provide drive frequencies below 1 Mc. Since L15 has a powdered-iron core, its inductance at 120-140 kc will not be quite the same as its inductance at 1 kc or 1 Mc. In addition, shunt capacitance across L15, representing perhaps 1/3 of 1% of L15's admittance at 140 kc, will throw a measurement at 1 Mc off by about 20%.

Question: How does the "Inductance Standardizer," mentioned in the Type 130 L-C manual, work? Isn't it "circular calibration" to use the Type 130 to check its own standard?

Answer: The Type 130 L-C is used only as a frequency source and null indicator for adjustment of L15 in the S-30. The actual scale calibration of the Type 130 is not important. What is important is that the Type 130's fixed oscillator be within frequency tolerance (± ½ kc or ± 0.35%).

The inductance standardizer circuit consists of two circuits: a capacitor which is resonant at 140 kc with 300 μh, and a resistor which has the same resistance as the series-resonant circuit of 4310 pf and L15 where they are resonant at 140 kc.

The Type 130 is first adjusted so that the variable oscillator produces just 140 kc (zero beat with the fixed oscillator) in the 300 μh position when looking into a circuit which appears to be a (nearly) pure resistance of 7.5 ohms at 140 kc.

The Type 130 is then connected to the series circuit of 4310 pf and L15. If this circuit is resonant at 140 kc, the Type 130 meter reads "zero."

If L15's value is too high, the series circuit presents an inductive reactance to the Type 130, forcing the variable oscillator frequency down and causing the meter to read upscale. If L15's value is too low, the inductance standardizer appears as a capacitive reactance (negative inductance) in series with the inductance of the variable oscillator tank coil, forcing the variable oscillator frequency up. Since the meter circuitry reads only the "difference" between the fixed and variable oscillator frequencies, without regard to which is higher, an increase in variable oscillator frequency also reads upscale on the meter.

The 100 to 400 μh inductor across the input to the inductance standardizer is there to complete the oscillator's dc grid return, which is blocked by the 4310 pf capacitor. Since it is in the circuit both during the zeroing operation and during L15 standardization, its small reactive effect across the 7.5 ohm circuit (its reactance is 90-350 ohms at 140 kc) has no material effect on the operation. A low-value resistor here would swamp the null, so an inductor is used.

Question: The 130 L-C manual says to use 2% components in constructing the inductance standardizer. Will a standardizer, so constructed, be adequate to hold 1% calibration of L15?

Answer: No! 2% components will assure calibration to only within about 3%. The 4310 pf capacitor should be made up of stable, low-loss units (such as silvered micas) bridged out to ±½%, or closer at 1 kc or—preferably—140 kc. Tolerance on the 7.5 ohm resistor is not critcal. The inductor can be any convenient value between 100 and 400 μh.

Question: I'm piping the multivibrator output from the Type 130 L-C into a highly accurate frequency counter in order to obtain 0.01% resolution and 0.1% accuracy. The Type 130 seems to drift considerably with temperature and line voltage. Can I put a 140 kc crystal into the fixed oscillator circuit?

Answer: You can, but you'll wish you hadn't. The two oscillators (fixed and variable) in the Type 130 use identical transformers and component types so they will be self-compensating. Tie one of them down "solid" and you increase thermal sensitivity and drift by a factor of seven or more.

We designed the Type 130 L-C as a 3% device. With *careful*—and we repeat, *careful*—calibration it will give 1% (of full scale) accuracy. No part of its circuitry is so far overdesigned as to permit reliance on it to provide greater accuracy than the meter gives. We do not represent the Type 130 L-C to operate except as a self-contained "system."

Question: I'm experiencing some difficulty in measuring capacitance in a small relay assembly on my bench. Even though I keep it away from all metal objects, "guard" all unwanted contacts and use the P93C probe, I obtain two different C readings between points X and Y, depending upon which side I ground. What's going on?

Answer: The surface of your bench may be slightly conductive, thus forming a grounded capacitor "plate" which will have more capacitance to the larger or less isolated contact. Try slipping your Type 130 L-C manual under the relay. If this improves your measurements, you may want to build an insulated platform on which to make your more critical measurements; or, you might consider putting the relay into a guarded enclosure.

VINTAGE WORKBENCH

The Tektronix Type 130 LC Meter – Part 1

How it works

By Alan Hampel, B. Eng. (Electronics, Honours)

Unfortunately this sort of thing does happen. I was ripped off by a dodgy eBay seller – sold a bill of goods, you could say. But this story has a happy ending. I had a lot of fun converting a dirty, unusable relic into an as-new laboratory instrument with a rich history.

The T-130 LC meter from Tektronix was built from 1954 until 1975 and has five capacitance measuring ranges (3pF, 10pF, 30pF, 100pF and 300pF) with 1% FSD accuracy and a stable zero. Thanks to its 4.5-inch (~11.5cm) meter, it can easily resolve down to 0.05pF. It also has five inductance ranges from 3µH through to 300µH.

I bought it because I needed a capacitance meter that could accurately resolve sub-picofarad values for a project. I also collect and restore valve test gear, so the T-130 seemed like an ideal candidate. As such, one for sale on eBay caught my eye. The price was very reasonable, and it looked clean and original in the photos, so I bought it.

The seller claimed he had run it for a couple of days with a 25pF capacitor, and got a correct stable reading.

When it arrived, the package was not damaged, but turning it over produced clunking sounds. That's a bad sign!

As it turned out, the instrument was generously coated inside and out with cigarette smoke residue, and was inoperative due to many faults.

The origin of the T-130

During Tektronix's early days (see the side panel for a brief history), they needed an instrument to measure small capacitances, eg, stray wiring capacitance and valve capacitances, as well as small inductances. The production lines needed a stable instrument, usable by semi-technical operators. The lab needed accuracy and sub-picofarad sensitivity.

After joining Tek in 1951, young engineer Cliff Moulton designed the T-130 to meet just these needs.

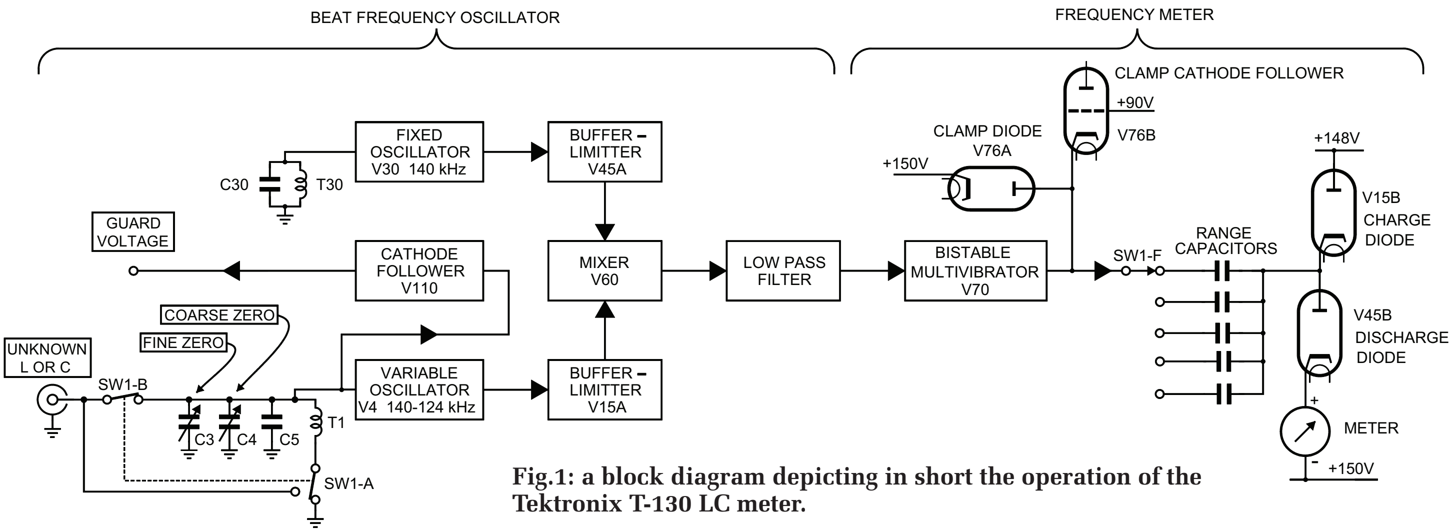


Fig.1: a block diagram depicting in short the operation of the Tektronix T-130 LC meter.

The T-130 was not intended for sale to Tek's customers – it was purely for use in the factory. It therefore wasn't designed and engineered to quite the same standards as Tek's catalog products. It was quite cramped inside, with components hidden under other parts, compromising ease of repair. But it used innovative circuitry, offered excellent performance and was easy to use.

Factory visitors noticed it in use, and many asked if they could buy one. So it was cleaned up and documented, with production beginning in 1954. It remained in the catalog until 1975, indicating just how good an instrument it was.

How it works

It operates on the beat-frequency oscillator principle. Refer to the block diagram, Fig.1; a built-in analog frequency meter responds to the difference in the frequency of two oscillators. The capacitance (or inductance) under test forms part of the tuned circuit of one of the oscillators, thus shifting its frequency.

The fixed oscillator runs at 140kHz, set by tuned circuit C30/T30.

With RANGE SELECTOR switch SW1 in any of the "µµF" (picofarad) positions, the variable oscillator is tuned by T1 and the capacitance connected to the UNKNOWN jack plus capacitors C2-C5. With SW1 in any of the "µH" positions, the tuned circuit comprises C3-C5 and T1 in series with any inductance connected to the UNKNOWN jack.

C3 and C4 are adjusted to get 140kHz from the variable oscillator with whatever wiring or cabling capacitance or inductance appears on the UNKNOWN jack. When the capacitor or inductor under test is connected, the variable oscillator frequency drops below 140kHz in approximate proportion to its value.

An LC oscillator's frequency is proportional to the square root of total tuning capacitance and to the square root of total inductance; but in this case, the change is kept approximately linear by keeping the highest calibrated inductance or capacitance under test to a small fraction of the total. The meter scales are calibrated to match.

After passing through buffers (operating in an overdriven, limiting mode) to prevent the oscillators from coupling together and synchronising, the two frequencies are mixed, and a low pass filter substantially removes all but the difference frequency. The difference frequency is approximately 62Hz per UNKNOWN pF or µH, and is fed to a bistable circuit (Schmitt trigger) to make the waveform rectangular.

Each time the multivibrator output jumps to its low level, the 'clamp cathode follower' turns on and holds the output very close to +90V (set by 100kΩ resistor R78), as the impedance of a cathode follower is 1/gm – in this case, 160Ω. The selected range capacitor is charged to +150V less the 90V via the charge diode. The amount of charge is always the same.

Each time the multivibrator output jumps to its high level, the cathode follower is cut off, and the clamp diode limits the voltage to very close to +150V. The range capacitor is discharged via the discharge diode into the meter. The meter thus receives a pulsating direct current with an average magnitude accurately proportional to frequency.

The history of Tektronix

Tektronix was founded in December 1945 by four friends: Howard Vollum, a young engineer/physicist; Jack Murdoch, radio technician; Glen McDowell, accountant; and Miles Tippery, who served with Murdoch and McDowell in the US Coast Guard during World War II. Vollum was the president and chief engineer.

Tektronix, or "Tek" as it became known, started at the beginning of the post-war golden age of the American electronics industry. Their innovative and high-class products led to rapid growth.

This was a time when the captains of industry were often engineers, passionate about making the very best of products. This includes the founders of HP, Bill Hewlett and Dave Packard, the Varian brothers with Hansen and Grinzton at Varian Associates, Melville Eastham at General Radio and Howard Vollum, passionate about oscilloscopes, at Tek.

It was quite different from today's business leaders, who seem to care much more about the financial side of the business than the 'nitty-gritty'.

Tek focused on laboratory-quality oscilloscopes and quickly revolutionised the industry, driving the US oscilloscope leader DuMont out of the market.

Why 140kHz?

As readings go below about 0.3pF (difference frequencies <18Hz), the meter pointer increasingly shakes, as the pointer then responds to individual pulses from the multivibrator. So you wouldn't want the oscillator frequencies to be any lower.

Resonance at 140kHz occurs with values of L and C of 1136μH and 1136pF respectively. These values are sufficiently larger than the instrument's top range of 300μH and 300pF full-scale that the meter is acceptably linear. You wouldn't want it any less linear.

When the instrument was designed (about 1951), very few electronics laboratories had a frequency counter, so some other method was needed for calibration. While folk involved with radio transmitters had analog heterodyne frequency meters such as the BC-221, everybody had an AM radio receiver.

In most parts of North America, high-power clear channel broadcast stations were easily received at frequencies that were multiples of 140kHz, such as WLW (700kHz), WHAS (840kHz) or KMOX (1120kHz).

So, by running a wire from the buffer output to near the radio antenna, you could tune for a null beat note, and thereby set the fixed oscillator very accurately.

And if you could not pick up a clear channel station, you could probably receive a local station on 980kHz – the 7th harmonic of 140kHz. If you couldn't do that, the 5th harmonic from the T-130 could be nulled against the 7th harmonic from your trusty 100kHz quartz reference oscillator.

Careful and thoughtful design

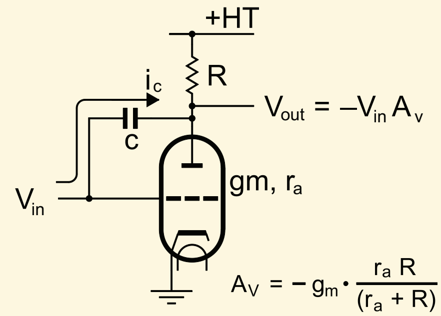
The full circuit is shown in Fig.2; it's quite complex for an LC meter. But it's clear that Cliff Moulton took care with the design to ensure the instrument is stable and accurate.

Many cheap capacitance meters employ the capacitor under test as the timing element in a multivibrator, and so interpret high leakage or shunt resistance as increased capacitance. But the T-130 substantially ignores resistance unless it lowers the Q enough to stop oscillation.

So the instrument either reads correctly or not at all. This is explained further in the panel detailing the oscillator design.

The Miller effect

The Miller effect is where any capacitance between the input and output of an inverting amplifying stage (triode, pentode, transistor, FET, op amp etc) makes the input impedance appear to include a much larger shunt capacitance.



In the circuit shown, Vout appears across the load R in parallel with the valve internal anode resistance r_a. The stage voltage gain for low values of C (ie, where the reactance of C is much larger than R) is $A_V = -gm \times r_a \times R \div (r_a + R)$. The negative sign denotes phase inversion.

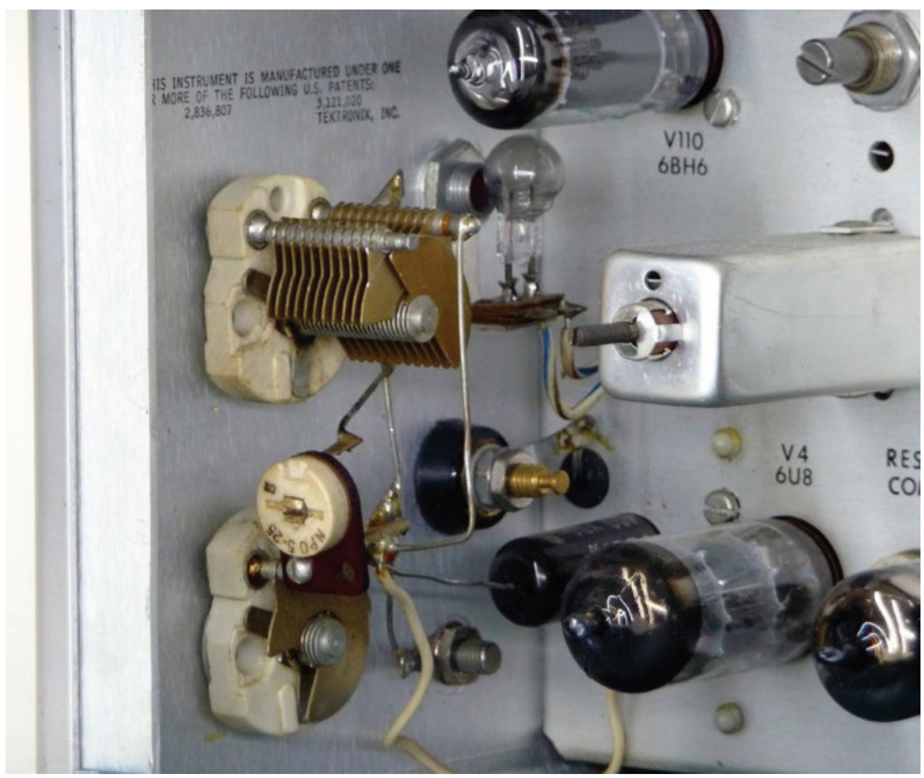
For typical triodes in typical circuits, Av is around -10 to -40. The capacitor then sees a voltage across it of ($V_{IN} + A_V \times V_{IN}$), ie, $V_{IN} \times (1 + A_V)$, and its current is thus increased by the A_V term.

Since the capacitor current is also included in the input current, the input impedance (the load on the previous stage) appears to include, in addition to the grid-cathode capacitance, a shunt capacitance of $C \times (1 + A_V)$ or approximately 10-40 times C.

The capacitor C comprises tube internal grid-anode capacitance, tube socket capacitance and any stray capacitance due to proximity of grid wiring to anode wiring.

The Miller effect with triodes, by its large capacitive load on any previous stage, typically causes the bandwidth of the preceding stage to be a small fraction of what it otherwise would be.

For more details, see John M Miller, Dependence of the input impedance of a three-electrode vacuum tube upon the load in the plate circuit, Scientific Papers of the Bureau of Standards, 15(351), pp367-385, 1920, USA.



A close-up of part of the variable oscillator section, incorporating V4 and variable capacitors C2-C5, as described in the panel labelled "An ingenious oscillator design".

