The Secret Life of the Tektronix P6137 400MHz Scope Probe & T Coils- Pg. 1-16.

Additional 2465B Tek Scope Repairs & Solutions- Pg. 17-29. H. Holden. March. 2026

INTRODUCTION:

Most Technicians performing any serious board level electronic repairs use Oscilloscopes. These also have applications in new equipment designs. Circuit simulations can only get you so far, especially in Radio Frequency work and in the end the real circuit requires examination & testing.

Oscilloscopes evolved rapidly after the late 1950's and early 1960's era when most scopes were limited to a 10MHz bandwidth. Over time they morphed into what we have today. Scopes capable of more than 1GHz effective bandwidth are not uncommon now. As this happened with the scope itself, the scope's probes also had to evolve, to make sure that their frequency response could support the scope's bandwidth.

The passive x1 probe, or non attenuating probe, has reduced utility because not only does it have the 1 Meg Ohm DC load of the scope itself, it adds significant load capacitance, often in the range of 80pF to 150pF. This causes it to substantially interfere with the operation of circuitry where the resistances are in the 100's of k Ohms to Meg-Ohm region. But also in many RF circuits where the additional load capacitance detunes and alters the circuit function. It was said by Tektronix(Tek) themselves, that the utility of the x1 probe, was to use it on power supply rails with AC coupling, to do a job such as checking for ripple voltage. Essentially Tek were describing a type of very low impedance circuit node where the loading of the x1 probe has no significant electrical effect.

POPULAR SCOPE PROBES:

The most popular general passive scope Voltage Probe in use today is the x10 variety. The reason for the general popularity of the x10 probe is that these provide relatively low loading on the circuit being tested. Ideally at least, the impedance of the scope probe should be a lot higher than the circuit node being tested and therefore the probe sees the signal as a voltage source and does not draw any significant current from the node.

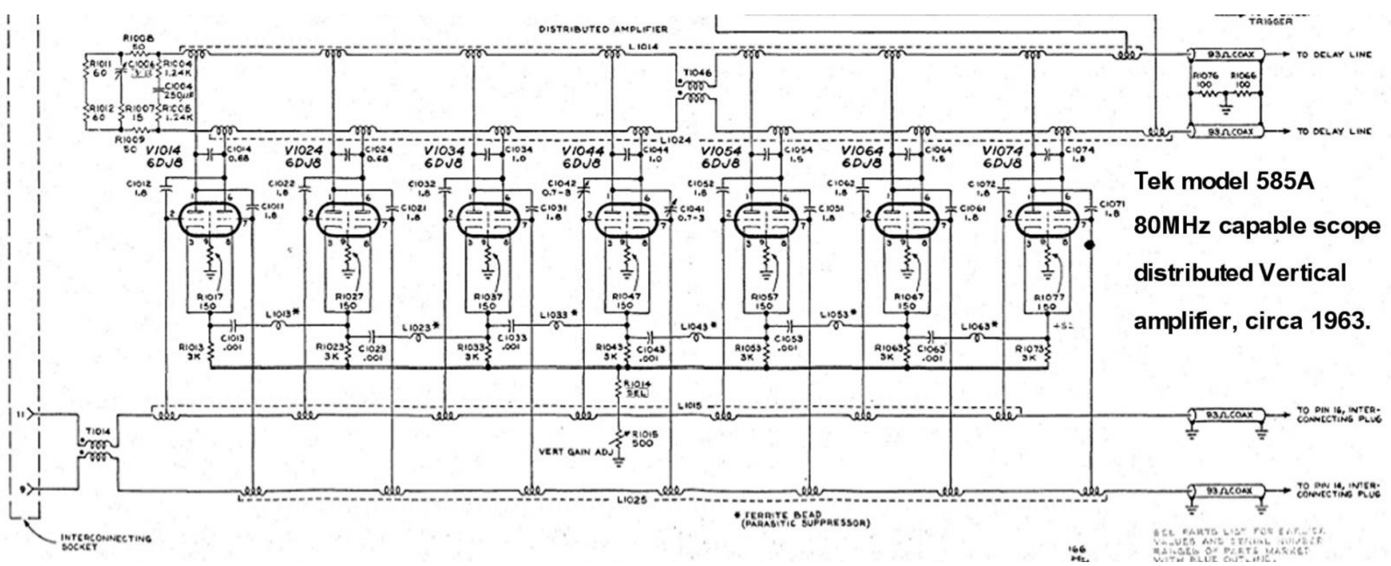
The x10 probe represents a DC load of 10 Meg Ohms and a Capacitive load in the order of 10 to 12pF. A very good example, such as the 400MHz bandwidth Tek P6137 model probe, for use with Tek's famous 24xx series of Oscilloscopes, has an input capacitance of 10.8pF.

It always should be realized that the impedance at the probe's input drops with increasing frequency. At 1MHz the impedance of a typical quality x10 400MHz rated probe, such as the P6137, has dropped to the order of 14k Ohms due to its input capacitance.

A Secret Life for the Tek P6137 probe? Perhaps, because Tek did not publish the schematic or design layout for this advanced and popular probe of the 1990's era, either in the probe's manual or elsewhere that I have been able to find. And up to this point in time, nobody else appears to have reverse engineered in documentation. This probe is still in wide use today. And as noted below, some aspects of the design such as the asymmetrical T coil system, has a proprietary nature.

INTRODUCTION TO THE THE T COIL:

The T coil technology is not just for scope probes. T coil techniques were pioneered by Tek and also used inside their scope's broadband Vertical Amplifiers to widen the bandwidth and improve the amplifier's transient response. The technique was also used in Vertical Amplifiers of a "Distributed Amplifier" design, where the entire Vertical amplifier chain with multiple Tubes, is broken up into sections that were equivalent to sections of a Transmission Line. A staccato transmission line if you like, made from lumped constants of R,L,C and Tubes themselves:



Tek model 585A 80MHz capable scope distributed Vertical amplifier, circa 1963.

