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):

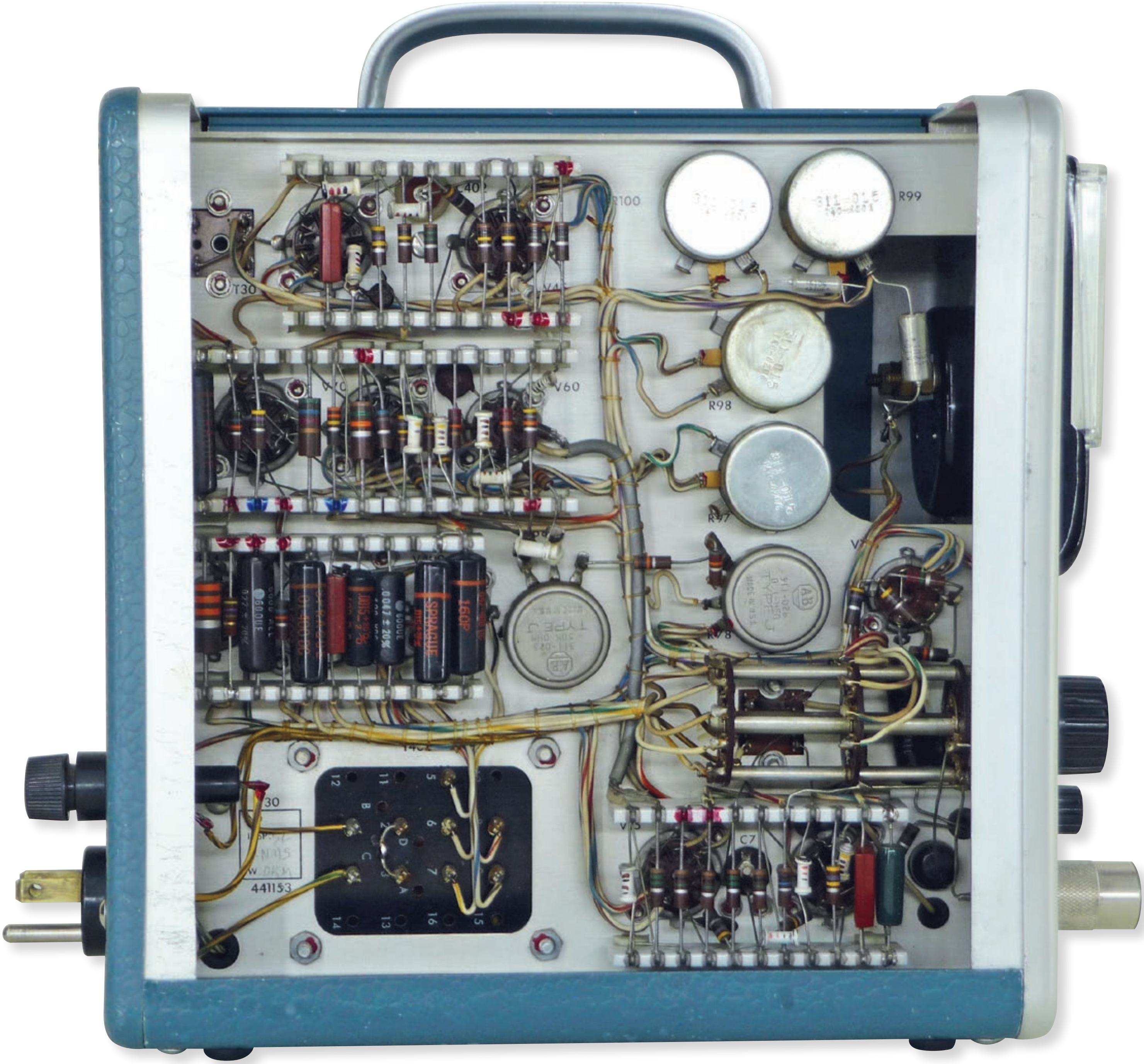
Every single time you replace a component, do a comprehensive set of checks to verify both that the fault due to that component has been cleared, and that no new symptoms have appeared.

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.