The cathode interface layer

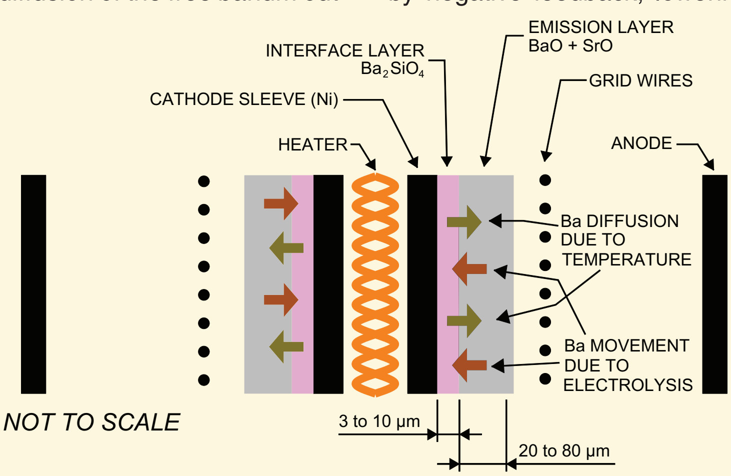
The nickel used in cathode sleeves before the early 1950s usually contained trace amounts (~0.05%) of silicon. During factory processing, and sometimes during early service, silicon diffuses to the surface and reacts with barium oxide. This forms a microscopically thin 'interface layer' of barium orthosilicate between the nickel sleeve and the oxide emission layer:

$$Si + 4BaO \rightarrow Ba_2SiO_4 + 2Ba$$

Pure barium orthosilicate has very high resistivity. As the interface layer is so thin and has free barium atoms within it, the resistance is low, and it does not initially affect tube operation. During tube operation, the high temperature required for emission drives diffusion of the free barium out of the interface layer, increasing the resistance.

Fortunately, cathode current causes barium atoms to diffuse back into the interface layer via an electrolysis process. The balance of these opposing effects results in interface resistance being quite sensitive to heater voltage. A 10% drop in heater voltage reduces cathode temperature by about 3.5% and interface resistance for a given cathode current by about 50%. The diffusion processes are very slow.

Interface layer resistance has the same effect as any resistance in series with the cathode; it increases cathode bias, possibly biasing the tube back to where the gain is lower, and also, by negative feedback, lowering gm.



Note that although the tube may test low for gm, its emission can be entirely normal.

A tube with low gm due to the interface layer can usually be rejuvenated by operating it in a tube tester or rejuvenator with the maximum rated cathode current for a few days or more. This is not to be confused with rejuvenating a low emission tube by running it with a high heater voltage, which often doesn't work. And if it does, it's only for a while.

As the interface layer is so thin, it makes a pretty good RF bypass capacitor for its own resistance. Thus, you can easily detect the presence of an interface layer by measuring gm at an audio frequency and at RF, say 2MHz. The gm at 2MHz will be normal (unless the valve has some other fault), but the gm at audio frequencies will be lower.

Valves manufactured after about 1955 generally have high-purity cathode sleeves (less than 0.001% silicon), markedly reducing interface layer thickness and avoiding these problems.

Reference: M. R. Child, The Growth and Properties of Cathode Interface Layers in Receiving Valves, The Post Office Electrical Engineers' Journal, Vol 44[4], pp176-178, London 1952.

The variable oscillator operates under starvation conditions – very low anode and screen current – which results in a high gain. This means only 600mV peak-to-peak on the tuned circuit, even though the output to the buffer is quite high.

The low amplitude on the tuned circuit not only reduces the chance of forward-biasing junctions when in-circuit testing. It also means that the T-130 can be used to measure the Miller effect, as typical triode circuits under test will not be driven into overload. If you aren't familiar with the Miller effect, see the panel with the same name at upper left.

Running a valve under starvation conditions gives a high space charge density. The 6U8 triode-pentode variable oscillator valve (V4) has its heater voltage reduced by 1.5Ω resistor R405. This reduces the effect of any interface layer and reduces space charge, so oscillator drift with AC mains voltage better matches the fixed oscillator.

See the panel later in this article for an explanation of space charge density, and above for the interface layer.

The meter is pegged to the +150V rail and not ground as might be expected. This reduces the average DC voltage across the range capacitor, so that it's much less likely to develop leakage, and any leakage won't matter as much.

Bistable multivibrator

The circuit around V70 is called a bistable multivibrator by Tektronix but will be known to most people as a Schmitt trigger, after American Otto H. Schmitt, who invented it in 1934. Considerable positive feedback via common-cathode 5.6kΩ resistor R71 forces the pentode section, V70A, to operate in two fixed states – cut off, or drawing 4.2mA anode current.

When triode V70B is cut off, pentode V70A is on, due to the voltage divider R73 and R72 (470kΩ & 180kΩ respectively). 43V is dropped across R71 – a pentode cathode current of 7.7mA. Hence, the screen-to-cathode voltage is 110V, and the 6U8 data sheet shows that the screen draws 3.5mA at this voltage. Hence the anode current is 4.2mA (7.7mA - 3.5mA).

When the input from the filter rises above V70B's grid cut-off level (about 37V), V70B begins to turn on, reducing the voltage to V70A's grid. So V70A begins to turn off, dropping the voltage on R71. This turns on V70B harder, and the circuit immediately snaps over to V70B fully on with V70A cut off.

C73 compensates for wiring and socket stray capacities and ensures the snap action is fast.

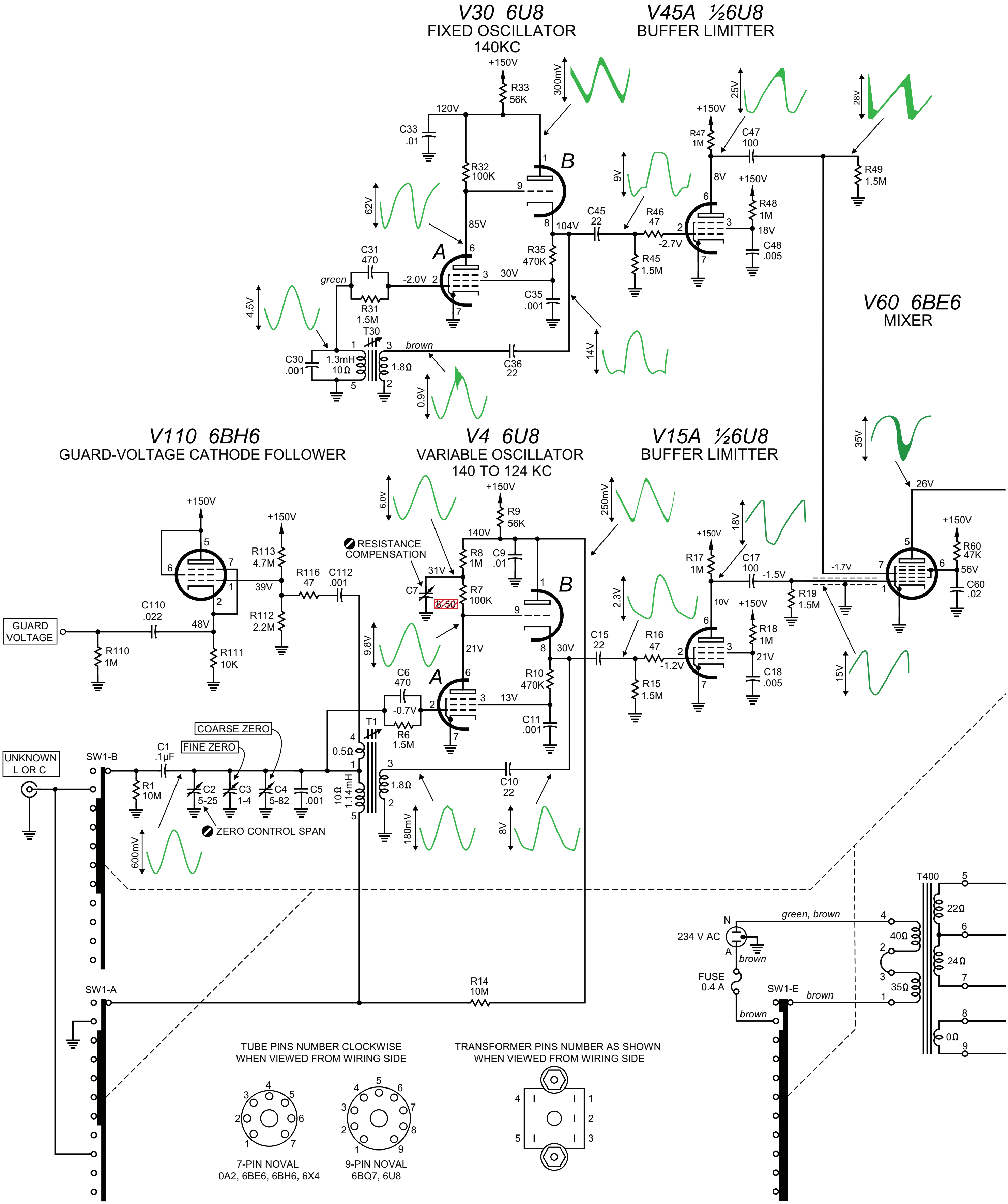
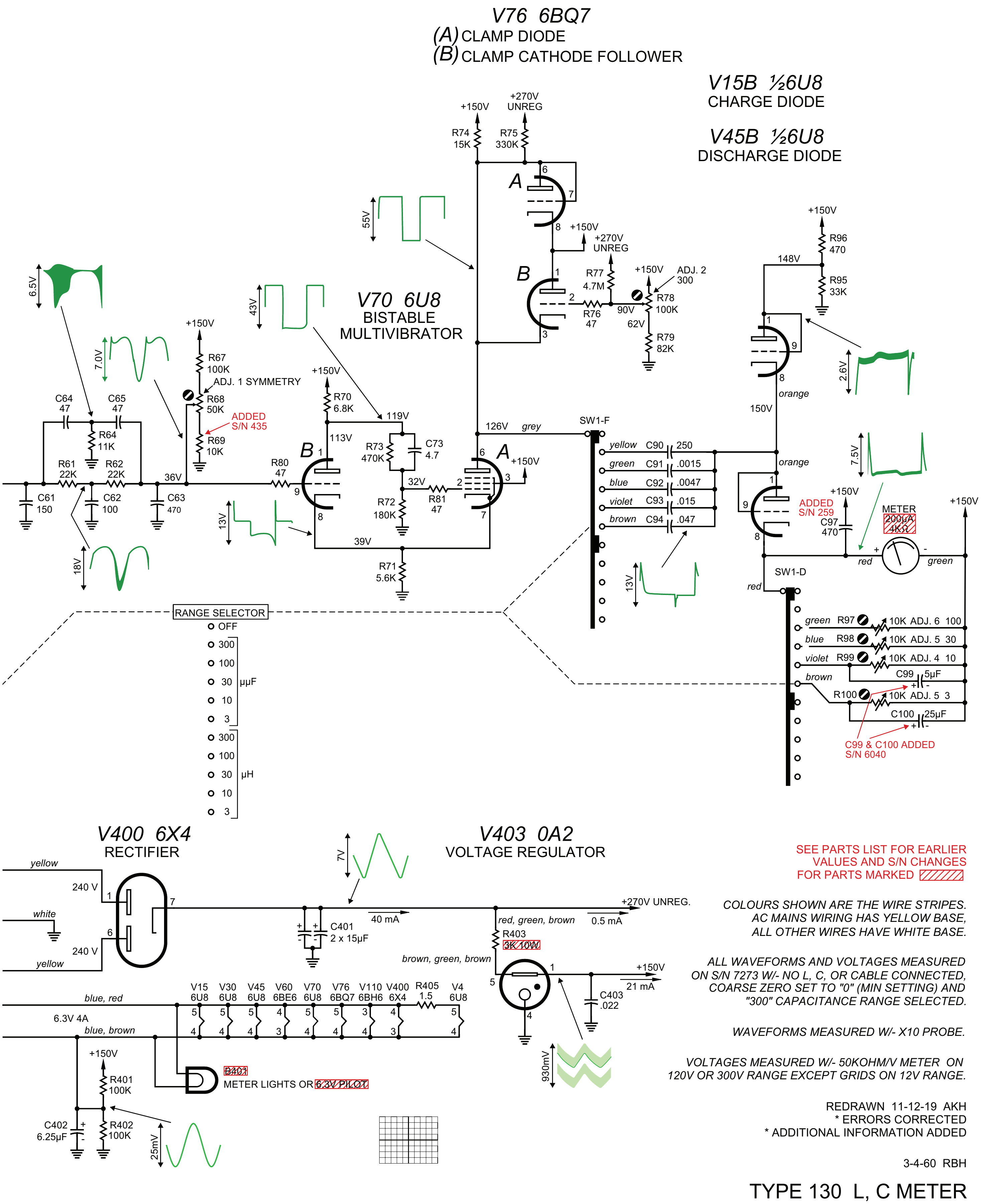
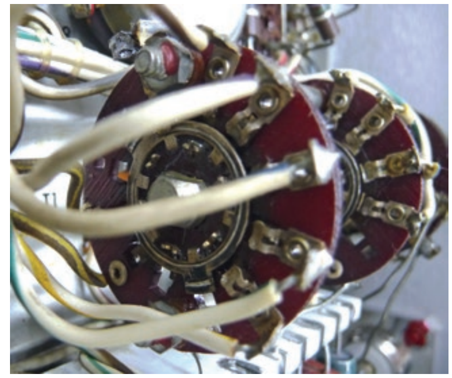


Fig.2: complete circuit diagram for the Tektronix T-130 LC meter.



V76 6BQ7
(A) CLAMP DIODE
(B) CLAMP CATHODE FOLLOWER
V15B ½6U8
CHARGE DIODE
V45B ½6U8
DISCHARGE DIODE
V70 6U8
BISTABLE
MULTIVIBRATOR
+150V
+270V UNREG
R74 15K
R75 330K
55V
6.5V
43V
7.0V
R67 100K
ADJ. 1 SYMMETRY
R68 50K
ADDED S/N 435
R69 10K
R70 6.8K
119V
113V
R73 470K
C73 4.7
32V
R81 47
R72 180K
R80 47
36V
C64 47
C65 47
R64 11K
R61 22K
R62 22K
C61 150
C62 100
C63 470
13V
18V
39V
R71 5.6K
126V grey
SW1-F
R77 4.7M
R76 47
90V
62V
ADJ. 2 300
R78 100K
R79 82K
yellow C90 250
green C91 .0015
blue C92 .0047
violet C93 .015
brown C94 .047
R96 470
148V
R95 33K
2.6V
orange
150V
7.5V
ADDED S/N 259
C97 470
METER
200µA
4KΩ
red
green
SW1-D
green R97 10K ADJ. 6 100
blue R98 10K ADJ. 5 30
violet R99 10K ADJ. 4 10
brown C99 5µF
R100 10K ADJ. 5 3
C100 25µF
C99 & C100 ADDED S/N 6040
RANGE SELECTOR
OFF
300
100
30 µµF
10
3
300
100
30 µH
10
3
V400 6X4
RECTIFIER
V403 0A2
VOLTAGE REGULATOR
7V
yellow
white
240 V
C401 2 x 15µF
40 mA
+270V UNREG.
red, green, brown
0.5 mA
R403 3K 10W
brown, green, brown
21 mA
C403 .022
930mV
blue, red
6.3V 4A
blue, brown
V15 6U8
V30 6U8
V45 6U8
V60 6BE6
V70 6U8
V76 6BQ7
V110 6BH6
V400 6X4
R405 1.5
V4 6U8
R401 100K
R402 100K
C402 6.25µF
25mV
B401
METER LIGHTS OR 6.3V PILOT
SEE PARTS LIST FOR EARLIER VALUES AND S/N CHANGES FOR PARTS MARKED
COLOURS SHOWN ARE THE WIRE STRIPES.
AC MAINS WIRING HAS YELLOW BASE,
ALL OTHER WIRES HAVE WHITE BASE.
ALL WAVEFORMS AND VOLTAGES MEASURED
ON S/N 7273 W/- NO L, C, OR CABLE CONNECTED,
COARSE ZERO SET TO "0" (MIN SETTING) AND
"300" CAPACITANCE RANGE SELECTED.
WAVEFORMS MEASURED W/- X10 PROBE.
VOLTAGES MEASURED W/- 50KOHM/V METER ON
120V OR 300V RANGE EXCEPT GRIDS ON 12V RANGE.
REDRAWN 11-12-19 AKH
* ERRORS CORRECTED
* ADDITIONAL INFORMATION ADDED
3-4-60 RBH
TYPE 130 L, C METER



This socket connects to the RANGE SELECTOR on the front panel. The visible ring connects to V70's anode, and the crimped lugs of the ring on the other side connect to the 230V AC mains input.

Shown above is the T-130 testing an MSA 100pF capacitor, which returned a reading of ~98pF. Below is a short description of the controls on the front panel:
<u>RANGE SELECTOR</u>: an 11-position switch (five each for capacitance and inductance), which also functions as the power switch.
<u>COARSE ZERO</u>: used to adjust for capacitance in connecting leads or connectors.
<u>FINE ZERO</u>: finer range adjustment compared to COARSE ZERO.
<u>GUARD VOLTAGE</u>: used to cancel out the influence of any other component connected to the part under test.

While V70B is on, it acts as a cathode-follower and thus the voltage across R71 is about 2V more than the input voltage at V70B's grid. When the input from the filter is reversing later in the cycle and drops to about 35V, V70B starts to turn off, turning on V70A via the voltage divider formed by R72 and R73. V70A then raises the voltage across R71, forcing V70B further off and the circuit snaps back.

Thus, V70A snaps from cut-off to drawing a constant 4.2mA when the filter output rises above 37V, and snaps back to full cut-off when the filter output falls below 35V. The filter output considerably exceeds this range.

Guard cathode follower

V110 (6BH6) is a pentode connected to function as a triode cathode-follower. It takes a signal from the variable oscillator tuning coil and makes it available as a low-impedance (250Ω) guard signal on the front panel.

Since the voltage gain of a cathode follower is slightly less than unity, the cathode follower is driven from an over-wind on the tuning coil to compensate.

You can connect the guard output to the other end of any components connected to the item under test. Because there is then the same voltage at both ends of these components, the T-130 ignores them and gives a true reading.

Power supply

V400, a 6X4, rectifies the AC from the power transformer to derive the unregulated 270V HT rail. A 0A2 (V403) regulates the 150V rail. The 0A2 is a cold-cathode gas-filled valve that performs the same function as a zener diode.

The valve heaters are run at 75V above ground. This is because the heater-cathode rating of the valves is only 100V. Since some cathodes are at or near ground, and some are at +150V, the heaters are run halfway between to keep all valves within their ratings.

Next month

That concludes the description of how the T-130 works. But what about the one that I purchased? What was wrong with it? How did I fix it? Don't worry; I have documented all the work in detail.

It will be described over the next two issues, starting with the aesthetic restoration and finishing up with circuit repairs and calibration.

Space charge capacitance

Valve cathodes are typically designed to emit electrons at about 2.5 times the rated maximum cathode current.

Taking the 6U8 pentode as an example, the rated maximum cathode current is 13mA, so the emission should be 33mA. In typical use, the sum of the anode and screen current would be around 4mA due to negative grid bias. The current is even less in the T-130 variable oscillator valve (V4).

So if the cathode is emitting 33mA, and only 4mA is getting past the grid, what happens to the remaining 29mA? It goes back into the cathode!