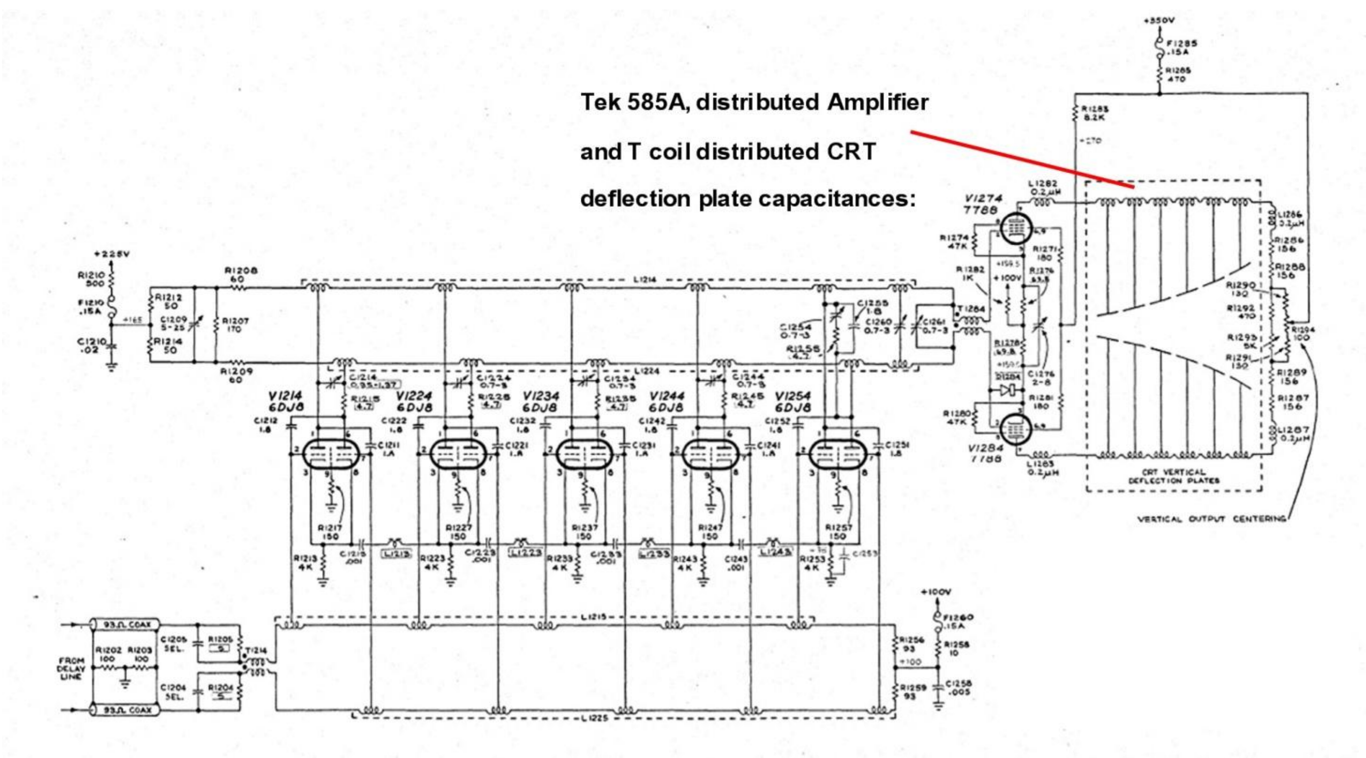
Using this technique, as early as 1963, Tek pulled off the astonishing feat of making an 80MHz bandwidth Oscilloscope, using Tubes, the model 585A.

Although Tubes are intrinsically high frequency capable devices, especially in tuned RF circuits which operate on one frequency with resonant circuit loads, Tubes have an enemy working against them, when it comes to making a broadband amplifier, compared to using Transistors.

For any given power, the Anode Voltages are higher and the Anode Currents are lower with Tubes than for the lower range Collector voltages and higher Collector Currents in the Transistor amplifier’s case.

This necessitates higher value Anode load resistances for Tubes than Collector load resistances for Transistors, so as to gain high level voltage swings, for example to drive a CRT’s deflection plates. Therefore stray and other associated parasitic capacitances have more of an R-C roll off effect for Tube circuitry than Transistor circuitry in the broadband amplifier design scenario. In a nutshell, it is more difficult to make a very wide bandwidth Tube amplifier, than a wide bandwidth Transistor amplifier.

It is quite miraculous how Tek got around this with the distributed amplifier design in their 585A Oscilloscope. They did the same thing at the end of the amplifier chain, by breaking up the CRT’s deflection plates, each which has a small capacitance and associating those with T coils to create a Transmission Line effect. They explained that the propagation of the signal along the deflection plates matched the velocity of the electrons in the CRT:



T COILS IN OSCILLOSCOPE PROBES:

Oscilloscope manufacturers usually made their own mating probes of their own designs to sell with their scopes. Most latter day oscilloscopes, on their input connectors (typically BNC types) have a fairly standard input resistance of 1 Meg Ohms and an input capacitance of around the 15pF to 20pF mark.

The Low frequency (LF) compensation capacitor, in a generic x10 probe, can be adjusted to suit the particular scope's input capacitance to match the scope. There is no need to have to stick to some specific manufacturer's probe, in most cases, but many prefer to have a probe brand which matches their scope's brand.

Some probe connectors carry pins with other functions. For example Tek probes usually have features such as a Readout Pin on their BNC connector. This pin allows the correct volts/cm to be displayed on the scope's data display. The probe termination and plug assembly contains a resistor connected to the readout pin. The resistor value will cause the scope display to show the correct x1, x10, x100 value, so there is no confusion about the true volts/cm value seen on the scope's screen.

The voltage withstand ratings of the x10 probe are generally good with a figure of 500V (DC+ peak AC) up to about 1.3MHz. Above that frequency the voltage withstand rating falls dramatically because as the frequency increases the impedance of the capacitances drop. Above 40MHz the voltage rating is down to around 50V.

If more signal attenuation is acceptable, then the x100 probe allows a lower value of input capacitance (the reason to be explained below) and higher input voltage tolerances.

For example the common x100 P4100 probe, now readily available for less than $40 is rated with a 100Meg Ohm input resistance combined with a 6pF input capacitance and 2kV rated for low frequencies. The LF compensation capacitor allows it to cover scopes with a 10pF to 35pF input capacitance. However, not many may be aware that there are two totally different types of x100 high voltage scope probes, with two different design philosophies and both will be discussed below.

In a nutshell, the task of a good very high frequency capable x10 or x100 scope voltage probe is a tough one. It requires the ability to place a minimal load on the circuit node tested and to have a flat frequency response. This is required to support the Oscilloscope's bandwidth capabilities. In addition the probe must possess good transient and rise-time behaviour when confronted with a fast rise signal. Bandwidth Bw and rise-time Tr, are generally related with the equation Bw = 0.35/Tr.

HISTORICAL PASSIVE SCOPE PROBE DESIGNS:

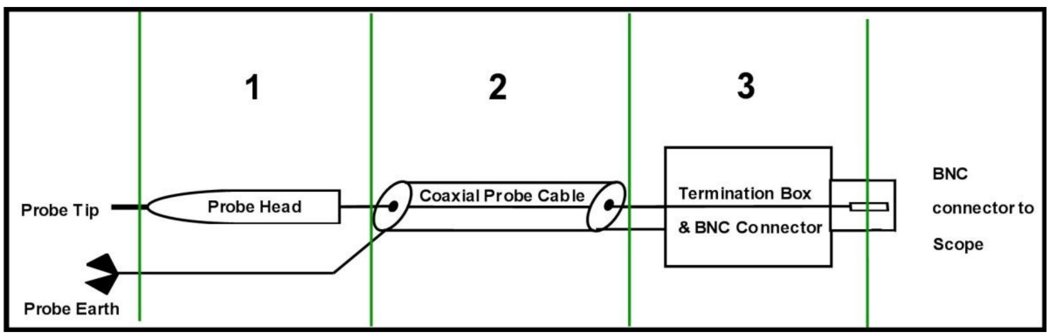
There is much more to it than meets the Eye, especially for a high performance probe, capable of a flat frequency response to over 100MHz and a good transient response.

It is better to break the design into three parts:

1) The Probe Head.

2) The Cable.

3) The connector/termination box at the oscilloscope end.



I think it is good to describe the probe's cable first, because it is far from your average piece of coaxial cable.