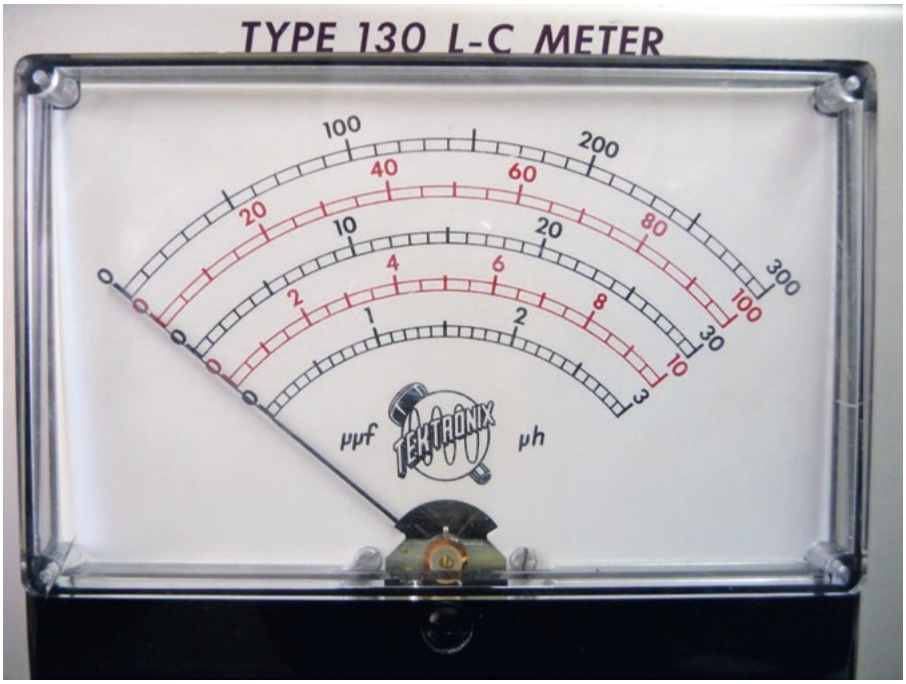
- Schmitt triggers can oscillate if the valve gm is very low. Sure enough, checking it (V70, 6U8 again) showed that was the case. I replaced it with a NOS valve (following Rule 10 of course). The wild pointer swings no longer occurred when rotating a tuning capacitor under test.
- V45 (another 6U8) had 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%.

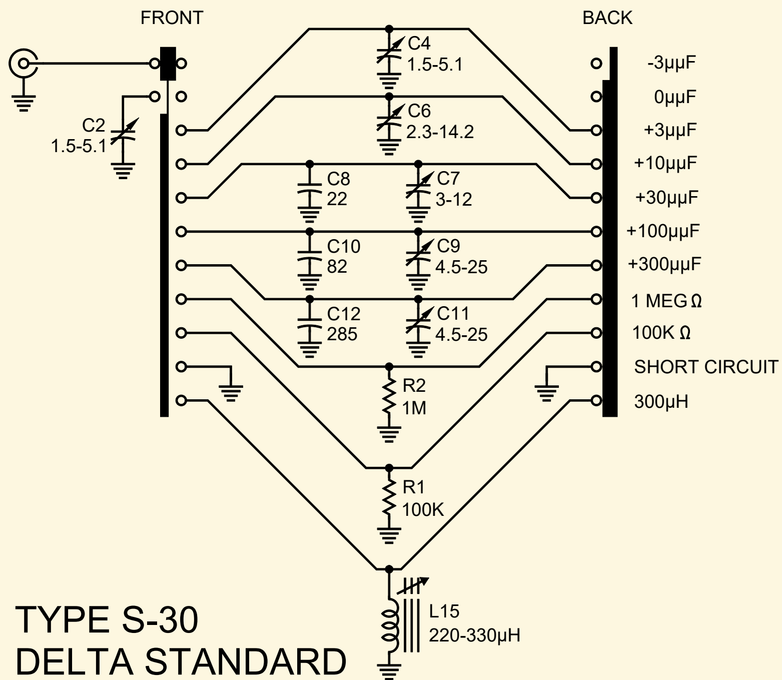
I purchased an S-30 from another eBay seller. It arrived with the outside marred by wear and tear and some gum from ownership stickers was present.

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.

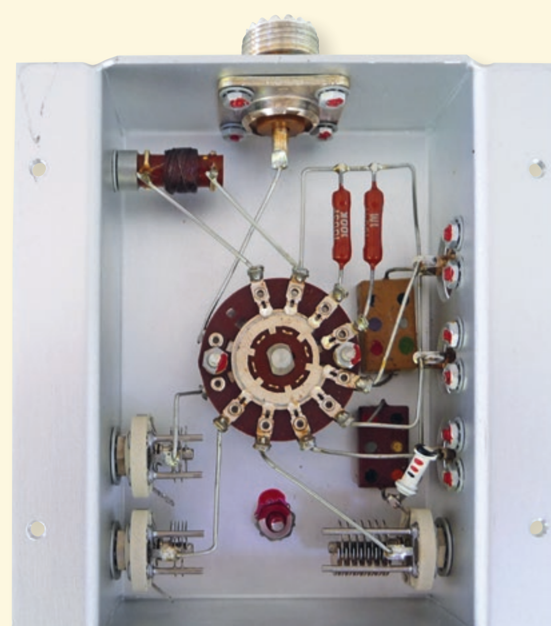
What was more of a concern was that the inner chassis had rotated within the case, so that a connection could not be made. Further disassembly revealed that the inner chassis was secured only by the switch boss and nut – there was nothing to stop rotation when the switch knob was turned.