In any conductor, conduction electrons are in continuous motion whizzing about at random velocity and direction. Collisions with atoms continually cause electrons to change direction. But at ordinary temperatures, practically none have enough inertia to escape the conductor due to the attraction of nearby nuclei – if electrons are not bound to particular nuclei, the nuclei must have a positive charge.

By heating the cathode, we raise the velocity of the conduction electrons so that some have enough inertia to escape. Any electrons leaving the cathode that are more than the number required to make up the anode current (which must return to the cathode via the external circuit) leave a positive charge in the cathode. So these excess electrons are inevitably sucked back into the cathode.

They follow individual parabolic paths outside the cathode, much like stones thrown up into the air returning to the ground. Negative grid bias encourages more of these electrons to give up and return to the cathode.

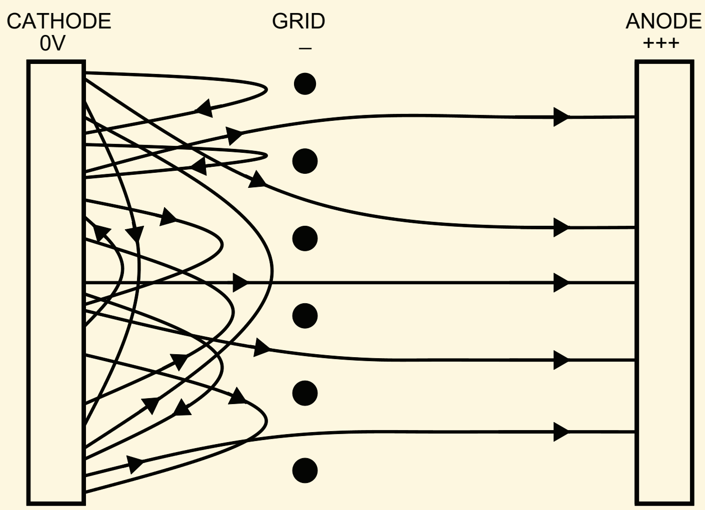
The cloud of electrons between the cathode and grid is called a "space charge" and tends to self-limit in local density, as space charge electrons repel more electrons leaving the cathode.

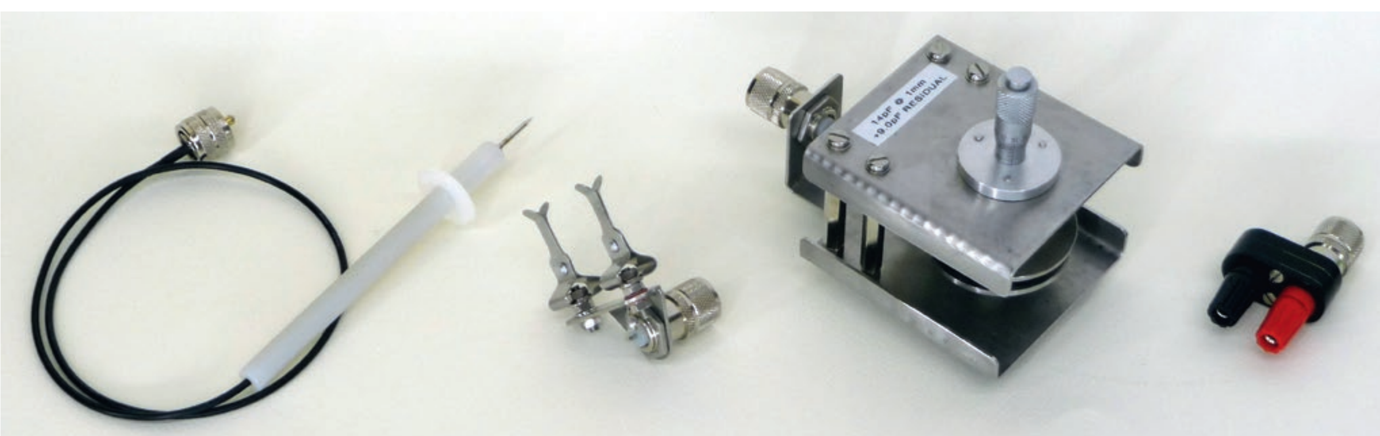
But it is considerably denser than the electron density between the grid and anode. The lower the anode and screen current, the denser the space charge. Our 6U8 example cathode always emits 33mA, but it may have up to 33mA returning.

The space charge electrons are in frequent contact with the cathode, and can be influenced by a varying electric field, so they constitute an electrical conductor, just as electrons do within a metallic conductor. So, we have a conductor – the space charge – near to, but not touching, another conductor – the negative grid. That's a capacitor! And it has a plate spacing less than the physical grid-cathode spacing.

The space charge capacitance typically adds 0.5-2.5pF to the inherent capacitance of the grid-cathode structure. This capacitance decreases with increasing grid bias (a more negative grid pushes the space charge further back toward the cathode) and increases with decreasing anode + screen current.

It increases about 10% for each 1% increase in heater voltage; hence, heater voltage variation due to AC mains variation is a significant cause of frequency drift in grid-tuned oscillators. An increase in heater voltage causes a decrease in oscillator frequency.





Shown above are a variety of homemade adaptors which can be connected to the UNKNOWN jack on the front panel. The largest one (second from the right) is a variable space capacitor for measuring permittivity – the degree that an insulating material increases capacitance between the plates over the capacitance obtained with air or vacuum spacing.

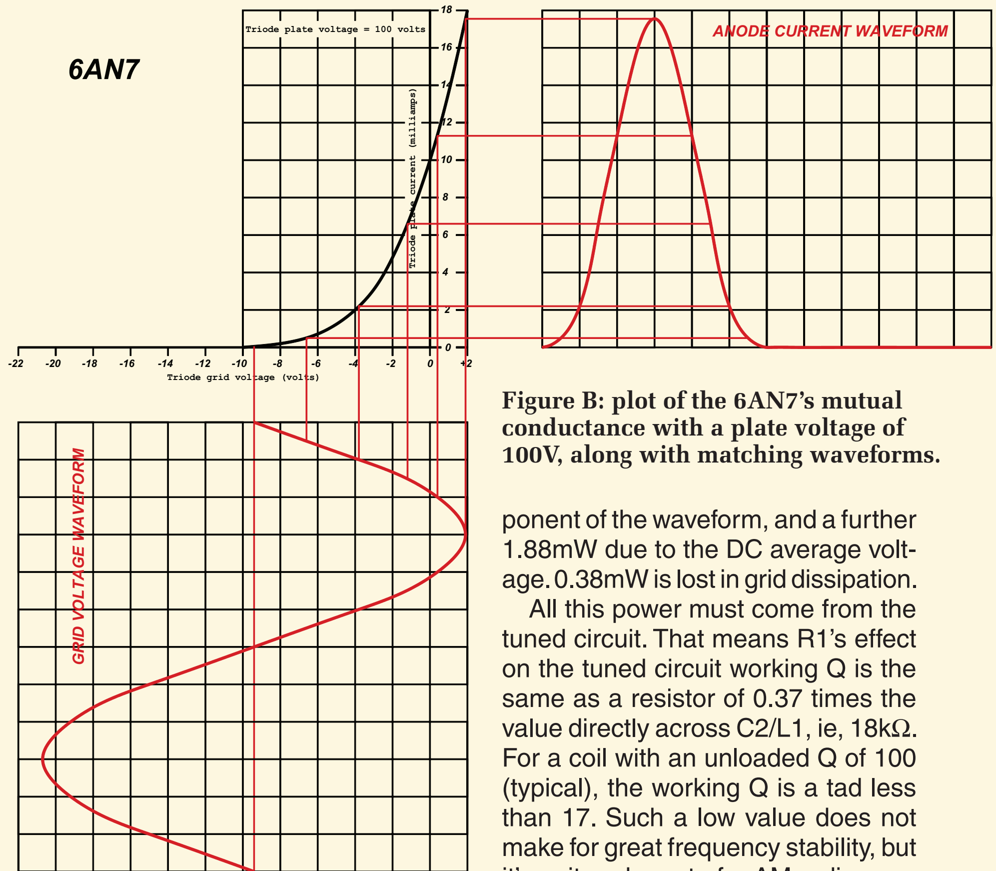


Figure B: plot of the 6AN7's mutual conductance with a plate voltage of 100V, along with matching waveforms.

The fundamental requirements of a sinewave oscillator are:

- Something to set the frequency – a tuned circuit
- An amplifier to make up for the inevitable losses in the tuned circuit by feeding some of its output back to the tuned circuit – "tickling" the tuned circuit
- Feedback in-phase with the tuned circuit oscillation.
- A means to control the oscillation level

Often the amplifier was a single grounded-cathode valve that inverts the phase. This is corrected by connecting the tickler winding to give a second phase inversion.

Figure A shows a typical AM radio oscillator at mid-band. Let's take a look at how it works, and how the T-130 oscillators differ.

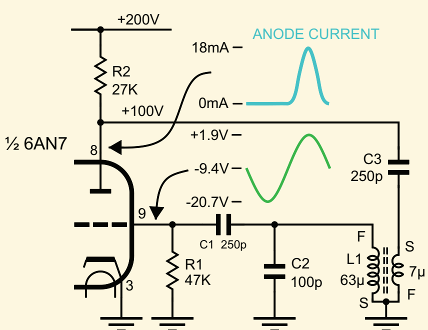


Figure A: a typical AM radio oscillator configuration. The T-130's implementation is shown at lower right in Figure D.

100pF capacitor C2 (comprising one section of the gang, a trimmer, and padder if used) and inductor L1 form the tuned circuit. The optimum oscillation voltage on the grid is 8V RMS, ie, 23V peak-to-peak. Grid current flows briefly on the positive peaks, clamping the tip of the peaks to about +1.9V. This forces the average grid voltage to be -9.4V by charging C1.

The 6AN7 triode section has a semi-remote cut-off, beginning at about -3V and fully cut off at -10V. Thus, significant anode current flows for only about 120° – as shown in Figure B.

250pF capacitor C3 and the tickler winding offer a low impedance, so almost all of the AC part of the anode current flows in the tickler winding, and only the DC part, about 3.8mA, flows in 27kΩ resistor R2. The valve works quite hard, conducting 18mA peak.

Oscillation always starts because the anode current without oscillation (and so no grid bias) is 5.1mA and gm (transconductance) is maximum at this level – as shown in Figure C.

The oscillation amplitude is regulated because if the grid oscillation increases, a greater fraction of the sinewave is beyond cut-off. As the grid will not allow any increase in the positive direction, the peak anode current is fixed at about 18mA. Still, the grid excursion goes further beyond cut-off, so the valve conduction angle decreases.

Therefore, the energy fed back via the tickler winding decreases, holding back the increase at the grid. This is called grid-controlled amplitude or grid stabilisation. Almost all LC valve oscillators use grid stabilisation.

R1 is typically 47kΩ. A much higher value is not used as it will let the circuit 'squeg', ie, multivibrate at a lower frequency and amplitude modulate the desired oscillation. R1 dissipates 1.36mW due to the AC component of the waveform, and a further 1.88mW due to the DC average voltage. 0.38mW is lost in grid dissipation.

All this power must come from the tuned circuit. That means R1's effect on the tuned circuit working Q is the same as a resistor of 0.37 times the value directly across C2/L1, ie, 18kΩ. For a coil with an unloaded Q of 100 (typical), the working Q is a tad less than 17. Such a low value does not make for great frequency stability, but it's quite adequate for AM radio.

Figure D shows the T-130 Variable Oscillator. The fixed oscillator is identical except for its operating level.

The pentode stage operates as a Class-A voltage amplifier under starvation conditions. This provides a high output level with only 0.3V peak on the tuned circuit, comprising C2-C5 and T1. This low level is essential for in-circuit testing, especially when using the T-130 to measure Miller effect capacitance.

The pentode is biased not by grid rectification but by its own space charge. The grid never goes positive and never draws energy from the tuned circuit. Since the energy dissipated in 1.5MΩ resistor R6 comes from the pentode space charge and not from the tuned circuit, the tuned circuit operates at its unloaded Q.

Since the grid never goes positive and doesn't rectify, the circuit cannot squeg no matter how high the grid resistor (R6) is.

For an iron dust core of the size used, the Q is probably about 150-200. It will be lowered by resistance in the circuit under test, of course, but

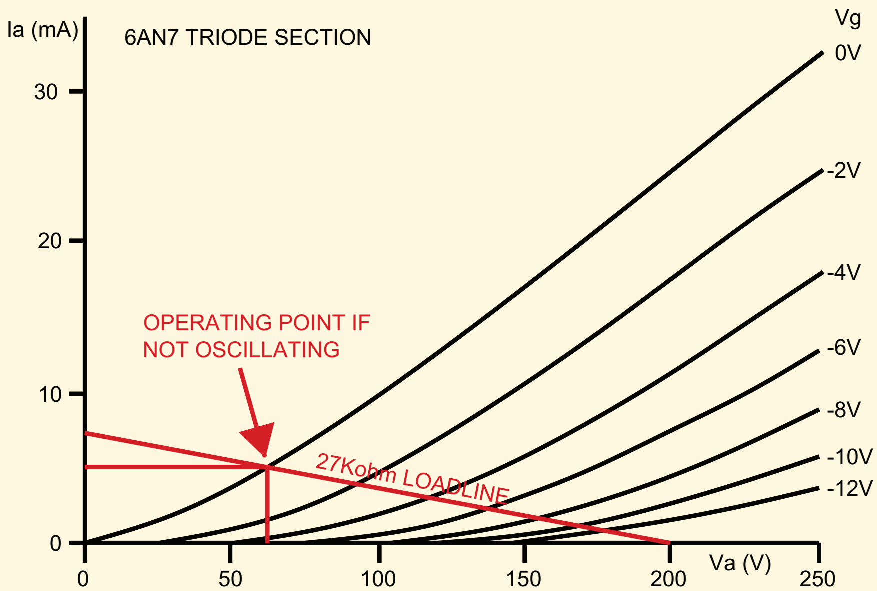


Figure C: plot of the 6AN7's anode voltage versus anode current for various grid bias amounts. The 27kΩ is the load connected to the plate of the 6AN7 (R2 in Figure A).

will always be above 30, and usually well above. The low-impedance tickler winding is loosely coupled and 'looks into' a small capacitance (22pF capacitor C10). So the tickler has no significant effect on Q.

The triode only conducts on positive peaks, as C10 can be charged by the cathode but not discharged by it. The triode conducts for only about 80°. That's why the signal at the cathode is half what it is at the grid. The cathode current peaks at 280μA; during the peaks, 120μA flows in C10, 120μA in C15, and 36μA in R19. The pentode current averages 110μA. The 6U8 is far from being worked hard.

If the oscillation level increases, C10 and C15 will charge up a bit more so that the signal on 470kΩ resistor R10 remains at about 6V peak-to-peak. But the greater swing on the grid means that the triode conduction angle must decrease. So less energy is fed back to the tuned circuit.

Unlike most LC tuned oscillators, this circuit is cathode-regulated. By using a triode-pentode with cathode stabilisation, we get a very stable oscillator. Considerable negative DC feedback via R10 holds the DC working point close to the designed level regardless of valve aging.

Ideally, signal feedback in an oscillator should be in-phase. What happens if it is not precisely in-phase? The first effect is that slightly more amplifier gain is needed. That's unimportant; plenty of gain is available, and the circuit will self-adjust anyway. The second effect is important in this application: it changes the frequency slightly.

Say the feedback is slightly late. By holding back the rate of change in the tuned circuit, the frequency drops slightly. Conversely, if the feedback is a little early, the rate of change is reinforced, and the frequency increases.

The ordinarily high Q of the tuned circuit strongly resists this influence over frequency. This means that if Q is lowered, say by a resistance across the tuned circuit, the frequency will change in the direction pulled by the feedback phase.

The pentode output is phase-inverted and of high impedance; about 800kΩ. Variable capacitor C7, together with stray wiring capacitance and the grid-anode capacitance of the triode section (~2pF), causes an additional phase lag of about 80°. So the signal at the triode grid, and the cathode, is lagging by 260°.

Most of the triode output voltage is dropped across C10, which means that C10 causes a phase lead, of about 80°. So we are back to approximately 180°, and, like many oscillator circuits, the situation is corrected by the phasing of the tickler winding (between pins 2 & 3 of T1).

Part of the calibration procedure is to adjust the phase by adjusting C7 so that the frequency doesn't change when two different test resistances are connected across the UNKNOWN terminals. This means that the feedback is precisely in-phase, and the T-130 reading is independent of any shunt resistance when in-circuit testing – within reason. Clever, eh? Too much loss stops oscillation.

Correct adjustment of C7 also means that the variable oscillator is maximally tolerant of contact resistance in the RANGE SELECTOR switch, improving frequency resetability. SC

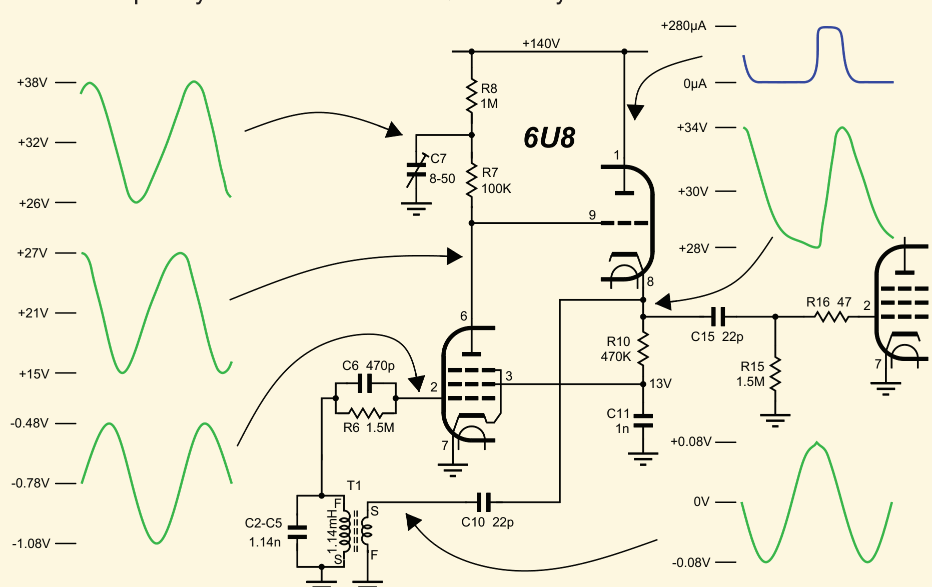


Figure D: the variable oscillator configuration used in the T-130 uses a 6U8 triode pentode.