The Coaxial Cable:

A lot of the Scope probe's magic happens in the cable. Fundamentally the coaxial cable is required for shielding or stray signals would be very problematic.

Typical 50 Ohm coaxial cable has significant capacitance, for example around 30pF per foot. Therefore a 3.5 foot cable has a capacitance of around 105pF. However, as the frequencies increase the cable, which has a distributed capacitance C and distributed inductance L per unit length, has Transmission Line effects. These effects are especially problematic for scopes & their probes with a better than 10MHz bandwidth.

Of note, in the case of scope Voltage probes, the cable is not terminated at the scope end at the cable's characteristic impedance with a resistive load, as it normally is in radio frequency capable systems. The impedance looking into the scope's input connector is frequency dependent and drops as the frequency increases. Unless the scope input is selected for a 50 Ohm resistive termination and using 50 Ohm Coax. Also the impedance of scope probe cable itself is frequency dependent.

Near DC levels and with Audio signals for example, for the typical 1M scope input arrangement, at the scope's connector, it is close to 1Meg Ohms, however at 100MHz it is a capacitive reactive load in the order of 80 Ohms.

(There are "Impedance Probes" called Z probes which use 50 Ohm coaxial cable and are terminated into a 50 Ohm resistance at the scope end, these are not the topic of this discussion on scope "Voltage" probes)

Typical coaxial cable on its own is a "High Q structure" in that it is of low loss architecture. It contains elements of R, C and L per unit length. It does have minor dielectric losses and minor resistive losses. If the cable is "shock excited" by a very fast rise voltage transient injected into the end of the typical 50 Ohm coaxial cable of a few feet long, it Rings, at a frequency in the order of 60MHz.

In the days when most scopes had a bandwidth of less than 10MHz or so, the ringing in scope probe cables was not a problem observed or that needed to be solved. The cable's global capacitance was the main issue, not its Transmission Line properties. As new model scopes bandwidths improved, the probe cable issue had to be solved.

Tektronix created an elegant solution to the problem of scope probe cable ringing. Firstly they found it was improved, as expected, with damping resistors in series, at either end of the cable's central conductor. Resistors dissipate the energy and damp the oscillations lowering the cable's Q. But the better solution was to make the central conductor of the coax a resistor. This way the resistance is spread along the cable proportionally with the capacitance and inductance.

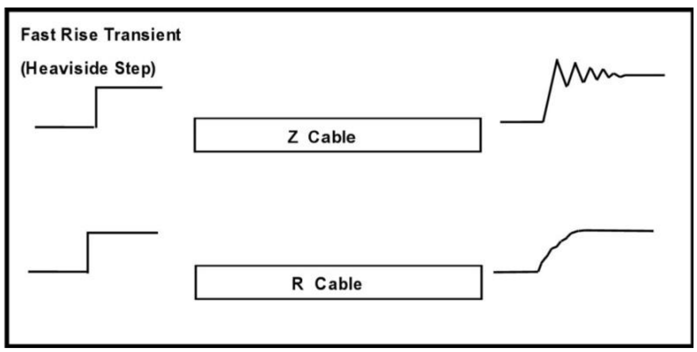
For this Tek used Nichrome wire. It was a double stroke of genius because it greatly solved the capacitance issue too. The Nichrome wire used has a small diameter and surface area, yet it is still physically strong. This reduced the cable capacitance down from around the usual 30pF per foot to a nominal figure of 8pF per foot.

The probe's cable could then be a made thinner and more flexible. Typically the chosen Nichrome wire is in the order of 100 Ohms per foot to create a total resistance for a 3.5 foot cable of around 350 Ohms. This value has the correct proportions for damping the cable's distributed L-C structure and largely curing the problem of transient induced ringing.

As will be shown below, with a reduction in the overall capacitance of the "special scope probe coax" to about 27% of what standard coax has, it also means that the input capacitance at the x10 or x100 probe tip can be lower values than they would be for standard coax.

The special scope probe cable has a name, to distinguish it from standard coax. Standard coax is referred to as "Z cable" (impedance cable) on the other hand, the special damped scope probe cable is called "R cable"

Comparing Z cable with R cable, the response to a fast rise transient is shown in the diagram below. With R cable the voltage rises in an inverted exponential manner with some small ripples on it, the frank oscillations seen with Z cable are largely suppressed.



In the ideal world to transmit waves down a coaxial cable over a wide range of frequencies, the cable should be terminated in a non reactive load (resistance) equal to the cables characteristic impedance. Coupling signals from a scope probe tip into the variable impedance of the scope's input connector is a different problem and was bound to create challenges.

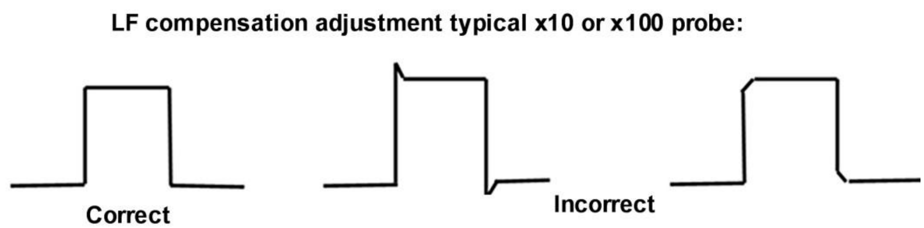
However with lumped L, R & C corrective elements added into the the probe's termination box, along with the use of R Cable and sometimes T coil inductors, the situation can be significantly improved. This is why the more advanced scope probes associated with progressively higher bandwidth scopes, have these added components, as will be shown below.

The Probe Head and Termination/Compensation Box:

For all passive voltage probes other than x1, the probe's head contains the input resistor, typically a 9 Meg resistor for the x10 probe and in most cases a 99M resistor for the x100 probe.

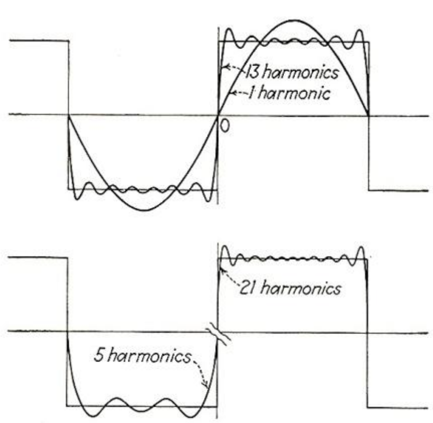
The termination box at the other end of the cable for the x10 probe, in its simplest form, just has a connector and contains no additional parts. However in this case the probe tip capacitance must be made adjustable. Or alternatively the LF compensation capacitor has to be added to the termination box. This became the fashion as probe heads became more slimline and probes with adjustable sleeves in their heads became less common.

Most Technicians who have used scope probes are familiar with the notion of correctly compensating the probe with the LF compensation adjustment. Typically it is done with a 1kHz fast rise square wave and most scopes provide this on a front panel for the purpose of checking both amplitude calibration and the LF frequency compensation.