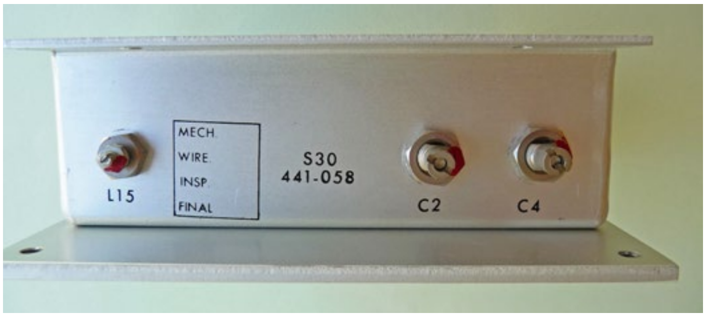
Using a generous amount of Blu Tack to contain chips and prevent them spreading within the inner chassis, I carefully drilled a location hole and installed a nut and bolt to prevent rotation – something Tektronix should have done.

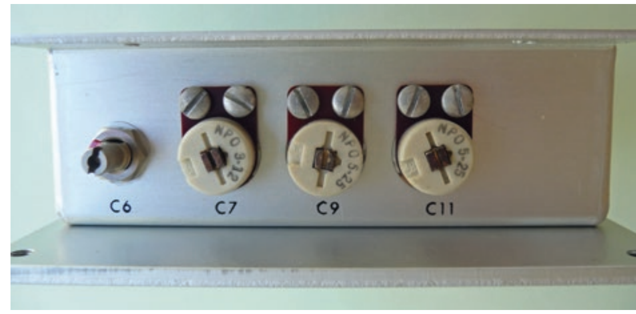
The Blu Tack left a grease mark, so I used a cotton bud and isopropyl alcohol to get rid of it.



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.

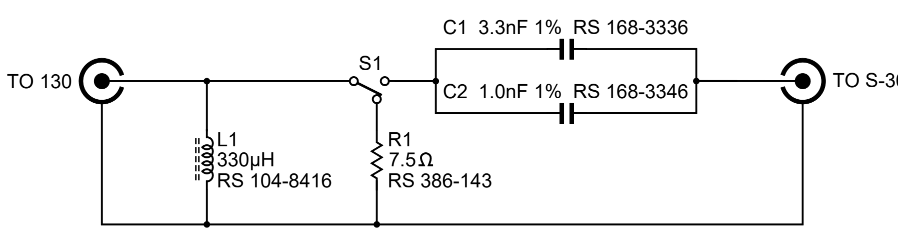
Next, connect a scope to the Schmitt trigger output on R74 (15kΩ). Select the 300pF range and insert the 300pF capacitor. Adjust R68 (symmetry) for the best waveform symmetry.

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.

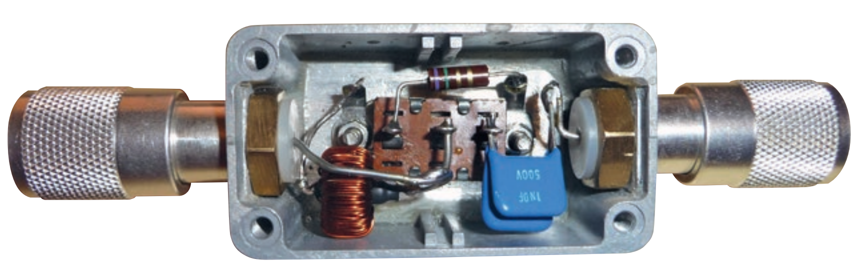
Repeatedly adjust COARSE ZERO, FINE ZERO and T1 until you get dead beat and 15,477Hz without further adjustments. Then, with the 300pF capacitor still inserted, adjust R78 for exactly full-scale deflection of the meter.

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 instrument 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.

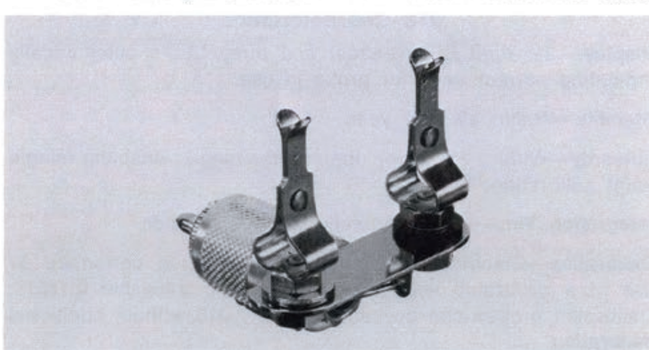
Power Requirement—40 watts, 50 to 60 Hz. Instrument factory wired for 105 V-to125 V (117 V nominal) operation. Transformer taps permit operation at 210 V to 250 V (234 V nominal). Instrument can be ordered factory wired for 210 V operation.

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.

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.**

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...