VINTAGE WORKBENCH

The Tektronix Type 130 LC Meter – Part 2
Restoration

By Alan Hampel, B. Eng. (Electronics, Honours)

Last month, Alan Hampel described how the valve-based T-130 LC meter worked. He also described how he purchased a non-working unit from eBay (with "non-working" omitted from the description). Now he opens it up and starts work on restoring it to its former glory.

I unwrapped the package from the eBay seller and took the T-130 cabinet sides off. It was covered inside and out with cigarette smoke gunk. That's not uncommon in old laboratory instruments. Instead of the cabinet being an attractive blue, it was a dull blue-grey.

The cause of the clunking noises was immediately apparent – there was no 6X4 in the rectifier socket, but a 1N2630 solid-state valve replacement rectifier was loose amongst the works.

The 1N2630 was no doubt put in the 6X4 socket by a previous owner. But it's about four times as heavy as the original valve, being solid epoxy and not mostly vacuum. It also has a larger diameter, fouling the socket retaining screws and preventing the socket fully gripping the pins; so it fell out.

A 1N2630 (left) was used instead of the original 6X4 (right) as the rectifier. Due to its larger diameter and weight, it came loose from the socket in transit, damaging one of the 6U8s.

The loose 1N2630 smashed one of the 6U8s and bent the plates of a trimmer capacitor. Annoying, but easily fixed. I also noticed the meter clear plastic casing was broken in one corner – the only corner not shown in the eBay photos.

Preliminary evaluation

I carefully straightened out the bent trimmer capacitor plates and performed a thorough search for glass fragments within the instrument and in the packaging. I only found two tiny pieces jammed in out-of-the-way spots, but not anywhere near enough to account for the smashed 6U8. So someone cleaned out almost all the glass before shipping, without replacing the smashed valve. Interesting.

The front panel glass was cracked along one edge. There was also grime and dirt inside and outside the case.

I then removed all valves, carefully noting which valves came from which sockets. It's a good idea to keep valves separate, even if they are the same type, especially if they are double-valves like 6U8 triode-pentodes and 6BQ7 twin triodes.

Such valves, when faulty, have a high probability of producing entirely different symptoms or no symptoms at all depending on which socket they are plugged into. Nor do you want to allow circuit faults to cause any more damage than has already occurred.

The T-130 came from the USA, so the next thing I did was to rewire the power transformer twin primaries for "234VAC" operation, and I also changed the fuse to one half the original amperage.

The seller supplied a power cord, with the correct US NEMA 3-pin female on the instrument end, and a standard US 3-pin male plug on the other end. That's no good in Australia, and it was a very short cord too, so I bought a longer NEMA power cord on eBay and changed the male end to an Australian 3-pin plug.

I then plugged the instrument into a Variac and slowly wound it up from 0V. Nothing dramatic happened (no smoke released), but when I got it up to 200V AC, I noticed that the front panel pilot light was still not lit. The lamp socket pins were bent and shorting out the heater wiring. More damage from the loose 1N2630, most likely.

I lengthened the short circuit and tried again with the full 230V AC mains. The secondary voltages on the power transformer were correct, so I

If you have a Tektronix instrument with this AC mains connector on the back, check the Earth pin. It may show high resistance due to a loose retaining nut.

plugged in a 6X4 taken from an old radio, and the 0B2 regulator. I knew the 6X4 was pretty weak, but the HT drain in the T-130 should be a lot less than a typical radio, and I needed to quickly work out what was what before contacting the seller.

I now had 260V and 149.5V on the HT rails, and 75V DC on the heater wiring, so things were looking good.

As the 6U8 in the V30 socket had been smashed, I plugged in a 6U8 taken from an ancient TV, checking that the heater wiring was still at +75V in case there was heater-cathode leakage. It was still good, and my CRO showed oscillation at about 140kHz.

Next, I plugged in V4, another 6U8, functioning as the variable oscillator. I was rewarded with weak oscillation on the CRO at about 140kHz, varying with the position of the front panel COARSE ZERO control. The heaters still measured +75V DC, so no major faults were apparent.

I proceeded to replace the remaining valves one at a time, checking the +75V rail each time, and was rewarded with front panel meter deflection, varying with the COARSE ZERO control. Now I knew there was nothing major wrong, so I probably wouldn't need any parts made from unobtainium to fix the set (eg, transformers or coils). I therefore decided to proceed with a full clean and restoration.

To conduct further tests, I connected a 415pF tuning capacitor to the UNKNOWN socket, set the capacitor to minimum, and adjusted the COARSE ZERO and FINE ZERO controls for a zero reading on the 0-300pF range. Slowly turning the tuning capacitor towards maximum, I noticed two things:

1) The meter reading increased from zero up about 80pF indicated, then slowly decreased back to zero at about 120pF from the test capacitor! I thought this might be a problem with the Schmitt trigger circuit, perhaps the 6U8 (V70).

2) As the tuning capacitor was turned, there were violent swings of the meter (and I do mean violent!) at certain settings. The CRO showed this was due to the Schmitt trigger breaking into RF oscillation.

Schmitt trigger circuits can sometimes oscillate if the valve is weak, or a resistor has gone high, usually because the positive feedback is insufficient to produce a definite snap action, but enough to oscillate with reactances present in the circuit.

14 rules of restoration

I follow 14 rules when repairing or restoring vintage professional electronics. I learnt these rules when I was employed servicing professional electronics at the tail end of the valve era. The rules maximise reliability and preserve resale value.

1) Never unsolder any component until, by deduction or in-circuit testing, you have proved that it is faulty.

2) Never put back any part that you unsoldered. Replace it with a new one (or NOS/NIB if a new part is unavailable).

3) Never replace non-electrolytic capacitors just because they are old and might be leaky. In professional equipment, leakage is a lot less likely as higher grade parts are used, voltages are lower, temperatures are lower than in typical valve radios, and circuits are more tolerant.

4) Never replace electrolytics just because they are old. The long-life types used in professional equipment are often perfectly good; there's no sense in sacrificing the factory look if there's nothing wrong with it.

5) Never swap valves of the same type around in the chassis as a diagnostic strategy or to fix a fault. Each valve stays where it is unless and until it is proved defective, at which point it is replaced with a new valve (these days, a NOS/NIB valve).

6) Clean and touch-up paint before addressing faults. Cleaning does sometimes cause more faults, and a nice clean instrument is a pleasure to work on.

7) After cleaning, check every single resistor for correct resistance (without unsoldering it) and every electrolytic in-circuit before proceeding with any diagnostic procedure. But don't replace anything found faulty yet.

8) Don't rely on an overall functional check or rely on a check against performance specifications. Go through each stage with a scope and verify that each stage works precisely as it should. Replace parts identified as out of specification as you go through each stage.

9) Some brands of capacitor are known to fail sooner or later. Replace these after each stage is verified good and the instrument meets and exceeds specifications. My T-130 did not have any such components.

10) Every single time you replace a component, do a comprehensive set of checks to verify both that the fault due to that component has been cleared, and that no new symptoms have appeared.

11) Where possible, replace resistors and capacitors with the same original type, or if you cannot obtain originals, use comparable components of the same vintage.

12) Clean and lubricate all switches, pots, variable capacitors and (later, during alignment/adjustment) presets. Don't just apply contact cleaner/lubricant to switch wafers and pots, do variable capacitors as well. Make sure you apply grease to wafer switch clicker mechanisms.

13) Never touch calibration adjustments or presets until there is nothing else left to do or check. Mostly, you'll find that an apparent need for adjustment (beyond minor touch-up) is in fact due to a faulty component.

14) Do not modify to fix a fault. Resist the temptation to modify to improve performance. Reputable manufacturers knew what they were doing.

Tektronix component strips and soldering

Tektronix installed pig-tail type resistors, capacitors, and other small parts on ceramic terminal strips (see photo below).

These strips have a glazed finish; they look nice and are rigid, which helps stable circuit operation and reduces vibration-induced failures. They also have negligible leakage and RF loss, and do not grow fungus in high humidity climates like phenolic tag strips can.

The strips also come in two different types, one that used nuts and bolts on the underside for mounting and the ones used here have snap-in fittings. The former was used in earlier models and could help determine the age of the meter.

Many people think these ceramic strips are unique to Tektronix, but a limited number of US manufacturers used them in tube-based military equipment. The Japanese test equipment manufacturer Meguro used similar ceramic strips.

Tektronix made these strips by coating the moulded but unfired strips with a paste of silver particles dispersed in an organic grease, then wiping the excess off. The wiping leaves the paste neatly confined within notches and slight depressions surrounding each notch.

Upon firing, the grease evaporated, leaving a microscopically thin coating of silver in and around each notch, bonded to the ceramic. They then tinned each notch ready for soldering in the components.

The downside of these strips is that silver readily dissolves in ordinary tin/lead solder, and solder does not stick to ceramic. Hence, using normal tin/lead solder will weaken the silver-ceramic bond and will, sooner or later, cause it to fail completely. In the factory, Tektronix used a tin/lead solder containing 3% silver, the 3% being sufficient to stop its affinity for more silver completely.

62% tin, 35% lead and 3% silver solder used to be available from Tektronix under part number 251-514, but they ceased selling it many years ago. Its melting point is 188°C.

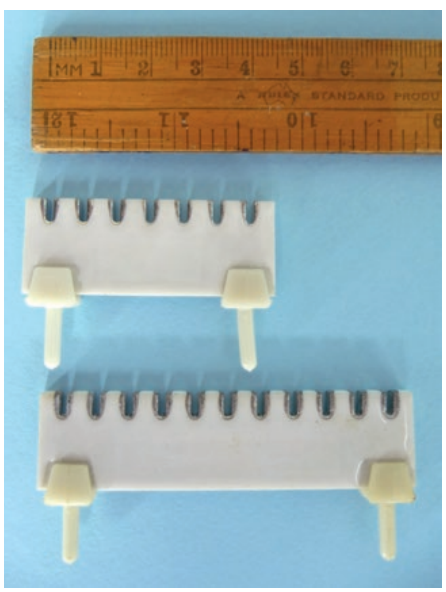
Note that this isn't "silver solder", which is a British term for brazing alloy. Nor is it modern lead-free electronic grade solder, which contains silver but has a significantly higher melting point that can damage the ceramic strips.

Tektronix usually installed a small roll of silver loaded solder inside their oscilloscopes. They often did not include it in cheaper instruments. If you have a Tektronix instrument that does not have the little roll, it's either because someone has swiped it, Tektronix never included it, or you have an instrument originally supplied to the military.

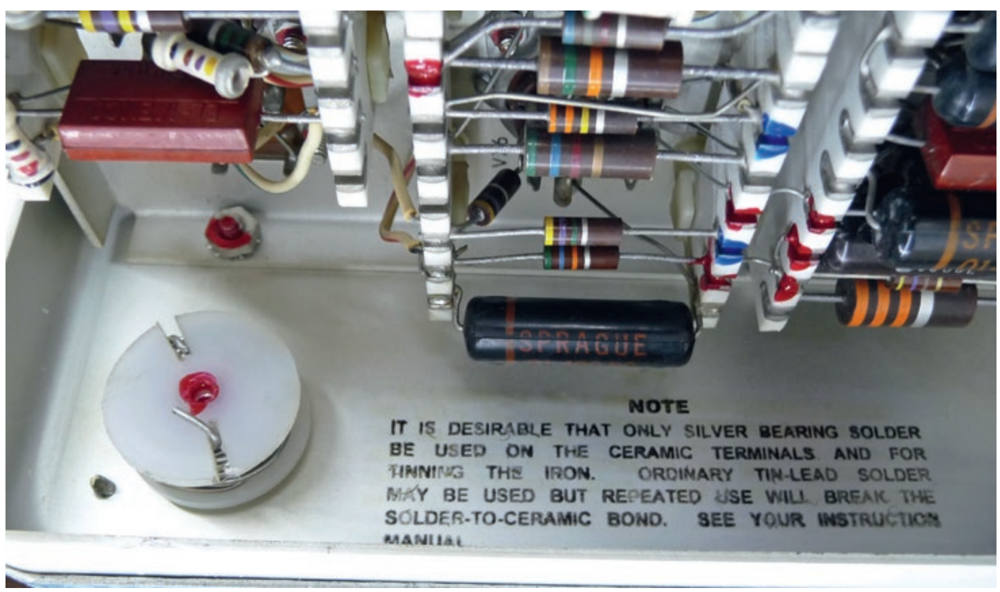
Fortunately, solder containing 62% tin, 36% lead, and 2% silver is readily available from RS Components (Cat 271-4172), along with element14 and other distributors.

When working on Tektronix ceramic strips, if you don't have the supplied roll, **always** use the modern 2% solder. Even 2% silver solder isn't optimal, and you probably don't know the history of the device, so you must assume the strips have already been weakened. New strips do occasionally show up on eBay, but only occasionally.

Never place the soldering iron tip within a notch and apply any force. The ceramic easily cracks if you do. Use a temperature-regulated chisel tip 5-6 mm wide and apply it to the side of the notch.



Two of the ceramic terminal strips, which many of the components mount on. The notches in this strip are lined with a silver alloy and the strip can be mounted via snap-in fittings (as shown) or bolt-on depending on type.



An example of the ceramic strips in place within the left-side of the chassis with components soldered in. You can also see a warning about only using "silver bearing" solder as tin-lead solder will eventually damage the silver alloy on the strips. The T-130 did not come with this solder, so I turned a replica reel (shown to the left of the note) and added 2% silver solder from RS Components. There is more detail on these strips and the recommended solder in the panel above.

I also noticed that the zero setting wandered about, and could not be brought to an actual zero beat, so that on the lowest range (3pF full scale), the meter had over full-scale deflection regardless of the COARSE ZERO control setting.

Contacting the seller

I sent a message to the seller via eBay, informing him that the instrument was not operational, thus not conforming to his description, and I explained why.

He promptly wrote back, apologising, and offering to send me two replacement NOS/NIB (new old stock/new in box) valves: a 6X4 and 6U8. I accepted that, but pointed out that the instrument uses five 6U8s and at least one more was probably faulty.

The seller then arranged for a US surplus valve dealer to courier one 6X4 and three 6U8s. They arrived two days later. They were mil-spec valves (W-suffix) too. I certainly couldn't complain about the after-sales service.

Making it pretty

Cleaning the cigarette smoke condensation off the cabinet was easy. I removed all cabinet parts from the central chassis and washed them, along with the front panel knobs. I did this in the sink with dishwashing detergent.

I used a soft sponge to clean the cabinet parts and a toothbrush for the knobs. I then thoroughly rinsed everything with running water and then Electrolube Saferinse, and dried the parts off. Everything came up like new, except for a few places where the paint had been worn off over the years.

"Tek Blue" touch-up paint used to be available from Tektronix under part number 252-0092-02, but not any more. Googling, I discovered that this paint was made by the Chemtron Aerosol division of Rudd Company Seattle. They no longer exist.

So instead, I bought the following from Bunnings: White Knight Rust Guard Quick Dry Advanced Enamel, Neutral Tint Base 500mL Stain Finish, colour coordinates W 36.5 B 16.5 D 27 E 16.

This gives an excellent match. 500mL is far more than I could ever use for touching up Tektronix instruments, but is the minimum they let me buy. I used a cotton bud to apply the paint where needed on the T-130 parts.

The UNKNOWN connector on the front panel is an old-fashioned UHF (SO-259) silver-plated socket, common on test gear made before the 1960s. It is much better than a BNC type in this application – a BNC connector does not have the mechanical strength to support accessories typically used with the T-130.

The connector was badly tarnished and missing many of its 'teeth', so I replaced it with a new one. Next, I reassembled the instrument using new screws, because the old ones were all corroded and unsightly. Shiny new screws make all the difference – the instrument now looked brand new – on the outside, anyway.

As with many electronics manufacturers in the 1950s and '60s, Tektronix painted internal cabinet and chassis screws and adjustments with what Tektronix staff called "Red Glyptal". Glyptal is a USA-based specialty paint manufacturer. The original formulation is no longer available, at least in small quantities.

Replicating Red Glyptal on the screws and adjustments is a nice touch in restoration. Many restorers use nail varnish, but it's far from ideal, in appearance or mechanical strength. A close equivalent is "BLR Tamper Proof Seal", available from RS Components (Cat 196-5245).

Estimating the age of a T-130

This can be difficult, as the T-130 was manufactured for 21 years, and there are no date codes on any of the parts, except the valves.

Of course, valve codes are useless, because you don't know what valves have been replaced during the instrument's life, and you don't know if any replaced valve was new, NOS, or merely an old valve somebody had on hand, good or otherwise.

You also can't rely on the serial number, at least not directly, as it is not known how many were sold in any given year, and that can vary widely. For an instrument like the T-130, which filled a niche need for the first time, there were probably brisk sales in early years, and then just a trickle each year, as new laboratories and factories started up.

For oscilloscopes, Tektronix used a few different coding schemes. These encoded the factory which produced the unit, country of origin, the revision level, and in some cases the date of manufacture. But it appears no coding scheme was used for the T-130, and the serial numbers were purely sequential.

In some cases, the serial number for smaller Tektronix instruments was sequential to the production line output, not to the instrument type.

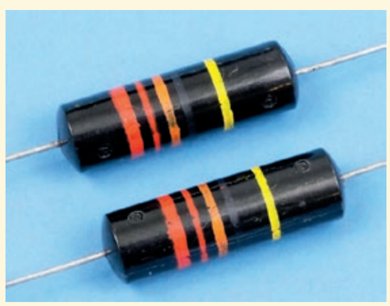
For example, a production line may have been making a batch of T-130s and then changed over to making T-123s (an oscilloscope preamplifier). If the last T-130 in the batch was given serial number 00226, the first T-123 would receive serial number 00227.

Thus, some smaller Tektronix instruments had large gaps in their serial number ranges. This likely applies to the T-130, as the number sold would not justify a dedicated production line.

Any Tektronix instrument with a serial number comprising a single letter and two digits is a pre-production sample or a laboratory prototype. Once in a while, these show up on eBay.

T-130 production started with serial number 101. The T-130 got a major facelift in 1958 (serial numbers 5000 and up) and a change in meter in 1965 (serial numbers 6168 and up).

If a T-130 has Sprague Black Beauty 160P capacitors (tubular capacitors with red printing), it was made 1960 or later. If it has Sprague Bumble Bee capacitors (colour-coded), it was probably made in 1960 or earlier.



Sprague "Bumble Bee" capacitors (left) mean the T-130 was likely made pre 1960, while "Black Beauty" 160P caps (right) indicate post 1960. The Bumble Bee caps usually leak, although leakage will often not affect the T-130's operation.