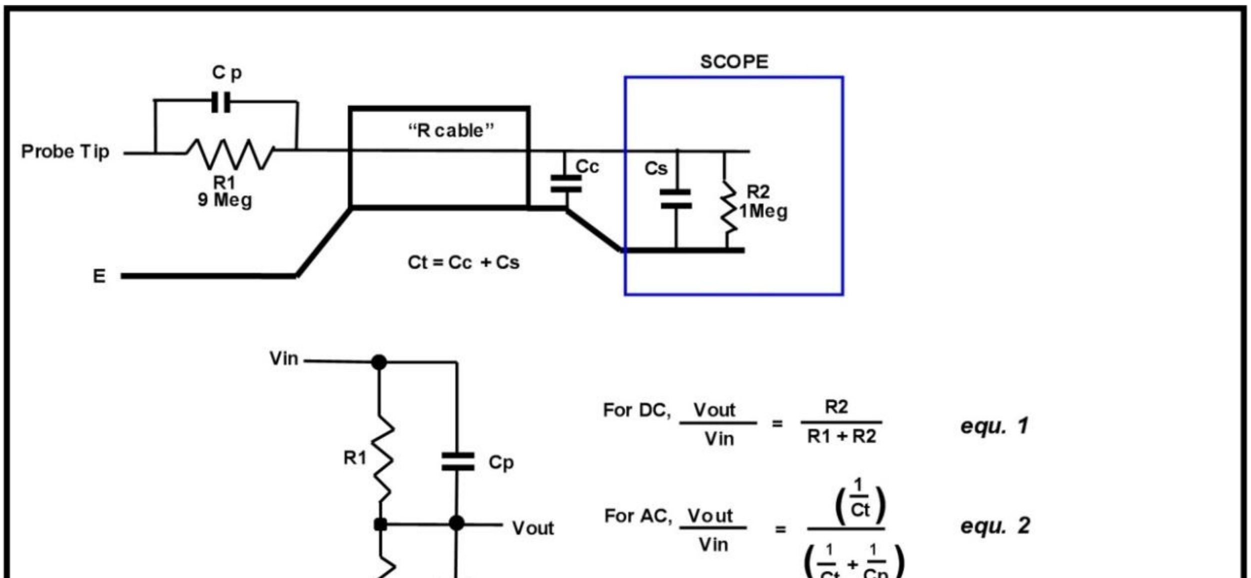
As the probes evolved for wider bandwidths, the number of components in the connector box required to properly compensate the probe, dramatically increased. Manufacturers also made the square wave on the scope's calibration output connector a fast rise square wave. However, be aware, that in early model scopes, the calibration signal was not a fast rise wave, but merely a fixed amplitude pulse for amplitude calibration of the Vertical Amplifier's gain alone.

Square wave testing has become the standard for checking the fidelity of wideband amplifiers, including both the scope probe itself and the scope's Attenuators & Vertical amplifiers. According to the Fourier Theorem a periodic wave such as a square wave can be thought of as a wave composed of a fundamental frequency and a number of odd harmonics of sine waves. The high order odd harmonics make up the fast rising edge of the square wave:



If an amplifier, or any form of passive signal coupling device for that matter, such as a scope probe, or an attenuator network, is able to reproduce an input square wave properly, it would have to treat all of the harmonics in it in exactly the same manner. With correct relative amplitudes of each and the correct phase delay for each frequency component which formed the original wave. Or distortion of the reproduced wave will result.

The electrical equivalent circuit with the probe's termination box plugged onto the scope is shown below. The capacitance Cp is essentially that of the probe input, Cc the cable capacitance and Cs is the scope's input capacitance, which in most models is lumped at the scope end. The purpose of this diagram is to outline a fundamental theory of both Oscilloscope Probe and Attenuator design.



For DC, $\frac{Vout}{Vin} = \frac{R2}{R1 + R2}$ *equ. 1*

For AC, $\frac{Vout}{Vin} = \frac{\left(\frac{1}{Ct}\right)}{\left(\frac{1}{Ct} + \frac{1}{Cp}\right)}$ *equ. 2*

The Fundamental Scope Probe or Attenuator Formula

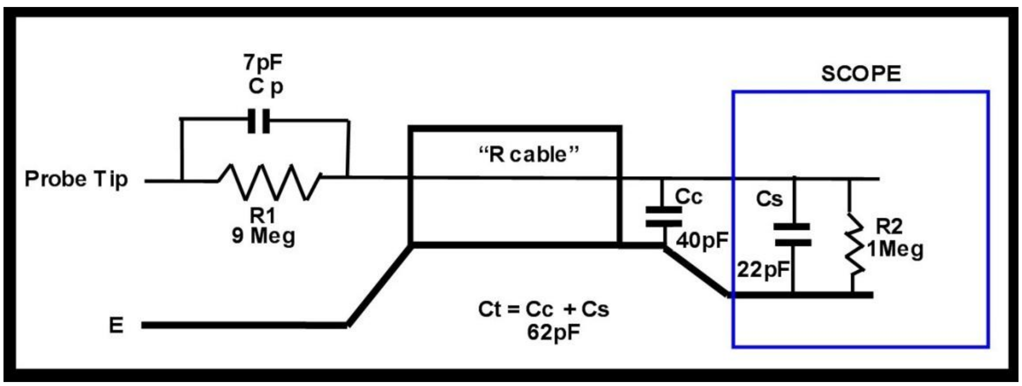
the time constants match: R1Cp = R2Ct

Since a capacitor's impedance is inversely proportional to its capacitance, the same formula can be used for resistors in a divider network, simply by inserting 1/C instead of R.

If *equ. 1* and *equ.2* for the DC and AC conditions of the network are made equal (eliminating Vout/Vin) so that the voltage division ratio for AC signals is the same for DC signals, it turns out that the time constants of the RC values at the input and output of the cable must match in that: R1Cp = R2Ct, where Ct is the total capacitance at the scope input end.

Of note, the reason why the capacitance of Cp is required at all, is that the cable itself forces the dominant capacitance Cc on the system. If there was no capacitance added in parallel with R1, the network with R1 and the total capacitance Ct would simply create a very long time constant low pass filter, that would have no effect on DC measurements. However, it would turn a high frequency square wave into a sine wave by filtering off the of the high frequency components which make up the square wave.

Taking some typical figures for the x10 probe design are shown below. For matched time constants Cp is low, in the order of 7pF. In practice it could be a few pF or so higher. Even for a good x 10 probe, including stray capacitances, tend to add to the extent that the input capacitance Cp is in fact about 10pF and not quite as low as 7pF (except at higher frequencies-see below).



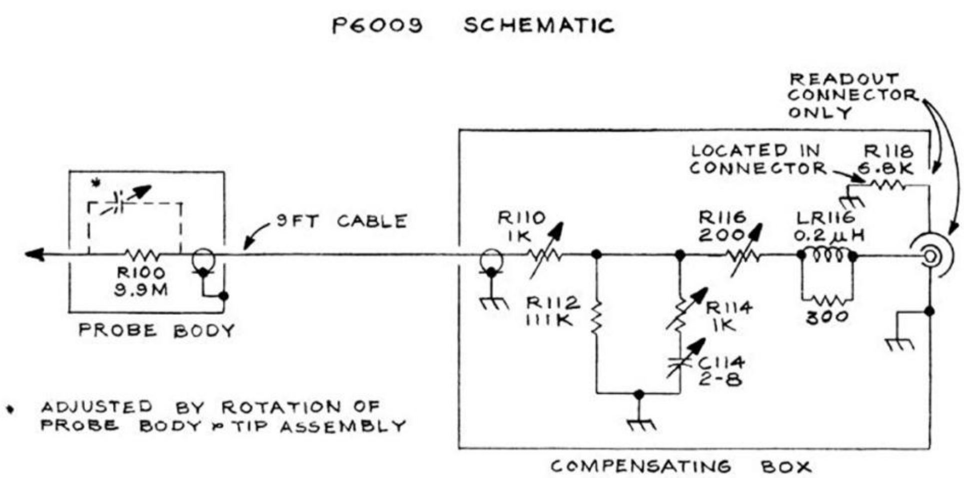
Now if the special "R cable" was not used and the cable capacitance Cc was in the order of 3.7 times higher for the same length probe cable, as it would be if standard Z cable was used, it would mean that the probe tip capacitance would have to be over double the value. So the benefit of the low capacitance R cable (aside from reduced ringing effects) is the reduction of the capacitance value required at the probe tip.

The typical x100 attenuation variety probe, in general because of the the R1Cp = R2Ct relationship, on account of the 99 Meg Ohm input resistor, it means that the input capacitance of the probe can be lower than for the x10 probe. For example, the popular P4100 model x100 probe has an input capacitance of only 6pF.

Is there any way that a passive x100 probe could do better? Yes there is: Historically Tek came up with an idea for a x100 probe, but instead of using a 99 Meg Ohm input resistance, they used a 9.9 Meg Ohm part, and at the termination box/connector end they fitted a 111k resistor to ground. Due to the fact that the time constants must match and now the resistance at the scope end was lower, this shortens the time constant there. Therefore the value of the input capacitance could be reduced from the typical 10pF for the x10 probe, to about 2.5pF for the x100 probe for the time constants to match.

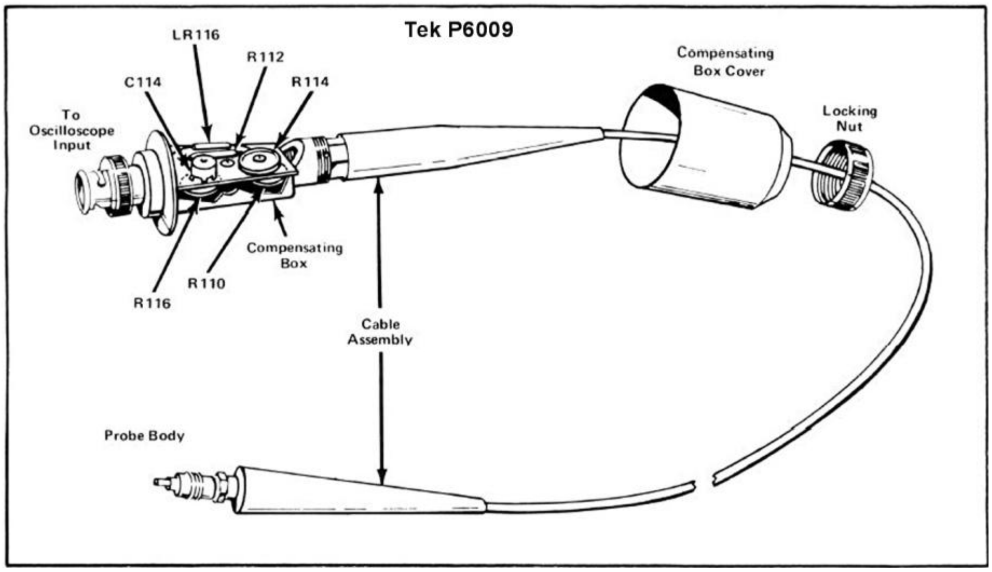
This was the design of their spectacularly good x100 probe of yesteryear, the Tek model P6009. It is rated at 120MHz & 1.5kV for low frequencies and has a 2.5pF input capacitance. Amazingly it was also able to support its 9 foot long cable too.

The P6009 probe contained four HF adjustments in the compensation box. The probe tip capacitance was also adjustable for the LF compensation with a rotating sleeve, blessing it with 5 calibration adjustments.



The "readout" 6.8k resistor is to tell the scope to display the correct volts/cm on scope models equipped with this feature.

In its day the P6009 was probably unbeatable. It still remains one of the lowest input capacitance x100 probe in my workshop for use with 100MHz bandwidth scopes. I use it with my Tek 464 model scopes.



The P6009 probe, more or less set the standard on how high frequency capable x100 probes should be made. Later though the trend became to make x100 probes with 99M input resistors, but all else equal they had a higher input capacitance of around 6pF.

A newer x100 version with this design philosophy is the Tek P5100 model which has a similar input resistance a higher bandwidth and voltage rating and a 2.7pF input capacitance.

The Tek P6137 400MHz Asymmetrical T Coil Probe:

These probes were intended for use with the 24xx series of Tek scopes.

With the 2465B or 2467X their -3dB bandwidth was quoted at >400MHz, >350MHz with the 2467 or 2465A, >250MHz with the 2455X and >200 MHz with the 2455X.

The cable length is 1.5m = 5 feet. And typically for frequencies below 20kHz their input impedance is dominated by the total input resistance at 10 Meg Ohms. By 100MHz the input impedance has dropped to around 160 Ohms capacitive-reactive. The P6137 can work with any 1Meg scope input with an input capacitance in the range of 12 to 18pF. The LF compensation capacitor in the termination box allows for that range.

Of note, those quoted bandwidths for the probe and scope combination are only achieved in a condition where the probe user cannot easily use the probe!

They only occur when a probe tip is plugged into a "probe tip to BNC adapter" connected onto a 50 Ohm levelled sine wave source terminated in 50 Ohms, such as the Tek SG504 Levelled Sine Wave Generator and no earth clip/wire is in use, or the PG506 calibrator with a Tunnel Diode Pulser and the BNC adapter.

The typical 6 inch probe earth wire has an inductance of around 140nH. This forms a series resonant circuit with Cin of the probe, with the damping being the source resistance. This inductance therefore resonates with the *effective input capacitance* at around 180MHz. This is in the mid frequency response of the 2465B. The Technician needs to be aware of this and this is covered in the P6137's probe's user manual.

Effective input capacitance: Of note and not particularly intuitive, one interesting thing about all passive voltage probes, is that the input capacitance is frequency dependent. For example if a probe is stated to have a 10pF input capacitance it will be that at 1MHz, but by 100MHz or more that capacitance could drop to the 5.5pF to 7pF region. This is why, if you calculate the resonant frequency of the 140nH 6" earth clip cable with the 10.8pF input capacitance of the P6137 probe, it comes out at a lower value than 180MHz. The effective capacitance decreasing in the high frequency region has the effect of up-shifting the resonant frequency to the 180MHz mark, with the 6 inch earth wire in practical use.

There is a low inductance short length ground lead accessory which fits to the probe tip area with a ground collar, it has a 32nH inductance. However these can be awkward to use if there is not a convenient earth point nearby, compared to the usual ground wire and crocodile clip arrangement.

There are also pcb mounted probe tip adapters which receive the probe tip, which can be mounted on pcb's to solve the ground lead inductance measurement problem. However they have to be built into the equipment under repair in the first place and they seldom are.