TYPE 130 L,C METER

Direct-Reading Inductance and Capacitance Meter

APPLICATIONS

Saves engineering time in circuit development work by providing quick inductance and capacitance readings even while circuit changes are being made. Aids in correct placement of critical components and leads.

Guard circuit produces a voltage of the same amplitude and phase as the voltage at the UNKNOWN terminals, but isolated from the frequency determining portions of the rest of the circuit. This permits separation of the capacitance to be measured from other capacitances and strays. Accurate measurements of direct interelectrode capacitance in vacuum tubes can be made with ease.

The Type 130 can also be used for component testing, sorting, and color code checking on a production basis.

GENERAL DESCRIPTION

The unknown value to be measured will determine the frequency of the variable oscillator in the Type 130. This frequency is beat against a 140-kc fixed oscillator. The difference frequency is shaped and counted, causing meter deflection proportional to the difference frequency. The direct-reading meter is calibrated in microhenries and micromicrofarads.

Guard Voltage

Permits measuring an unknown capacitance while eliminating the effects of other capacitances from the measurements.

Five Ranges

Microhenries—0 to 3, 10, 30, 100, 300.
Micromicrofarads—0 to 3, 10, 30, 100, 300.

Accuracy

Within 3% of full scale.

Coarse and Fine Zero Adjust

Four-Inch Illuminated Meter

VACUUM TUBE COMPLEMENT

Fixed Oscillator	6U8
Buffer Amplifier	6U8
Variable Oscillator	6U8
Buffer Amplifier	6U8
Mixer	6BE6
Bistable Multivibrator	6U8
Guard Circuit Cathode Follower	6BH6
CF Clamp and Diode Clamp	6BQ7A
Rectifier	6X4
Voltage Regulator	OA2

OTHER CHARACTERISTICS

Size—5″ wide, 9″ high, 8½″ deep.

Weight—9 lbs.

Construction—aluminum alloy.

Finish—photo-etched anodized panel, baked gray wrinkle cabinet.

Power requirements—117/234 volts, 50-60 cycles, 40 watts.

Price **$195**

Includes: 1—P93C Probe
1—W130R Lead
1—W130B Lead
1—Instruction Manual

Recommended Additional Accessories

Type F30 Production Test Fixture. Speeds sorting and testing of capacitors and inductors $3.00

Type S30 Delta Standards, for calibration of Type 130 L,C Meters $22.00

Prices f.o.b. Portland (Beaverton), Oregon.

Here is a page from the 1954 Tektronix catalog; when they started to produce the T-130 LC Meter.
***Source:* http://w140.com/tekwiki/wiki/Tektronix_Catalogs**

Safety hazards

I plugged in the power cord and checked the resistance from the Earth pin of the Australian plug to the T-130 chassis. High Earth lead resistance is a common fault in Tektronix instruments using a protruding NEMA 5-15 mains input connector. If you have one, best check it. Mine had an open-circuit Earth.

As is typical, the nut that secures the Earth pin to the connector backplate had worked loose. This is why you shouldn't use a mounting screw for an Earth connection, which isn't permitted by most authorities. There was tarnish on the Earth pin as well. I cleaned the pin and tightened the nut, using a drop of thread locker. I checked again with an ohmmeter – no perceptible resistance – good.

There is another safety hazard in the T-130. The range switch is a custom-assembled "Oak"-style three-wafer switch. The rear-most wafer selects the range setting capacitors and acts as the power switch on the primary side of the power transformer. So 230V AC is within a millimetre of the range selection common.

That's not very nice, Mr Moulton. It's an electric shock risk. One slip of a probe and the switch is history. And you can't buy a replacement now. I made a mental note never to probe with a voltmeter or CRO around the wafer while the T-130 is plugged in.

Internal cleaning

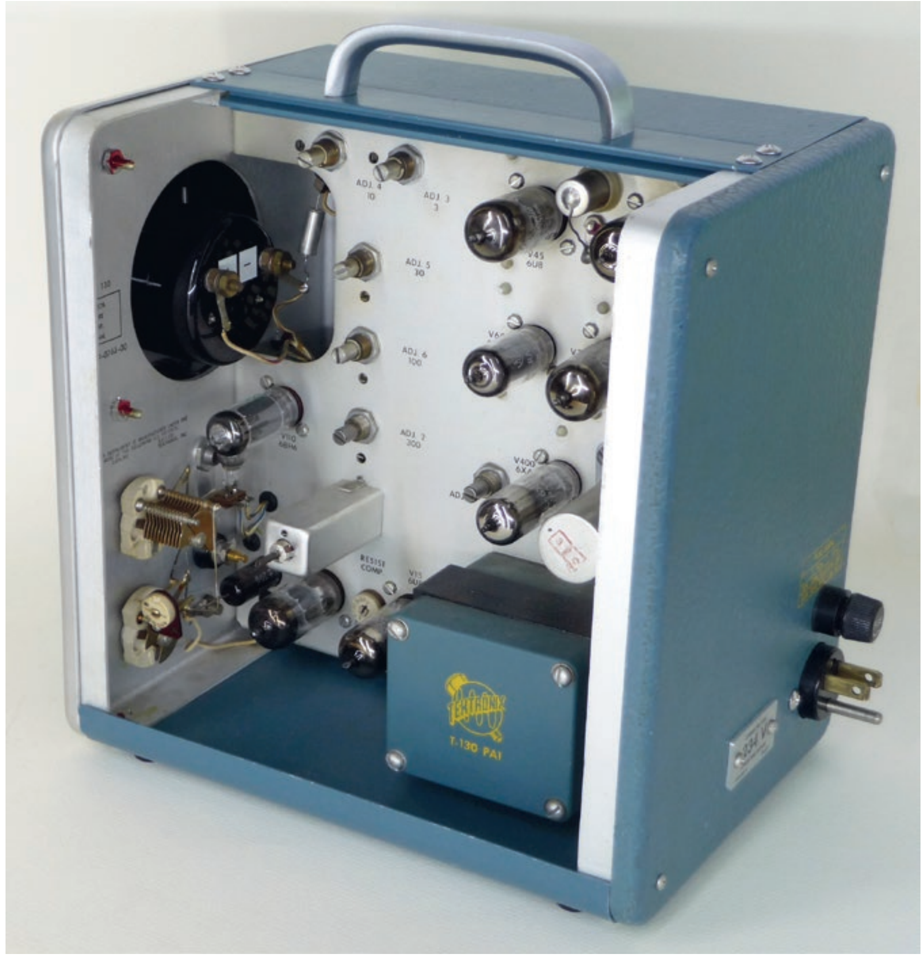
An internal clean was needed to get rid of accumulated cigarette smoke residue and the general dirt that accumulates in all valve equipment cooled by simple ventilation holes in the cabinet.

First, I washed the chassis, components and terminal strips with Safewash citrus solvent, applying it with a toothbrush and cotton buds.

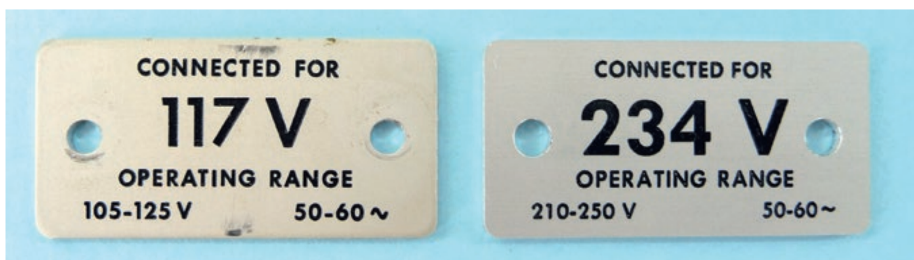
Then, I went over it all again with Saferinse to get rid of the Safewash, and then again with isopropyl alcohol to remove the Saferinse. I was very careful to avoid getting any Safewash or Saferinse in the oscillator coils.

It is essential with old Tek equipment to thoroughly clean the terminal strips back to an uncontaminated glazed ceramic surface.

If you don't, the cigarette smoke residue and general grime will in time cause electrical leakage, if it hasn't already.



On the rear of the T-130 is the fuse, AC input and badge showing the voltage. A desktop NC milling machine was used to make a 234V AC badge to replace the 117V AC version shown below.



After cleaning, I took some photographs. Reviewing the photos, I realised the terminal strips still were not completely clean. So I repeated the whole process over again.

The T-130 was designed before high-grade polyester capacitors became available, but almost all T-130s, including mine, were made with professional-grade Sprague "Black Beauty" 160P capacitors (black tubular capacitors with red printing).

These seldom show any leakage. T-130s made before 160P production started in 1960 have Sprague "Bumble Bee" (colour-coded) capacitors, which usually do leak.

But quite a high leakage in the range capacitors (C90-C94), say 5µA, will only result in a slight change in FSD, which can be adjusted out in calibration. 5µA leakage in a radio grid coupling capacitor would have a disastrous effect on audio quality.

The only other tubular capacitor in the T-130 bypasses the 150V rail – leakage short of a definite fault there will have no effect.

Next month

Now that the T-130 was clean and safe, I could get into the nitty-gritty of figuring out what was wrong, fixing it, and then adjusting it back to its original factory-spec condition. But that will be in next month's article.

A brief history of direct-reading frequency meters

Digital frequency meters (counters) were not widely used until integrated circuits reduced the cost in the 1970s.

Imagine even a three-digit frequency counter implemented with valves. You'd need four twin valves for each decade counter, four for each display latch, five for each display decoder and eight more for time-base division. Plus another three for the power supply. That's a total of 50 valves!

But there has always been a need in design laboratories to measure frequency, and an analog meter of 1-5% accuracy was often good enough. So there have been analog frequency meters for just about as long as there has been electronics.

The earliest direct-reading frequency meters were just an amplifier with enough gain so that it is well over-driven, and the output is almost a square wave. The output is fed to a rectifier and moving-coil meter circuit via a small capacitor, so that the meter just gets a series of narrow pulses, one pulse per input cycle.

Due to mechanical inertia, the meter responds to the average current, so its deflection is proportional to frequency. This arrangement is shown in the upper circuit.

But this circuit has some serious disadvantages: if the input level is not sufficient to overdrive the amplifier, you get a low reading. In fact, the reading always depends on the input signal strength to some extent. The calibration also depends on not just the HT voltage and R1 and C1, but also on the emission of V2, even when V2 is completely overdriven.

Plus the contact potential of V3 causes a continuous deflection even with no signal. The pulse-width set by C1 must be a small fraction of the cycle time; otherwise, C1 will not discharge adequately, and the meter deflection will become excessive.

Howard Vollum, when a student at Reed College in 1936, wrote a thesis, “A stable beat frequency oscillator equipped with a direct reading frequency meter.” The oscillator part was nothing remarkable, but his frequency meter significantly advanced the art. This is shown in the second circuit below.

Now V1 does not have to be overdriven. It can be an ordinary low-μ triode as its role is to provide a low-impedance drive to the transformer; this lowers its cut-off frequency.

The transformer provides push-pull drive to V2 and V3. V2 and V3 are small thyratrons and the circuit functions as a bistable (flip-flop).

Thyratrons (gas-filled triodes) function something like an SCR in series with a zener diode. If the grid is held sufficiently negative (-10V), no current flows in the anode and the grid. If the grid is taken less negative, anode current flow starts and ionises the gas. The anode current immediately rises to the maximum possible in the circuit.

The anode-cathode voltage stays close to 16V, regardless of what the anode current is. The grid is now more-or-less shorted to the cathode due to its position in the electron stream and proximity to the cathode.

Assume V3 is conducting (on) and V2 is off. The cathode of V3 is at 74V and C1 is charged to 74V, positive on the right. As soon as the left-hand end of the transformer goes sufficiently positive, V2 will snap on. V2's cathode rises immediately to +74V, so the right-hand end of C1 must rise to +148V, cutting off V3.

When the right-hand end of the transformer goes sufficiently positive, V3 turns back on, forcing V2 off again. The circuit flips back and forth at the input frequency, as long as sufficient input level is present.

C2 and C3 communicate short pulses to V4, which supplies two pulses to the meter for each input cycle.

So the output pulse amplitude and width is entirely independent of the input level. If the level is insufficient to trigger either thyratron, the action simply stops. As there are two pulses per input cycle, the meter pointer is a lot less likely to shudder with low (≲20Hz) input frequencies.

However, transformers were expensive, and Thyratrons cost more than hard vacuum triodes, yet were a lot less reliable and shorter-lived.

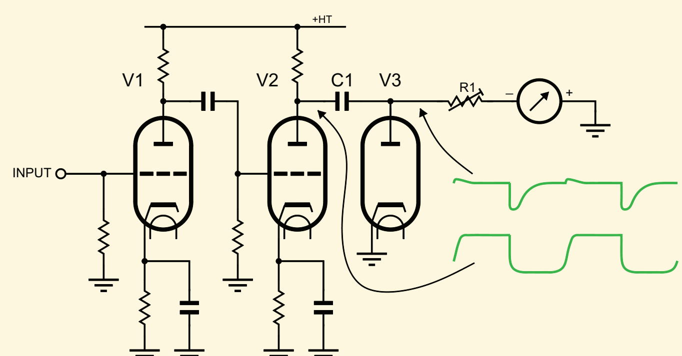
The next major advance came in 1941. National Cash Register Co. filed a patent (inventor L. A. DeRosa) disclosing a precision direct-reading frequency meter employing a flip-flop circuit based on two pentodes, triggered by an overdriven pentode amp.

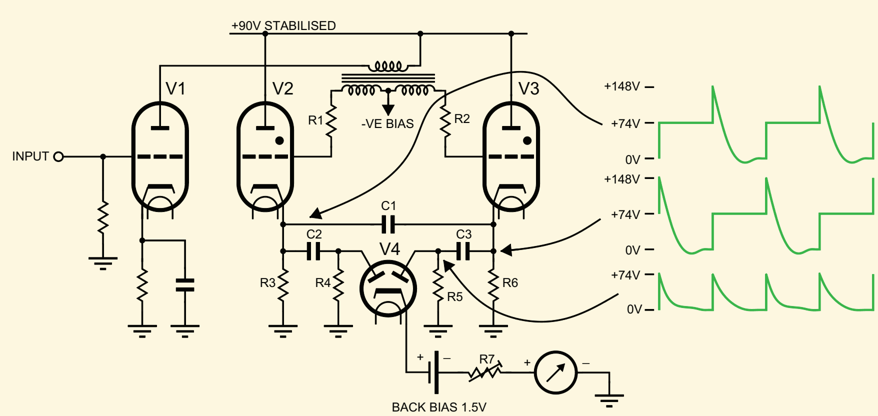
The flip-flop ran at half the input signal frequency, but two pentode monostable circuits were triggered from each flip-flop pentode. The meter then received one clean and square monostable pulse for each input cycle. It was a little more accurate, a lot more complex but not much more expensive than the Vollum circuit. It retained the correct-or-nothing reading operation.

In 1951, Howard Vollum was now Tektronix chief engineer, and new engineer Chris Moulton was designing the new ‘bistable’ configuration used in the T-130. With the amplitude clamp circuit added by Moulton, his circuit is a lot simpler than the DeRosa method and just as accurate.

Most, if not all, subsequent designs for audio direct-reading frequency meters are derivatives of the Moulton and/or DeRosa methods.

The Hewlett Packard 500B/C Frequency Meter/Tachometer used a Schmitt trigger followed by a monostable briefly turning on (once per cycle), with a constant current source feeding the moving coil meter. With a rectangular or on/off pulse instead of a capacitor decay, the need to keep the pulse width small compared to one cycle is removed. SC





VINTAGE WORKBENCH

The Tektronix Type 130 LC Meter – Part 3
Calibration

By Alan Hampel, B. Eng. (Electronics, Honours)

In the last two articles, Alan Hampel described how the T-130 LC meter works and how he cleaned up the dirty and faulty unit that he got from eBay. In this last part of the series, he describes how he got it correctly calibrated and working again.

Servicing the controls

Checking with a multimeter, I found that the resistance of each contact in the RANGE SELECTOR switch varied with each engagement from around 5-15Ω. That isn't very good, but the contacts looked OK to the eye, with no excessive wear.

I applied contact cleaner/lubricant sparingly (just achieving a wet appearance), and rotated the switch through the whole range numerous times. Checking again with the multimeter, all contacts showed no perceptible resistance. Then I applied some grease to the clicker mechanism.

I applied some contact cleaner/lubricant to the shafts of the COARSE ZERO and FINE ZERO variable capacitors. Everybody who is an electronics enthusiast or technician soon learns that pots need lubricant because of the racket dry pots make in audio gear. Variable capacitors need lubricant too. But the effect of dry capacitors is more subtle: a certain amount of oscillator frequency instability.

Checking components

I checked all 50 resistors for correct resistance and visual integrity. That was possible without unsoldering anything for all but 10, because unpowered valves are open circuits (normally). I checked the remaining 10 by powering up and checking for correct voltage division, and checking current by shorting each in the chain with a milliamp range of my multimeter.

This revealed three things:

1) Resistor R96 was 20% high. R96 (470Ω) and R95 (33kΩ) back-bias the charge and discharge diodes, balancing out contact potential. This would cause too much meter back-bias.

2) Resistor R405 (1.5Ω) was twice its correct value, which would starve the variable oscillator valve of heater current.

3) Valve V60 (a 6BE6) had about 50kΩ leakage between the first grid and the cathode.

I checked electrolytic capacitor C401 (2 x 15µF) by measuring the ripple voltage on it. It was still good; I measured 7V versus the 8V stated in the manual. I saw no corrosion; this is sometimes seen when electrolytics leak electrolyte.

I checked electrolytic C402 (6.25µF) by measuring the ripple voltage on it. It too was still good.

Surprisingly, electrolytics C99 (5µF) and C100 (25µF), factory originals, were installed backwards! Not surprisingly, they each had only about 10% of their rated capacitance and were very leaky.

As the ripple on the 150V rail was exactly as stated in the manual, that indicated that polyester capacitor C403 (22nF) was still good. The only other polyester capacitors are the range capacitors, which are Sprague Black Beauty polyester. I checked them in-situ for leakage (even though leakage is unlikely) – all had no measurable leakage.

All other capacitors are professional ceramic types that are known to almost never fail.

Methodical checking

I replaced the temporary and weak 6X4, and the 6U8 in the V30 socket, with the new 6X4 and one of the 6U8s

Restoring the manual

When I restore a vintage electronic item, I like to have an immaculate manual to go with it. When I bought this T-130, the eBay seller threw in an original printed instruction manual. Unfortunately, it was for a different serial number, and was in very poor condition, with numerous stains and pages missing.

I downloaded a manual from the Boat Anchor website (http://bama.edebris.com/manuals/), but it too had missing pages, and the scan quality was poor.