The thing to remember about passive scope voltage probes is that they typically measure the voltage between the tip and the ground wire, but inductance in the ground wire makes the voltage there mobile at high frequencies corrupting the recording. You will see many examples of published scope waveforms of rectangular waves from logic circuitry, with ringing on the GND and +5V parts of the wave, which is not actually there in the circuit. However they are there on the recording, due to ringing effects due to the scope's earth lead inductance and location of the earth point chosen by the Technician.

I wonder if Tek became fed up with others copying their probe designs. Normally as they did for the more vintage P6009 probe, they published schematics for it. For the P6137 400MHz probe there is no documented schematic or design documents from Tek, or even any third party that I have seen. The only way to find out what is in there is to reverse engineer it.

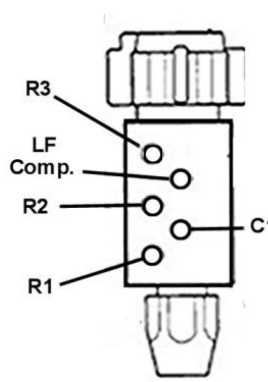
The P6137 probe has 5 frequency compensating adjustments in the termination box. One is exposed to the user for the main LF compensation.

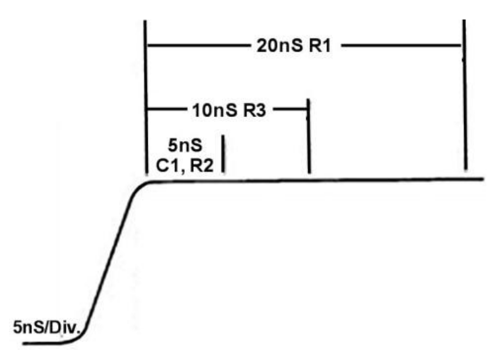
I many cases the LF compensation capacitor is the only one the probe user has access to, without disassembling the termination box. The adjustments for the other high frequency compensation components are mainly done at the factory. These require the same test gear and tools which are required for Oscilloscope calibration. I have these so I am able to calibrate my scopes and the probes. To get at these adjustments in the termination box, in the P6137 case, it requires partial disassembly.

A good pulse Generator for the task of calibrating scopes & probes is the Tek PG506 plug-In. It has a high amplitude output that is capable of driving a Tunnel diode Pulser. This creates an ultra-fast rise time pulse, typically less than 100pS.

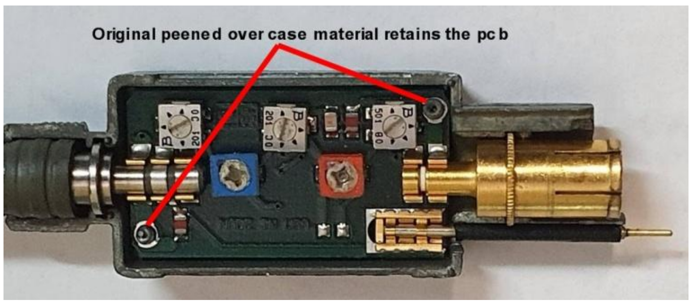
To use a fast rise pulse to check the performance of a system such as a scope or scope & probe combination, the pulse must have a shorter rise time that the limit set by the system being tested. And keeping in mind the relation of Bw = 0.35/Tr. Since the 2465B scope is 400MHz capable its rise time is in the order of 0.875nS. It is difficult to get faster than that without the Tunnel Diode. The PG506, on its own, has a fast rise output of about 1.2nS, so it can be used for testing/calibrating scope vertical amplifiers and probe up to and around the 250MHz region on its own without the Tunnel Diode Pulser attachment.

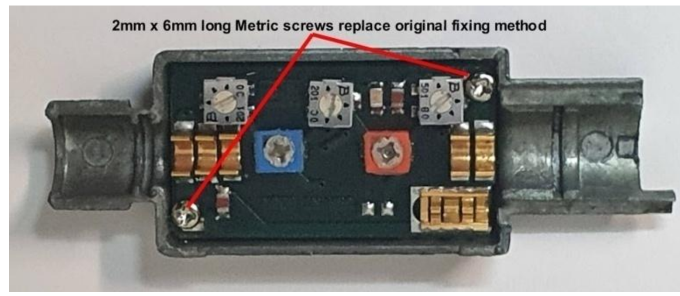
The diagram below from the P6137 probe's manual shows how the adjustment components affect the parts of the waveform after the fast rise.

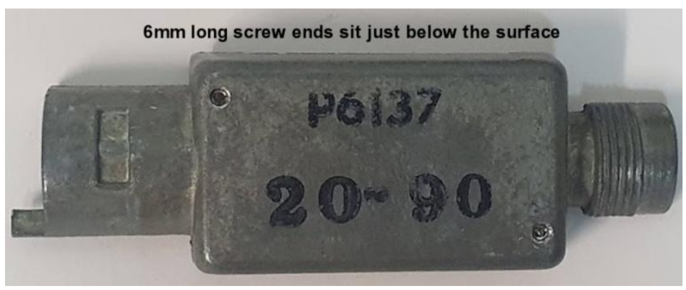




I disassembled the P6137's Compensation Box to document its contents. The pcb was effectively riveted into ½ of the casing, so I had to Mill off the projections which retained it very carefully to remove the pcb without damaging it. Then mill those studs off. To re-attach it I simply made 2mm metric threaded holes and used 2mm x 6mm metric screws as the new fixation method:





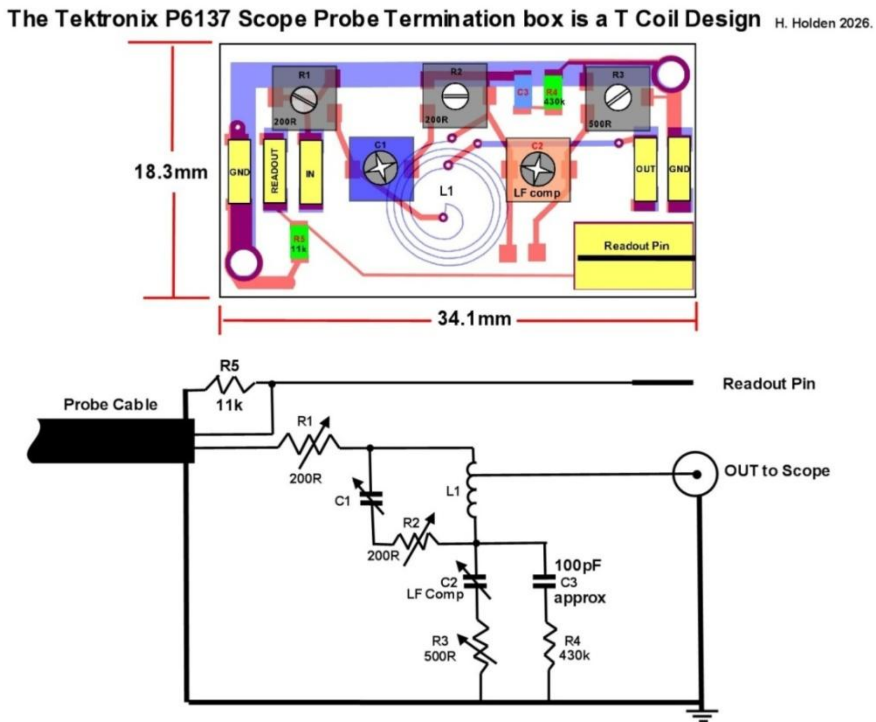


Once the pcb was out of the housing it became possible to examine it properly and document its schematic. It turns out that this type of probe termination box design was being used by Tek in some of their high end probes in the 1960's era. It is known as a T coil design.