I decided to re-create the manual in the Tektronix style by re-typing it and re-taking the photos from the same angles as Tektronix did. I also scanned the drawings and cleaned them up with Microsoft Paint and Media Impression (a software package that came with my PC and does much the same job as Photoshop).

I have a Tektronix/US-style symbol library in my CAD system, so I re-drew the circuit diagram in Tektronix style. The Tektronix original had several errors, which I corrected. I also drew component layout diagrams, though Tektronix never included them in their manual.

All this work on the manual was a good investment. It made me thoroughly familiar with the circuit, how it works, and what clever tricks the designer Cliff Moulton used to get excellent performance. That knowledge was invaluable for fault-finding and calibration.

The right side interior of the T-130 chassis neatly houses all the valves, transformers and a few other parts. The large transformer marked "T-130 PA1" at bottom right (T400) is used to power the valve plates and heaters, T30 at upper right is part of the fixed oscillator (V30), while T1 is marked at lower left and and is part of the variable oscillator (V4).

the seller sent me, following Rule 10 (from "14 rules of restoration" from the last article):

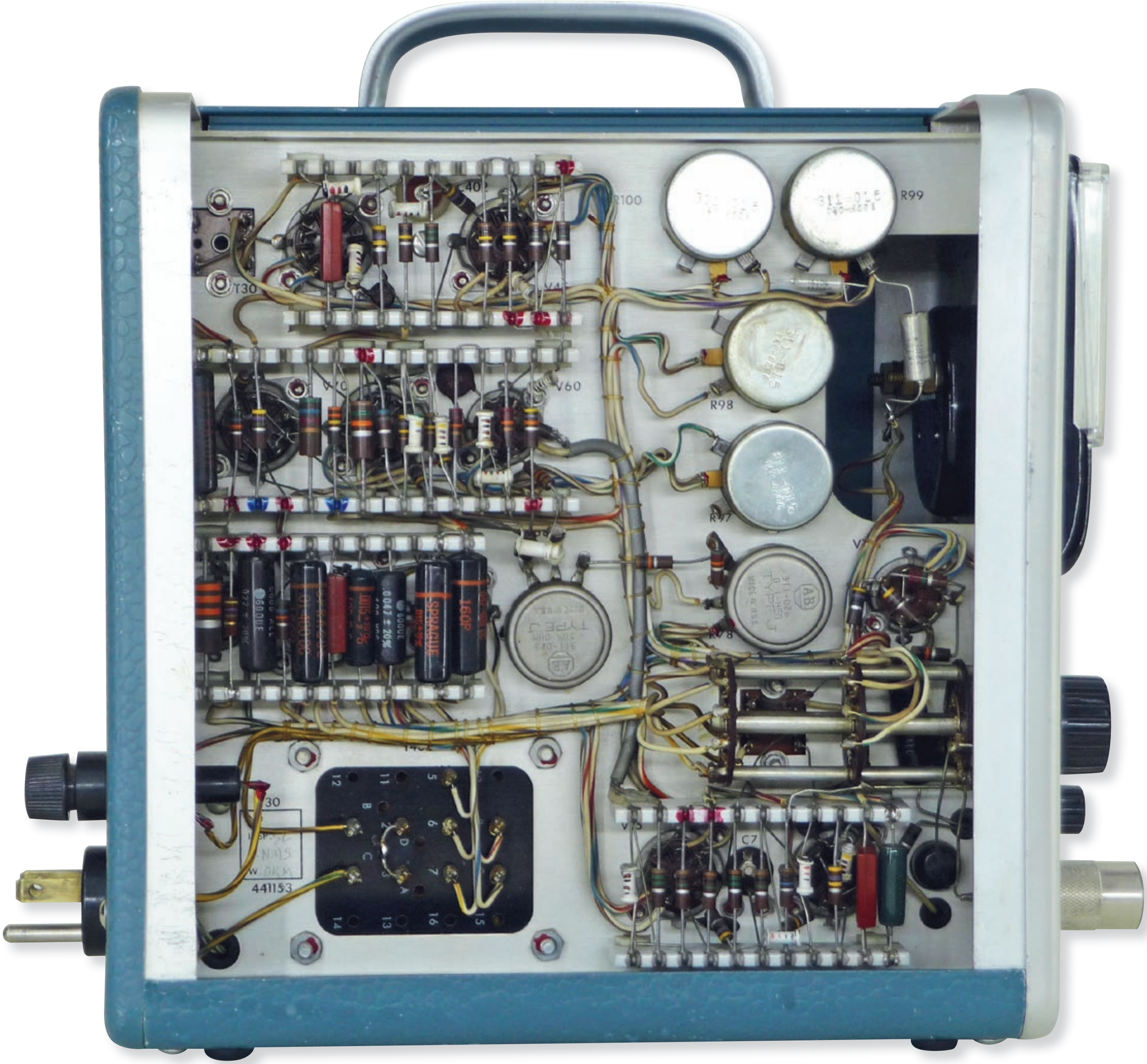
Every single time you replace a component, do a comprehensive set of checks to verify both that the fault due to that component has been cleared, and that no new symptoms have appeared.

I replaced faulty heater dropping resistor R405, again following Rule 10. As it's a wire-wound component, if it's high, it's most likely about to go open.

I couldn't find a source of resistors identical to the original, but I installed a Welwyn part that at least looks like a type available in the 1960s. Changing it made the instrument zero slightly more stable, but still too far off to allow the 3pF range to be used.

Now that I could deem the power supply good, I went through the rest of the instrument, stage by stage, checking waveforms. This revealed that:

- The 6U8 variable oscillator valve (V4) had low emission. I replaced it with another of the 6U8s the seller



The interior left side of the chassis houses nearly all the capacitors, resistors and other components mounted on ceramic strips and connected via point-to-point wiring. Note the two replacement silver-coloured electrolytics (C99 & C100) at the top right corner; Tektronix factory-installed the originals in backwards!

sent me. That stopped over-deflection on the 3pF range. The instrument zero became a bit more stable, but now had a small backwards deflection.

- Since the 6BE6 mixer (V60) had extremely high grid-cathode leakage, it could well be about to fail completely. I replaced it with a NOS valve from eBay. This improved things – instead of the meter dropping back past about 80pF, it didn't start to drop back until about 200pF.

The low-pass filter is pretty crude, and its output falls somewhat as frequency increases. The low-emission valve from the old radio had offset the input to the Schmitt trigger, so that triggering up and down ceased past a certain point.

- Checking waveforms around the Schmitt trigger confirmed that it couldn't follow the filter output past about 10.9kHz (200pF indicated). With resistor checks already done, presumably, the problem was valve V70 (another 6U8). On plugging in a replacement, the T-130 now followed a variable capacitor up to 250pF.

This was far from perfect, but as all other components have been checked, I assumed that I could correct it with 50kΩ symmetry trimpot R68, which adjusts the bias on the Schmitt input to centre the signal between the trigger levels. That turned out to be correct.

- I then replaced defective elec-

T-130 applications

The obvious applications of the T-130 are checking small capacitors and inductors before soldering them into circuit and – via the probe lead – checking suspect parts in-circuit.

The guard voltage output removes the need to isolate parts before checking them; a facility that most modern capacitance and inductance meters do not have.

Something that almost all design engineers of valve circuits had to grapple with is the Miller effect, which affects amplifier frequency response and may make negative feedback circuits unstable, requiring compensation (see the panel in part one). The T-130 makes the measurement of Miller effect capacitance easy.

First, the static (or stray) capacitance at a grid can be measured by the T-130 and probe lead with no HT on the circuit under test. Then the HT can be switched on, and there will be an increase in the measured capacitance – this increase is due to the Miller effect.

The T-130 can be used to identify short lengths of coax (<< 1/4 wavelength of 140 kHz, ie, << 500m) without knowing the actual length. Just measure the capacitance with the far end open, and the inductance with the far end shorted. Then, $Z \approx \sqrt{L \div C}$.

For example, let's say the inductance measured on the T-130 is 0.60µH and the capacitance is 104pF. Then Z is approximately 76Ω. If the sheath diameter is 10.3mm, the coax must be RG11/U.

The T-130 with the Dielectric Test Adapter can help with evaluating the effect plastics and other insulators have on RF circuits, provided a flat sample of at least 55mm diameter is available. It can, by measuring relative permittivity (dielectric constant), assist in identifying plastics.

There was another use for the T-130. The space charge increases the apparent grid-cathode capacitance of a valve – the denser the space charge, the greater the capacitance (this capacitance can appear to be negative at RF under certain conditions!). It's useful to know this variation when designing stable oscillators.

A valve produces both white noise and flicker noise due to the random emission of electrons from the cathode. Fortunately, both are reduced by the space charge. The denser the space charge, the lower the noise. This suggests an inverse correlation between noise level and grid-cathode capacitance, and indeed there is.

In a noise-critical application, it may be desirable to predict the noise in a tube operated in conditions different to the that given as typical in data sheets. One can measure the noise in a prototype circuit directly, but it can be quicker and easier to measure the capacitance.

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trolytics C99 and C100 with new tantalum units, following Rule 10. No symptoms were cleared, and no new symptoms appeared. C99 and C100 are too small to provide any meter damping. They were only installed from serial number 6040 onwards. Presumably, the Schmitt trigger sometimes oscillated due to the transients in the meter circuit wiring getting back to the Schmitt input.

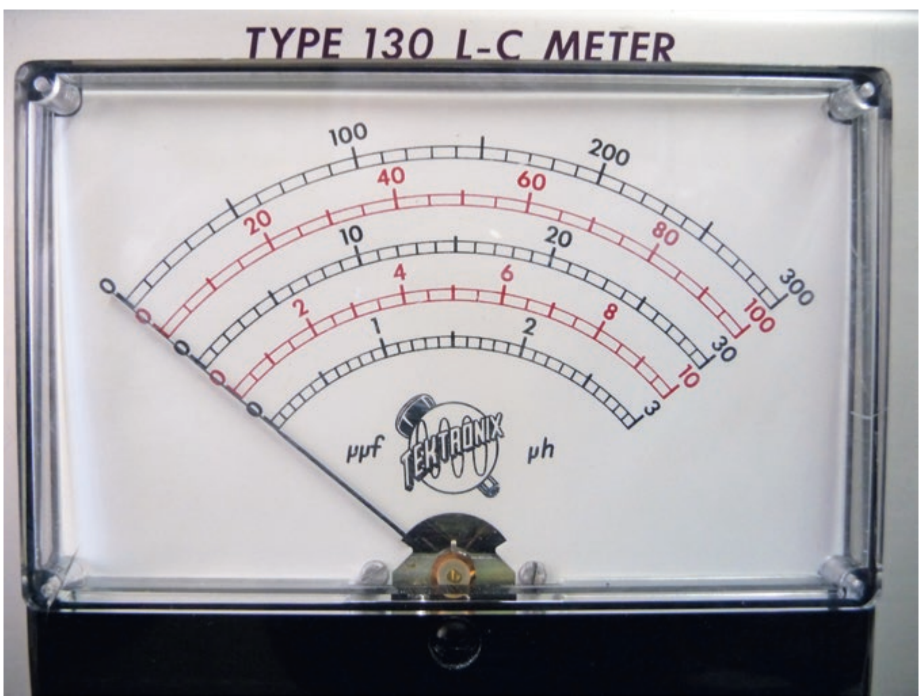
- Schmitt triggers can oscillate if the valve gm is very low. Sure enough, checking it (V70, 6U8 again) showed that was the case. I replaced it with a NOS valve (following Rule 10 of course). The wild pointer swings no longer occurred when rotating a tuning capacitor under test.
- V45 (another 6U8) had low emission in the triode, which works as the discharge diode in the meter circuit. This caused the backwards and somewhat unstable deflection of the meter, as its contact potential was too weak to balance out the back-bias from resistors R95 and R96.
- The output of the cathode follower was low, with a lot of hum. Changing the 6BH6 (V110) fixed it.

Damaged meter movement

As mentioned earlier, the meter movement plastic case was broken on the left-hand side. A previous owner had patched it up, but there was still a gap. That was unacceptable, as it would let dust in, eventually ruining the movement. The scale markings had faded as well.

Fortunately, I had another 4.5-inch meter that fitted the mounting holes and had the same full-scale deflection current. It even looks like the meter Tek fitted to later T-130s. It did not, of course, have the same scales.

I photographed the scales in the bro-



While not the original, the meter looks very close to some of the later models, which can be viewed at http://w140.com/tekwiki/wiki/130

Restoring the S-30 Delta Standards Box

Users of the T-130 could send it back to the Tektronix factory for adjustment and calibration, but this would have been inconvenient, to say the least.

Tektronix sold the S-30 Delta Standards Box as an accessory. The S-30 plugs into the UNKNOWN connector and enables you to check the T-130 accuracy. The S-30 contains preset capacitors for each range, an inductor, and a choice of 1MΩ and 100kΩ resistors.

Only one inductor is needed because if all the capacitance ranges read correctly, and any one inductance range reads correctly, the other inductance ranges must be right. The resistors allow you to check the resistance compensation of the variable oscillator.

The capacitors and the inductor in the S-30 were adjusted in the factory to within 1%. Combined with the T-130 basic accuracy and repeatability of ±1%, using the S-30 to calibrate the T-130 then gives you a T-130 with an accuracy of ±2%.

Typical of reputable American companies, only ±3% accuracy was claimed in Tektronix marketing – a “safety” margin of an additional 1%.

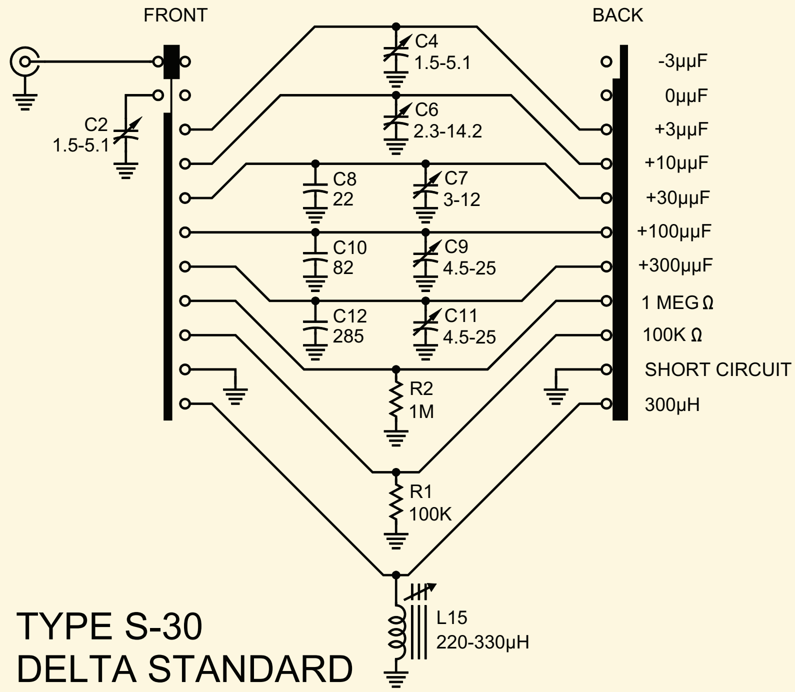
I purchased an S-30 from another eBay seller. It arrived with the outside marred by wear and tear and some gum from ownership stickers was present.

I removed the single control knob, the anodised front panel and the case, and gave them all a wash in the sink with dishwashing liquid. This easily removed the grime and the sticker gum, but made the wear and tear more obvious. I decided not to do anything about the wear and tear.

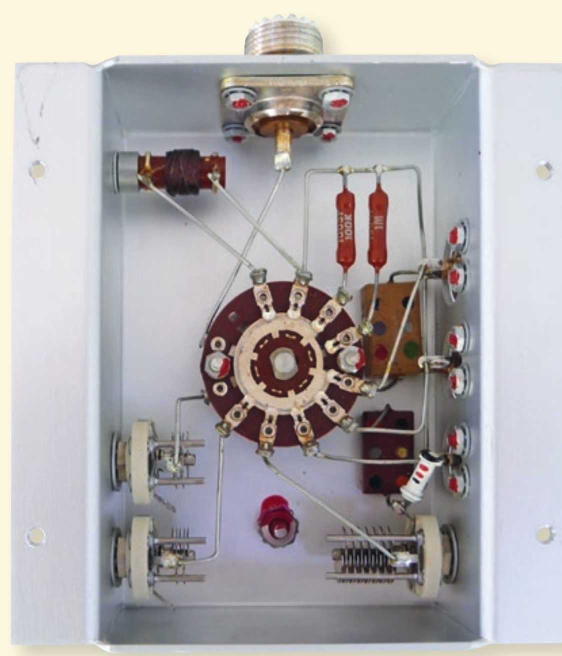
What was more of a concern was that the inner chassis had rotated within the case, so that a connection could not be made. Further disassembly revealed that the inner chassis was secured only by the switch boss and nut – there was nothing to stop rotation when the switch knob was turned.

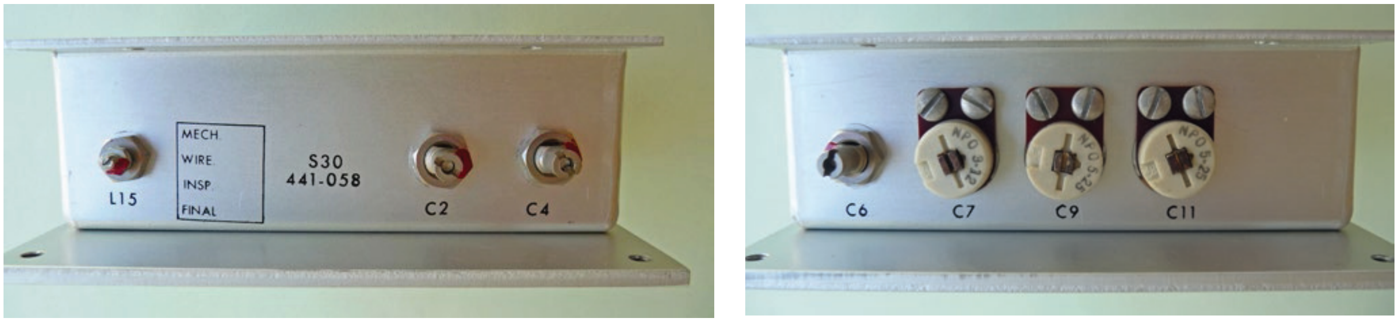
Using a generous amount of Blu Tack to contain chips and prevent them spreading within the inner chassis, I carefully drilled a location hole and installed a nut and bolt to prevent rotation – something Tektronix should have done.

The Blu Tack left a grease mark, so I used a cotton bud and isopropyl alcohol to get rid of it.



This is one of the ‘old’ style S-30s, the ‘new’ style ones are slightly taller with a visible logo and smaller print (http://w140.com/tekwiki/wiki/S-30).





The capacitance and inductance trimmers are mounted on the sides of the S-30 chassis. They are meant to be adjusted as required with the aid of an RLC bridge, and can be accessed by removing the blue case.

ken meter and converted them into a CAD file. I then jury-rigged a Rotring technical pen in a desktop NC milling machine and used that to inscribe new scales, complete with Tektronix logo, to fit the replacement meter movement.

Adjustment and calibration

T-130 owners could buy an S-30 Standards Box for calibration (see panel). This contained various adjustable capacitors that could be checked on a standard audio RLC bridge (see diagram at left). It also contained an adjustable inductor. Since this inductor was designed for 140kHz, it could not be checked on a standard RLC bridge.

The T-130 manual describes an "Inductance Standardizer" which contains a 1% tolerance 4310pF capacitor. This resonates when connected in series with a correctly adjusted S-30 inductor at 140kHz. The T-130 is used as a 140kHz null resonance indicator. Tek didn't sell the Inductance Standardizer – they expected S-30 owners to build it themselves.

I bought an S-30 from another eBay seller, and I made an Inductance Standardizer with paralleled 1nF and 3.3nF 1% capacitors.

However, calibration with a frequency counter is easier and more accurate. All you need is a Production Test Fixture, a 300pF 1% capacitor, a 100pF capacitor (accuracy unimportant) and two 0.5W carbon resistors, 100kΩ & 1MΩ. The resistors must be identical types.

The Production Test Fixture (shown overleaf) ensures the stray capacitance in connecting the capacitor and resistors is always the same. The T-130 can easily resolve 0.05pF, so physical precision in connection is vital.

Carefully zero the meter with the mechanical adjustment. Turn on the T-130 and leave it for one hour to warm up and stabilise. Connect a frequency counter to the output of the fixed oscillator buffer at R49 (1.5MΩ) and adjust T30 for a reading of precisely 140,000Hz.

Then, with the COARSE ZERO adjusted for half-scale deflection on the 3pF range, adjust resistance compensation trimmer C7 until the deflection is the same for both the 100kΩ and 1MΩ resistors. The manual says adjustment should be made last, but since it has a significant effect on the adjustment of T1, it's better to do it now.

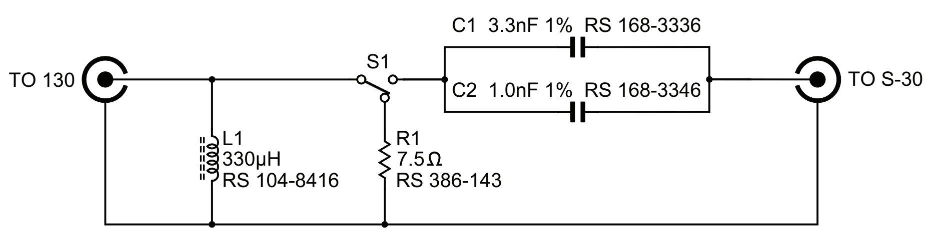
Next, connect a scope to the Schmitt trigger output on R74 (15kΩ). Select the 300pF range and insert the 300pF capacitor. Adjust R68 (symmetry) for the best waveform symmetry.

Now connect a frequency counter to R74 (or leave the scope connected, if it has an inbuilt frequency counter). Adjust the COARSE and FINE ZERO controls for a dead beat on the 3pF range with nothing in the Production Test Fixture. Re-insert the 300pF capacitor and adjust T1 for precisely 15,477Hz.

Repeatedly adjust COARSE ZERO, FINE ZERO and T1 until you get dead beat and 15,477Hz without further adjustments. Then, with the 300pF capacitor still inserted, adjust R78 for exactly full-scale deflection of the meter.

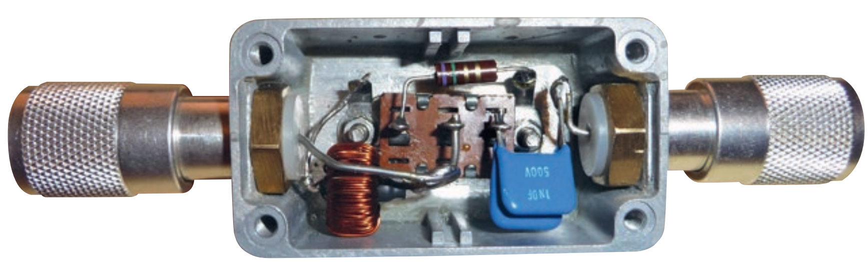
At this point, the total tuning capacitance without the 300pF capacitor is 1136pF, T1 is 1136μH, and both the 300pF and 300μH ranges are correct. The Schmitt trigger output for all ranges is correct and the range trimpots R97 through R100 can then be adjusted.

Insert the 100pF capacitor and adjust the COARSE and FINE ZERO controls to get precisely 5781Hz. Then adjust the 100pF range trimpot R97 for



The circuit diagram for the Inductance Standardizer is shown above, with the interior shown slightly below actual size (64mm long diecast box).

Inductance Standardizers were meant to be constructed from the circuit provided in the manual and as made obvious from the labelling, this wasn't made by Tektronix.



L-C Meter 130

Direct-Reading Measurement of Small Reactances

Measures Up to 300 µH or 300 pF

Easy-to-Read 4½-inch Meter

Convenient Operation

The 130 L-C Meter is a direct-reading reactance meter that measures small reactances in a series mode at a frequency between 125 kHz and 140 kHz. Meter indicates inductance up to 300 µH and capacitance up to 300 pF. The unknown inductor or capacitor is part of a resonant circuit whose frequency is compared to a 140-kHz reference oscillator. Meter indicates the two oscillators' frequency difference but is calibrated directly in µH and pF. Measurement of very small reactances is possible by using special measurement procedures that are described in the instrument instruction manual.

The 130 is particularly useful for measuring small capacitances in the presence of environmental strays. A front-panel Guard Voltage output connector provides in-phase drive to the environmental capacitance to eliminate strays from the measurement. Thus it is possible to measure vacuum tube interelectrode capacitances. Up to 300 pF environmental capacitance around an unknown capacitor can be guarded if the guard terminal loading is not excessive. Loading limits are outlined in the instruction manual.

Resistance loading compensation is optimized for 117-volts RMS operation. The following loads will not appreciably alter the measurement indication:

Capacitance: as low as 100-kΩ shunt.

Inductance: as low as 20-kΩ shunt, up to 10-Ω series.

Correction tables in instruction manual indicate needed corrections for other values of load resistance. Actual corrections determined for each instrument at time of each recalibration.

Range Selection—Microhenrys— 0 to 3, 10, 30, 100, and 300. Picofarads— 0 to 3, 10, 30, 100, and 300.

Accuracy—Meter indicates within 3% of full scale accuracy of any one range can be improved by special calibration at the time measurement is made.

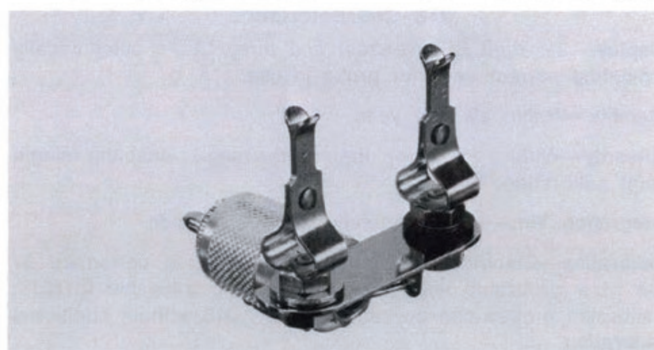
Power Requirement— 40 watts, 50 to 60 Hz. Instrument factory wired for 105 V-to125 V (117 V nominal) operation. Transformer taps permit operation at 210 V to 250 V (234 V nominal). Instrument can be ordered factory wired for 210 V operation.

Dimensions and Weights

Height	≈11 in	27.0 cm
Width	≈11 in	17.8 cm
Depth	7 in	28.3 cm
Net weight	9 lb	4.1 kg
Shipping weight	≈13 lb	≈5.9 kg

Included Accessories—P93C Probe package (010-0003-00); black output lead (012-0014-00); red output lead (012-0015-00); 3-conductor power cable (161-0010-03).

130 Direct-Reading L-C Meter **$400**



Production Test Fixture—Reduces production time required to sort and test capacitors and inductors, **order 013-0001-00 $8.00**

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An excerpt form the Tektronix catalog from 1975 showing the T-130 and a photo of the Production Test Fixture, right at the end of its production life. A replica of the Production Test Fixture, made from stainless steel and a standard UHF-to-N adapter, was shown in the first article of this series in the June issue on page 39.

exactly full-scale deflection.

When I made this adjustment, I found that R97 was hopelessly noisy. Applying lubricant didn't fix it. I could not locate an identical pot, so I moved the wire on one end of the track to the other end – that solved the problem.

Next, remove the 100pF capacitor and adjust the remaining trimpots for full-scale deflection on the remaining ranges with the correct frequencies. Use the COARSE ZERO and FINE ZERO controls to get the listed frequencies: 1812Hz to adjust R98 (for 30pF range), 612Hz to adjust R99 (10pF) and 184Hz to adjust R100 (3pF).

Finally, remove the Production Test Fixture, set COARSE ZERO to about 5° back from maximum and set FINE ZERO to its midpoint. Adjust zero span trimmer C2 for a dead beat on the 3pF range. Seal all adjustments with tamper-proof seal or red nail varnish.

Fun with screws!

I re-assembled the instrument using new screws because the old ones were all corroded and unsightly.

Typical for an American company, Tektronix used Unified Coarse (UNC) 6-32, 8-32 and 4-40 threaded screws to hold their instruments together. They used a mixture of CSK (countersunk), FH (flat head), PH (pan head) and TH (truss head – a wide version of pan head) screws. They used Keps nuts; these are the sort that have a star lock washer pre-attached to the nut.

I found I had run out of some of the screws needed. There are three specialist fastener shops in Perth. I rang the first one and asked:

"Do you have in stock screws UNC-8-32 x 1/2 THS plated or stainless?"

"Err, do you want wood screws?"

"No, I'm asking for UNC-8-32 x 1/2 screws."

"Err, um, but what sort do you want, do they have a pointy end?"

"Forget it, mate. You don't understand UNC screw terminology – that tells me you don't sell UNC."

I rang the second firm. The chap clearly knew his screws, and had them in stock. But his minimum sale quantity was 200 of each item. Cripes, I'll never use that many in the rest of my life, and all the sizes I need would cost me more than the instrument is worth.

I rang the third firm. That chap also understood the terminology, but he didn't stock them. He told me to ring firm number 2.

I fired up eBay and bought 20 of each size from a Chinese seller. They arrived within a week, post free, costing me about $4 for each size. And local shops wonder why they are losing sales...

Performance after restoration

The T-130 is very good. There is no perceptible drift in zero over the specified supply voltage range of 210-250V AC. The drift of the zero setting in the initial warm-up is less than 0.15pF indicated. After that, no drift in zero or full-scale deflection is perceptible on any range except the 3pF and 3μH ranges, which in any case remain within 5% and 1% when the FINE ZERO is adjusted just before making a reading.

Tek claimed that the oscillators will not pull in together above 1Hz separation (0.016pF indicated). Mine certainly betters that specification.

Did the eBay seller lie?

The seller claimed he tested it with a 25pF capacitor and got a stable reading. Clearly, with all the faults the T-130 had, it could not measure anything. Did he lie? Not necessarily.

He probably connected the 25pF capacitor, selected the 100pF range and switched the T-130 on. The 1N2630 probably didn't short the heaters until he shipped it to me. Because of the incorrect rectifier not being properly grasped by the socket, there was no HT, therefore no back-bias to oppose contact potential in the charge and discharge valves.

One of them had weak emission, and it just so happened that the weak emission produces about 25% meter deflection. So it might have appeared that the instrument was working, at least in that one specific test case! SC

◄ The T-130 LC Meter with the Inductance Standardizer and S-30 Delta Standards Box connected together.

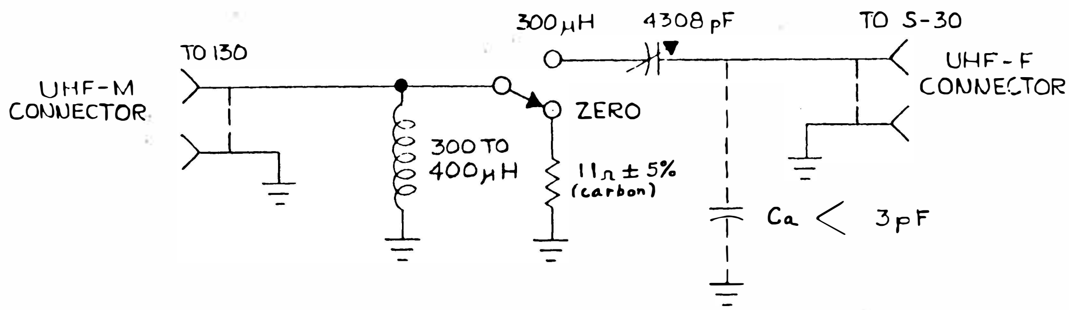
DELTA STANDARD
(Part No. 015-0001-00)

The S-30 Delta Standard provides a means for calibrating the Type 130 L-C Meter. The accuracy of the S-30 is ±1% or better in all ranges.

The S-30 provides seven calibrated capacitance ranges, two precision resistors, and one standard inductance of 300 µH at 140 kH_z.

Equipment Required

10kHz Capacitance Bridge with an accuracy of 0.04% of reading, such as ESI Model 701 •
Resistance Bridge with an accuracy of 0.25%
Parallel measuring Capacitance Bridge with an accuracy of 0.25%, such as Boonton Model 75D •
Inductance Standardizer, to be constructed from the following schematic:



Assembled in a metal box with approx. 2" x 2" x 3" dimensions.
C = Silver mica and trim capacitor adjusted at 10 kHz to 4308 pF ±0.2%.

Capacitance Ranges

NOTE

Only the stray capacitance of the connector and switch assembly is in the circuit in the -3 pF position. The actual capacitance of these strays is approximately 10 to 20 pF. No effort is made to standardize this value. As the switch is rotated, capacitors are switched into the circuit to provide a change (or "Delta") of capacitance as indicated. In the 0 pF position, an additional 3 pF has been added in addition to the strays.

Calibration of the capacitance ranges is verified by using a 10 kHz capacitance bridge. The procedure is to measure the capacitance of the S-30 in the -3 pF position, then switch to the 0 pF position and determine if the "Delta" change is 3 pF ±1%. Adjustment of C-2 will be necessary if not within tolerance. Continue to switch to each range and measure the capacitance while adjusting the trimmer indicated in Table 1 to give the correct "Delta" changes.

TABLE 1

Switch Position	Typical Value	Adj.
-3 pF	13 pF	None
0 pF	16 pF	C-2
+3 pF	19 pF	C-4
+10 pF	26 pF	C-6
+30 pF	46 pF	C-7
+100 pF	116 pF	C-9
+300 pF	316 pF	C-11

Resistance Ranges

Two 1% resistors of identical manufacture are used to standardize the resistance compensation. Measure the resistance with a resistance bridge. The capacitance of the 2 resistance positions should be within 0.1 pF of each other. This is verified by suing a parallel measuring capacitance bridge. The capacitance can be adjusted by positioning the 100k and/or 1MΩ resistors with respect to the grounded wire supporting these resistors.

Inductance Range

To calibrate the 300 μH range of the S-30, construction of the Inductance Standardizer is required.

The 130 LC meter's fixed frequency OSC must be 140 ± 0.2 kHz for this inductance calibration to be valid.

Insert the Inductance Standardizer between the S-30 and the Type 130 LC meter. Place the switch of the Type 130 LC meter in the 3 μH position. Place the switch on the inductance standardizer to zero. With the COARSE and FINE ZERO controls bring the meter reading of the Type 130 LC meter to 0.

Place the switch on the Inductance Standardizer to the 300 μH position and adjust L15 until the Type 130 LC meter reading is brought back to 0.

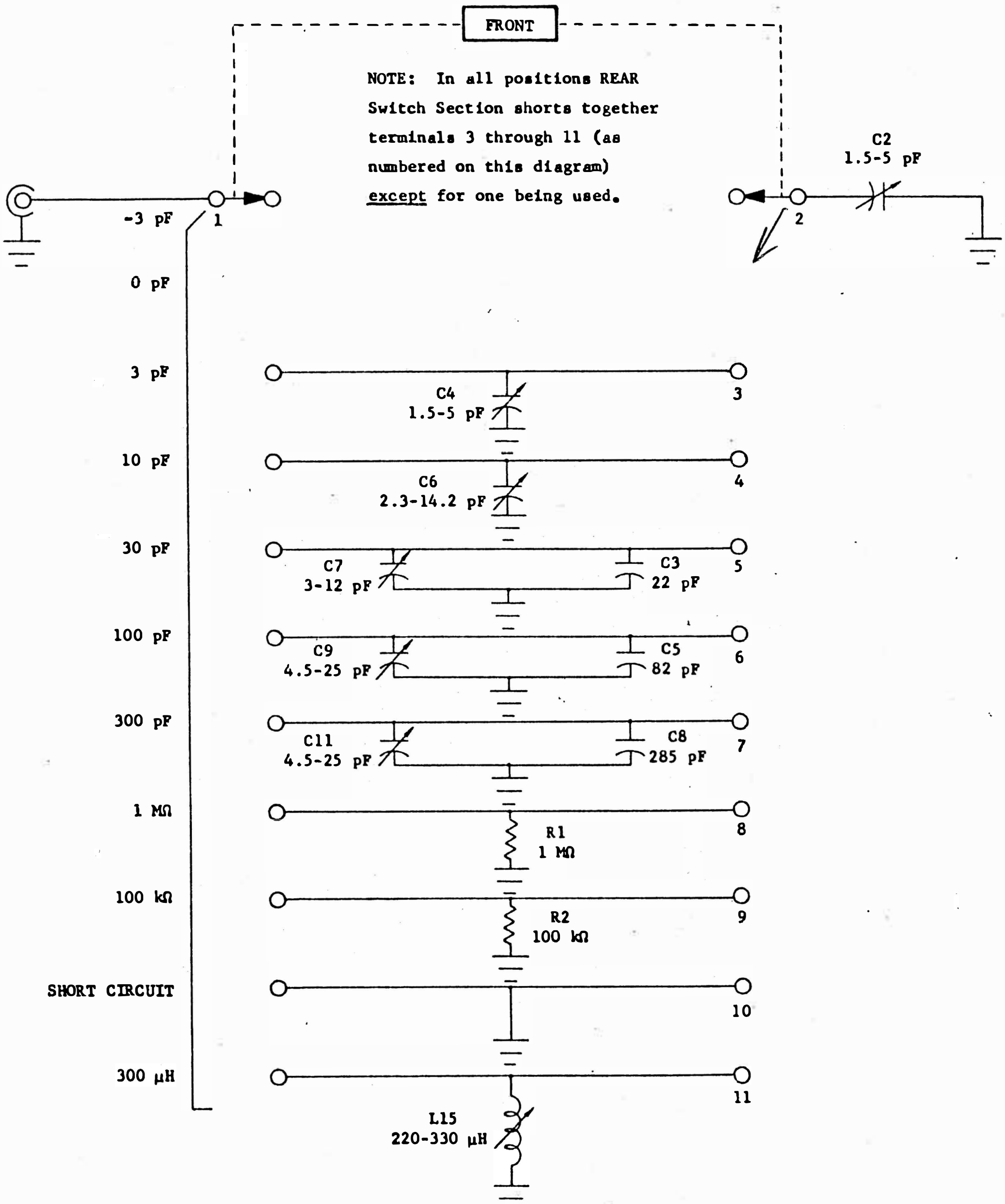
The 4308 pF Capacitor in the Inductance Standardizer is series resonant with the 300 μH inductor in the S-30 at 140 kHz. Therefore, the 130 LC meter sees only the residual AC resistance (≃11Ω) of this inductor.