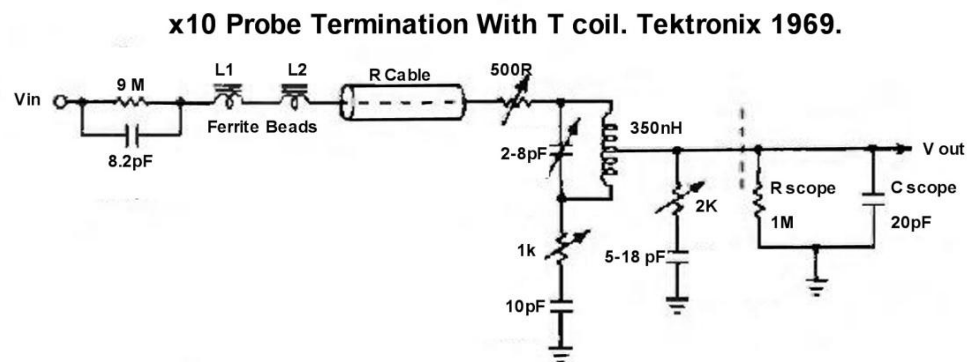
However there are two different types of T coil design; one is a symmetrical T coil, with the coil is centre tapped. This version is more amenable to mathematical modelling. In the other version the coil is asymmetrical and from the circuit modelling perspective is far more complicated.

The asymmetric T coil design has the benefit of resulting in an improved transient response & Bandwidth. But, in this case, it has been done with a pcb inductor rather than the usual copper wire coil.

As noted T coils are also used in some of Tek's Vertical amplifier circuits to improve the bandwidths there and they were thought of by outsiders as being a type of Magic Sauce brewed by Tek. Tek kept most of the T coil technology proprietary (and the mathematics behind it) a well kept secret. In the original Tek T coil probe designs from the 1960's, there were also sometimes small inductances (ferrite beads) fitted at the probe head at the cable input. They may or may not be present in the probe head of the P6137 probe, I cannot easily tell without damaging the probe head.



An early Tek x10 probe with a documented symmetrical T coil termination and Ferrite beads L1 & L2 in the probe head is shown below. At the time of this design the probe was said to support an Oscilloscope up to 150MHz bandwidth. Clearly the P6137 probe is an improved derivative of this design.



****

ADDITIONAL 2465B SCOPE REPAIRS & SOLUTIONS:

THE READOUT PIN:

Tek initially created this pin, on their scope's BNC connector, so that the scope user would not have to do any mental arithmetic to decide what the true volts/cm vertical scale was on the screen with different model probes plugged in. Other scope makers copied and various pins were added for assorted functions on special probes, including powered Active probes and to inform the scope of the probe in use.

Scopes equipped with digital readout displays simply displayed the Vertical volts/cm correctly with the probe in use. In earlier scopes without readout displays, a panel light would illuminate to remind the user it was the x10 probe in use.

This was achieved with a resistor to ground in the termination box. This formed part of a voltage divider to create a voltage that would identify the probe. If the resistance is infinite the x1 probe is assumed. In the region of 11k the x10 probe is assumed. But other resistances such as 6.8k code for variations such as x100 and yet others for x1000, as well as other resistance values coding for odd ratios such as x200 and x500.

However the readout pin initially assumed another purpose. When shorted to ground or with a low resistance of 10 Ohms or so, the scope channel goes in "ID" mode. This happens when the ID button is pushed on the probe head. This has the effect of killing the displayed waveform and placing a small DC offset on the trace. This helps the Technician quickly identify the scope waveform associated with the particular probe, when multiple probes are in use.

As if that was not enough, Tek found other applications for the ID button and the readout pin.

In the 2465B scope, serial numbers 050000 and up, there was a firmware upgrade, with ROMs labelled 160-5877-02. This was accessible by pressing the measure button and the CONFIGURE menu and selecting the option "PROBE"

(Of note in the earlier firmware ROMs labelled 160-5877-01 the PROBE option is not seen in the menu display. Also normally on the ROM's label the last two bytes of the ROM's checksum are documented, for example of the Checksum is EDAE34, then "AE34" is printed on the ROM's label too)

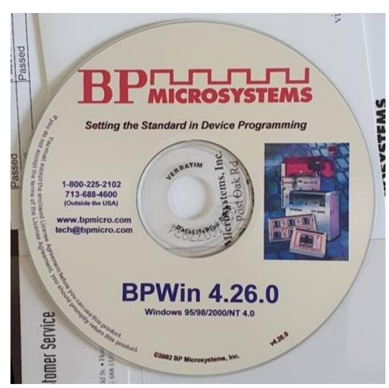
Four options were assigned to the ID button by the firmware upgrade, including making it do, with two brief pushes, initiate the scope's Auto-Setup feature. This is where the scope adjusts its own Timebase and Vertical amplifier settings to conveniently display the incoming waveform on the screen.

As is usually the case, for the 2465B at least, the earlier version of the ROM's firmware, such as 01, had it as a fixed setup where the ID button toggled the Auto-setup if pushed twice, or even pushed once with a mechanically jittery push from the finger. This somewhat annoying feature could not be user disabled.

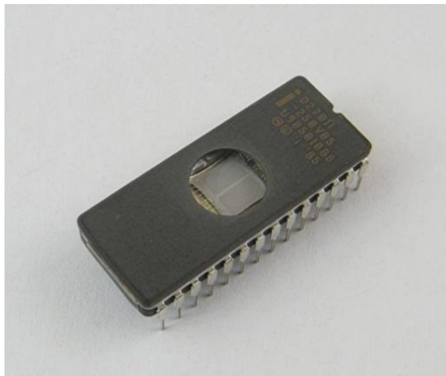
However, the later 02 Firmware, typically seen in scopes with serial numbers B050000 and up, allowed the ID button to be assigned to just ID, Auto-setup and two other options. However I have a very low S/N 2465B just above B050000 and it still has the version 01 firmware, though it is possible that its A5 board may not have the original ROM it was shipped with.

In light of this I dumped the 160-5877-02 Firmware from the Intel D27011 ROM with the aid of a vintage BP Microsystems BP1400 Device programmer.

Many modern programmers do not support the Intel D27011 UVeprom. The BP1400 can also program many now orphan OTP ROMs that modern programmers do not support and has a very extensive supported device list for vintage parts. The BP1400 communicates via the computer's parallel (printer port LPT1) so you have have a suitable vintage computer that has a real port for trouble free operation. I use a 2004 vintage HP Pavilion desktop computer with an Athlon 64 CPU running XP. The support software to run the BP1400 comes on a disk. The internal construction of the BP1400 is something of a masterpiece.



Therefore I was able to upgrade two of my 2465B scopes to the later firmware version. The photos below show the un-programmed new ROM.