After completing the adjustment, lock the slug of L15 in place.

Note

This method calibrates the Delta Standard's inductance to be 300 μH at 140 kHz. However, when the Delta Standard is connected directly to the 130 LC meter, the meter reading will be about .5% low. The 130 LC meter's measurement frequency is 125 kHz when 300 μH is connected to it. The frequency coefficient and 11 Ω of residual resistance are the factors that contribute to the 130 LC meter's low reading. This deviation can be neglected in most cases.

ELECTRICAL PARTS LIST
(Part No. 015-0001-00)



ELECTRICAL PARTS LIST
(Part No. 015-0001-00)

Values are fixed unless marked Variable.

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Capacitors			
Tolerance ±20% unless otherwise indicated.							
C2	281-0017-00			1.5-5 pF, Var	Air		
C3	281-0511-00			22 pF	Cer	500 V	10%
C4	281-0017-00			1.5-5 pF, Var	Air		
C5	295-0041-00			82 pF	Mica	500 V	2%
C6	281-0018-00			2.3-14.2 pF, Var	Air		
C7	281-0009-00	MDL 1	MDL 1	1.5-7 pF, Var	Cer		
C7	281-0007-00	2-1001		3-12 pF, Var	Cer		
C8	295-0042-00			285 pF	Mica	500 V	2%
C9	281-0011-00	MDL 1	MDL 1	5-25 pF, Var	Cer		
C9	281-0010-00	2-1001		4.5-25 pF, Var	Cer		
C9	281-0011-00	MDL 1	MDL 1	5-25 pF, Var	Cer		
C11	281-0010-00	2-1001		4.5-25 pF, Var	Cer		
				Inductor			
L15	*114-0032-00			200-330 μH, Var	Core not replaceable		
				Resistors			
Resistors are fixed, compensation, ±10% unless otherwise indicated.							
R1	309-0148-00			1 MΩ	1/2 W	Prec	1%
R2	309-0260-00			100 kΩ	1/2 W	Prec	1%
				Switches			
	260-0429-00			Rotary	1 Sec.	11 Pos.	

MECHANICAL PARTS LIST
(Part No. 015-0001-00)

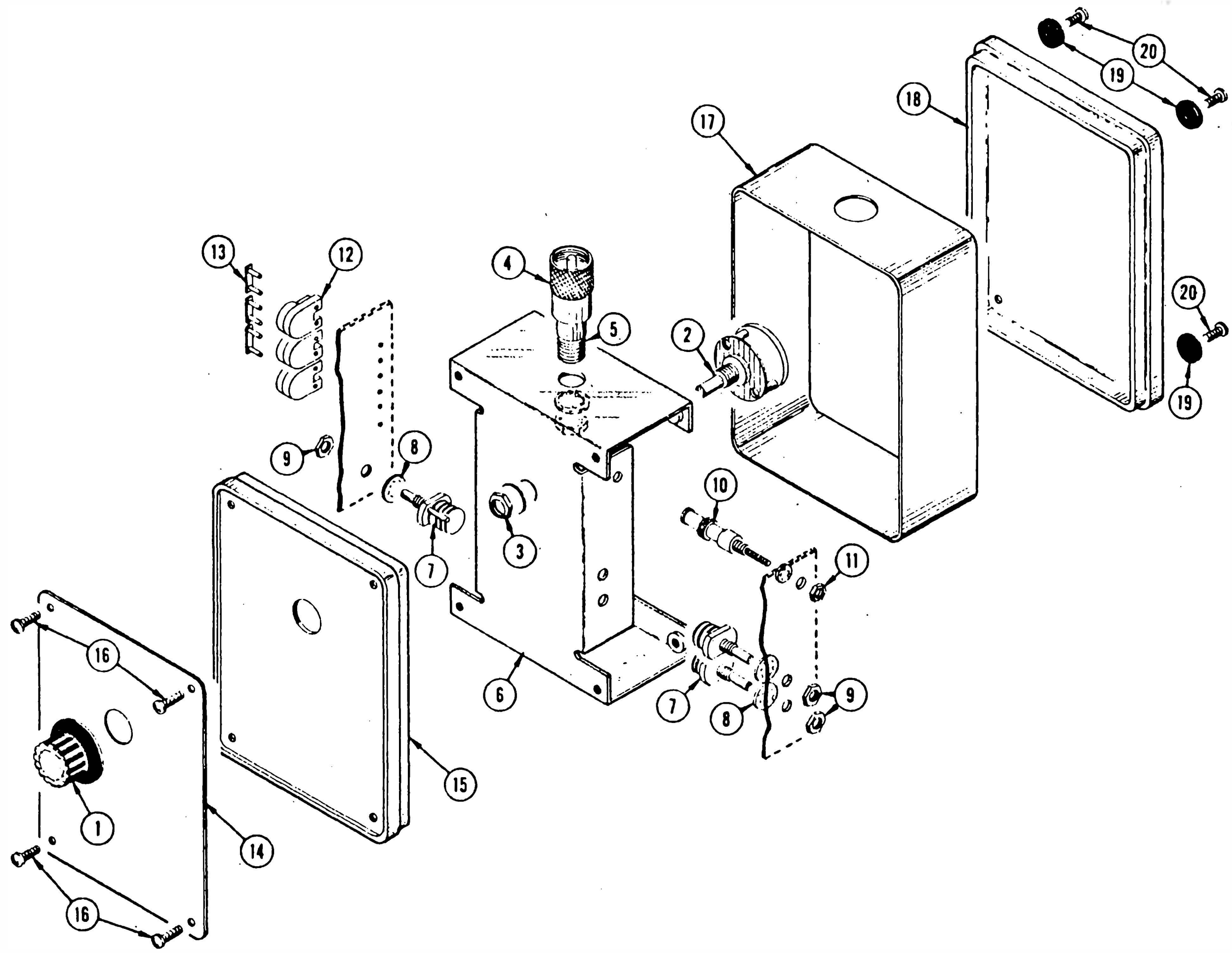


Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
1	366-0028-00	MDL 1	MDL 1	1	KNOB, black
	366-0117-00	2-1001		1	KNOB, charcoal
	- - - - - -			-	knob includes:
	213-0004-00			1	SETSCREW, 6-32 x 3/16 inch, HSS
2	260-0084-00	MDL 1	MDL 1	1	SWITCH, unwired, delta standard
	260-0429-00	2-1001		1	SWITCH,
	- - - - - -			-	mounting hardware:
	- - - - - -			-	(not included w/switch)
	210-0840-00	MD1	MDL 1	1	WASHER, flat, 0.390 ID x
	- - - - - -			-	0.562 inch OD
	210-0012-00	2-1001		1	WASHER, lock, internal,
	- - - - - -			-	3/8 x 1/2 inch
3	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
4	131-0012-00	MDL 1	MDL 1	1	CONNECTOR, coaxial, female
	131-0146-00	MDL 1	MDL 1	1	CONNECTOR, coaxial
	210-0004-00	MDL 1	1154X	4	WASHER, lock, internal, #4
	210-0406-00	MDL 1	1154X	4	NUT, hex., 4-40 x 3/16 inch
	211-0008-00	MDL 1	1154X	4	SCREW, 4-40 x 0.250 inch, PHS
	200-0026-00			1	COVER, coaxial, male connector
	358-0153-00	X2-1001		1	BUSHING, insulator, plastic
	131-0196-00	2-1001	1154	1	CONNECTOR, plug, electrical
	131-0168-00	1155		1	CONNECTOR, plug, electrical
	- - - - - -			-	mounting hardware: (not included w/connector)
5	102-0006-00	2-1001		1	REDUCER, 7/16 inch diameter x 1 inch long
	210-0012-00	2-1001		1	WASHER, lock, internal, 3/8 x 1/2 inch
	210-0413-00	2-1001		1	NUT, hex., 3/8-32 x 1/2 inch
	386-0342-00	MDL 1	1155X	1	PLATE, adapter
6	441-0058-00	MDL 1	MDL 1	1	CHASSIS
	441-0397-00	2-1001	1154	1	CHASSIS
	441-0441-00	1155		1	CHASSIS
7	- - - - - -			3	CAPACITOR
	- - - - - -			-	mounting hardware for each: (not included w/capacitor)
8	211-0011-00			1	SCREW, 4-40 x 0.312 inch, BHS
9	210-0442-00			1	NUT, hex., 3-48 x 3/16 inch
10	- - - - - -			1	COIL
	- - - - - -			-	mounting hardware: (not included w/coil)
	210-0008-00			1	WASHER, lock, internal, #8
11	210-0409-00			1	NUT, hex., 8-32 x 5/16 inch
12	- - - - - -			3	CAPACITOR
	- - - - - -			-	mounting hardware for each: (not included w/capacitor)
13	213-0034-00	MDL 1	1154	2	SCREW, thread cutting, 4-40 x 5/16 inch, RHS
	214-0153-00	1155		1	FASTENER, snap, plastic
14	333-0117-00	MDL 1	MDL 1	1	PANEL, front
	333-0681-00	2-1001		1	PANEL, front
	211-0504-00	MDL 1	MDL 1	4	SCREW, 6-32 x 0.250 inch, PHS
15	386-0343-00	MDL 1	MDL 1	1	PLATE, subpanel
	211-0502-00	MDL 1	MDL 1	6	SCREW, 6-32 x 0.188 inch, 100° csk, FHS
	200-0331-00	2-1001		1	COVER
	- - - - - -			-	mounting hardware: (not included w/cover)
16	211-0071-00	2-1001		4	SCREW, 4-40 x 0.375 inch, THS
17	437-0017-00	MDL 1	MDL 1	1	CABINET
	380-0028-00	2-1001		1	HOUSING, wrap around
18	386-0344-00	MDL 1	MDL 1	1	PLATE, 3 5/16 x 4 1/8 inches
	200-0309-00	2-1001		1	COVER, box
	- - - - - -			-	mounting hardware: (not included w/cover)
19	348-0037-00	X2-1001		4	FOOT, rubber
20	211-0012-00	X2-1001		4	SCREW, 4-40 x 0.375 inch, PHS

INSTRUMENT TYPE S-30 DELTA STANDARD

INSPECTION PROCEDURE

FINISHED PRODUCTS QUALITY CONTROL

S-30 DELTA STANDARD
015-0001-00

This procedure has been prepared for the Finished Products department. It will be a guide for a check of the instruments quality. The test limits in this procedure are, in the most part, internal limits set at the factory and are confidential. Inspection procedure test limits are the same as those found in the FCP.

This procedure, the test limits and any subsequent changes will be maintained and issued by Finished Products QC. Abbreviations used are taken from Tektronix Standard A-100. Words written in all capital, or upper case letters, are titles of procedure steps, front or rear panel labels, or TEKTRONIX instrument names. LH .

EQUIPMENT REQUIRED

1	TEKTRONIX TYPE 130 L-C METER (L-C METER)
* 1	TEKTRONIX TYPE S-30 DELTA STANDARDS (S-30 DELTA)
* 1	S-30 INDUCTANCE STANDARDIZER
1	UHF T Male to 2 Female (103-0026-00)
1	UHF Female to Female (103-0025-00)
1	UHF Male to Male (2 UHF Male cable connectors soldered together)
1	TRIPLETT MODEL 630 or equivalent Multimeter

* This equipment is calibrated to NBS for factory calibration standard (FC std)

PRESETS

130 L-C METER		
	RANGE SELECTOR	300µµF
	COURSE ZERO	midr
	FINE ZERO	midr
S-30 DELTA		
	RANGE SELECTOR	Opf
(Cal Standard)		
S-30 INDUCTANCE STANDARDIZER		
	SWITCH	ZERO

SHORT FORM

1 VISUAL INSPECTION

no defects

2 SET UP

1 CAPACITY RANGE ACCURACY

±1%

1 INDUCTANCE

≤ 1% (3μH)

2 SHORT CIRCUIT

no resistance (0 Ohms)

3 RESISTANCE

±1%

VISUAL INSPECTION

No defects

101 **CHECK** - for defects in workmanship, printed information, paint chips, scratches or any defects

SET UP

102 **CONNECT** - FC std S-30 Delta to L-C METER UNKNOWN L OR C (see Fig. 1)

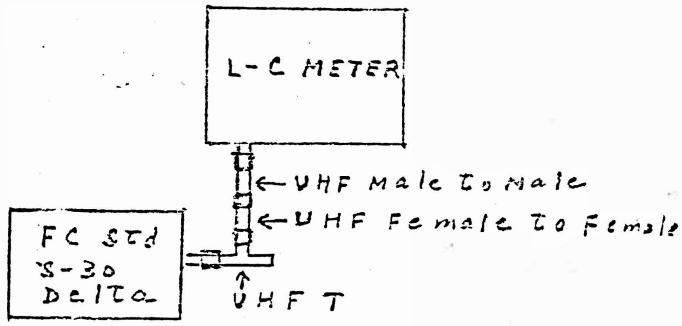


Fig. 1

ADJUST - L-C METER COURSE ZERO and FINE ZERO controls to set meter for 0 reading

SET - L-C METER RANGE SELECTOR to 3μμF

- S-30 Delta to + 3pf

CHECK - L-C METER reading and make note (should read 3μμF)

SET - S-30 Delta to -3pf

CHECK - L-C METER reading and make note

SET - L-C METER RANGE SELECTOR to 10μμF

- S-30 Delta to +10pf

CHECK - L-C METER reading and make note

SET - L-C METER RANGE SELECTOR to 30μμF

- S-30 DELTA to +30pf

CHECK - L-C METER reading and make note

SET - L-C METER RANGE SELECTOR to 100μμF

- S-30 DELTA to +100pf

CHECK - L-C METER reading and make note

SET - L-C METER RANGE SELECTOR to 300μμF

- S-30 DELTA to +300pf

CHECK - L-C METER reading and make note

SET - S-30 DELTA to 0 pf

- L-C METER RANGE SELECTOR to 3μμF

CHECK - L-C METER for 0 reading

PACITY RANGE
CURACY

1%

201 **NOTE** - leave FC std. S-30 DELTA range selector at 0 of on all capacity range checks

SET - S-30 DELTA (to be checked) to 0 pf

CONNECT - S-30 DELTA to other end of UHF T adapter (see Fig. 1)

SET - S-30 DELTA to +3pf

CHECK - L-C METER reading for $\leq$ 1% (+0.03μμF, -0.03μμF) of meter reading you made note of in set up

SET - S-30 DELTA to -3pf

CHECK - L-C METER reading for $\leq$ +0.03μμF , -0.03μμF of noted reading

SET - L-C METER RANGE SELECTOR to 10μμF

- S-30 DELTA to 10pf

CHECK - L-C METER reading for $\leq$ +0.1μμF, -0.1μμF of noted reading

SET - L-C METER RANGE SELECTOR to 30μμF

- S-30 DELTA to 30pf

CHECK - L-C METER reading for $\leq$ to +0.3μμF , -0.03μμF of noted meter reading

SET - L-C METER RANGE SELECTOR to 100μμF

- S-30 DELTA to 100pf

CHECK - L-C METER reading for $\leq$+1.0μμF. -1.0μμF of noted meter reading

SET - L-C METER RANGE SELECTOR to 300μμF

- S-30 DELTA to 300pf

CHECK - L-C METER reading for $\leq$ +3.0μμF, -3.0μμF of noted meter reading

REMOVE - S-30 DELTA from UHF T adapter

- FC standard S-30 DELTA with adapters from L-C METER

INDUCTANCE ≤ 1% (3μH)	301	CONNECT	- FC S-30 INDUCTANCE STANDARDIZER to L-C METER UNKNOWN L OR C
			- S-30 DELTA (to be checked) to INDUCTANCE STANDARIZER (see Fig. 2)
		SET	- S-30 DELTA to SHORT CIRCUIT
			- L-C METER RANGE SELECTOR to 3μH
		ADJUST	- L-C METER COURSE ZERO and FINE ZERO controls to set meter reading to 0
		SET	- S-30 DELTA to 300μH
			- S-30 INDUCTANCE STANDARD to 300μH
		CHECK	- for ≤ 3μH on 3μH range
		SET	- S-30 INDUCTANCE STANDARD to ZERO
		REMOVE	- S-30 DELTA from inductance std.
SHORT CIRCUIT no resistance (0 ohms)	302	SET	- S-30 DELTA to SHORT CIRCUIT
			- Multimeter selector to X100KΩ
		CONNECT	- test probes together and adjust Ω adj for 0 reading
			- probes to S-30 DELTA input and gnd
		CHECK	- meter for 0Ω (Ohms) reading
RESISTANCE ± 1%	303	SET	- S-30 DELTA to 100KΩ
		CHECK	- resistance for 100KΩ ± 1000Ω (1K)
		SET	- S-30 DELTA to 1 MEG Ω
		CHECK	- resistance for 1 meg Ω ± 10,000Ω (10K)

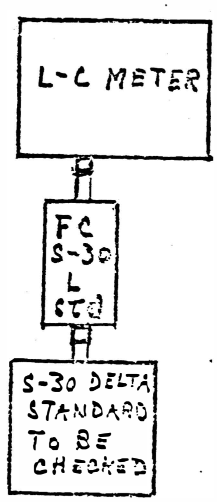


Fig. 2