Other Tek Scope Articles created to help keep this wonderful scope running & updates on these:

1) Dealing with the Dallas DS1225 NVram Two methods:

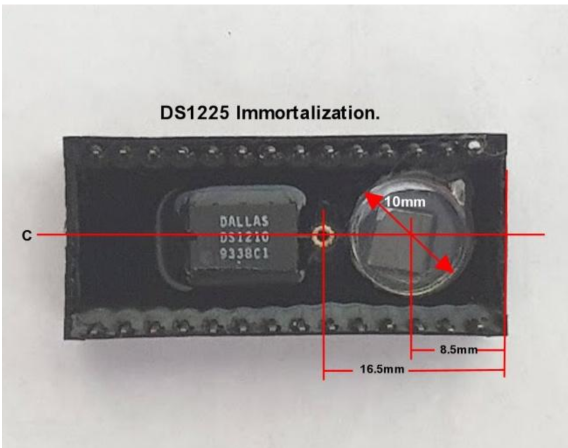
https://www.worldphaco.com/uploads/TEKTRONIX_2465b_OSCILLOSCOPE_CALIBRATION___REPOWERING_THE_DS1225.pdf

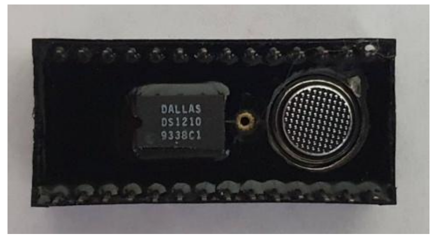
https://worldphaco.com/uploads/THE%20DALLAS%20DS1225-ReMastered..pdf

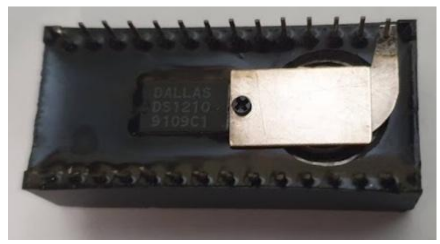
Of note, not included in the the original article on replacing the DS1225 with FRAM, while nearly all of the people who have done this have found my suggestion here successful, there was a case anomaly reported. I also observed one example of this myself, where the FM16w08 FRAM can get corrupted on power down. This tends to happen if the PSU's electrolytic capacitors are aging out and it affects the rate that the 5V rail collapses at power down on the A5 board. It can be ameliorated by adding a 330R chip resistor from pin27 (/WE) to pin28 (+5V) of the FRAM adapter. It is not a common issue and most FRAM upgrades have worked fine.

However, the DS1225 is completely resistant to even rapid power cycling due to the control IC within it and this could be one reason to prefer the Immortalisation technique I have developed more recently for the DS1225 over the FRAM upgrade.

For this immortalization technique, not stated in the above article, I settled on a 10mm diameter Milling tool, do it slowly with copious cutting oil lubrication. The resulting cavity in the original battery's shell ends up at about 10.1 to 10.2mm diameter and this clears the new battery without the need to remove any additional material.







Also as noted in my original 2013 article on replacing the Dallas DS1225 with FRAM, another option I tried was the Auto-store RAM. The type I tried at the time was the STK12C68. This part requires an external capacitor on the adapter board to support it during the power down Shadow RAM update. There is another part; the STK16C68, which does not require the external capacitor or an adapter board. This part is equivalent to the ZMD U63764DC.

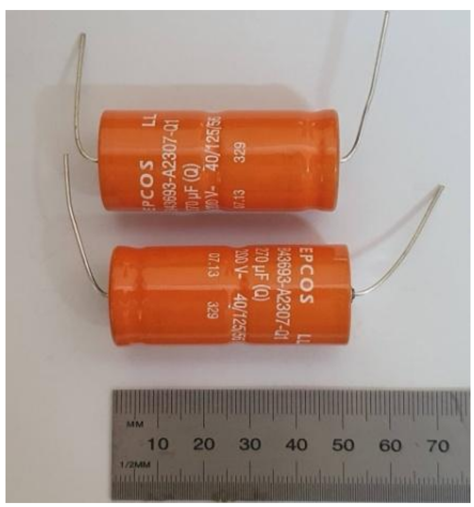
I elected for the 2465B project (at the time) not to use the STK12C68 Auto-store Ram because on experimental rapid power cycling I was able to corrupt its content. But I'm not certain if this is the case with the STK16C68 or not, as I have not tested this part, which some scope repairers have used in the 2465B in place of the Dallas DS1225.

Another point of interest related to using FRAM in place of battery backed up SRAM. SRAM has what could be thought of as a fast read mode, in that with the chip hard enabled in read mode, the addresses can be altered and the data at the selected address simply appears at the data outputs with minimal delay. The FRAM does not behave in this exact manner and the /CE terminal has to be validated for each new address. So whether the FRAM can be used as a direct replacement for SRAM depends on the system firmware and how the RAM addressing and /CE timing is executed, in the particular instrument. While it works in the case of the 2465B to substitute in the FRAM, this is no guarantee it will work in other instruments. Each case has to be tried out. For example there is a report on the internet where an FRAM was attempted to replace the battery backed up NVRAM (equivalent part to a DS1225) in an HP oscilloscope and it did not work.

2) Re-Capping the 2465B's power supplies:

https://worldphaco.com/uploads/2465BPSU.pdf

Of note this Re-Capping article as yet does not include the identity of a type high quality mil-spec Axial Electroltyic filter capacitor that can be used to replace the large Blue main axial filter capacitors in the 2465B's PSU inside the black carrier. It is difficult to find a quality capacitor with the correct form factor and specs, as axial parts are becoming less common. However, these are Epcos-Sikoral types made for Automotive and Industrial Grade applications. They test at close to 290uF and have extremely low leakage and very high temperature ratings. They are currently available on Ali Express and it would be wise to stock up up on these as spares, while they are still available:



3) An inter-track leakage problem that can crop up in some 2465B scopes:

https://www.worldphaco.com/uploads/TEKTRONIX_2465B_OSCILLOSCOPE_MAIN_BOARD_INTER-TRACK_LEAKAGE..pdf

4) Dealing with the U800 Heat sinking issue:

https://www.worldphaco.com/uploads/The%20U800%20Problem-%20Tek%202465B.pdf

Further to this article I have also discovered two things about the delamination of the transistors inside U800. One is that when it has started, the trace (mainly only detected on the data display) will shift a little to the left or right in the half hour period after warm up. The process before failure can take over a decade after that. A 10 year historical series of photographs of the screen showed that the data display moved slowly to left, about 7mm before flying off screen with total failure.

Of note, U800 is a highly specialised part which amounts to a super high slew rate high voltage OP amp with additional functions. The extremely high slew rate is required to support the high range sweep speed especially in the x10 MAG mode on the scope's maximum time-base speed. Any device that replicated it would have to generate an equivalent amount of heat and require an equivalent amount of heat-sinking or it would be a poorer performer.

The only way to perform U800's task, as well as the original part, would be to have a replica part manufactured in a semiconductor Fab house to conform exactly to the original design. It cannot be done as well with a substitute module on a pcb with assorted discrete components.

The goal now is to protect existing U800's with adequate heat sinking to reduce the magnitude of the thermal cycling.

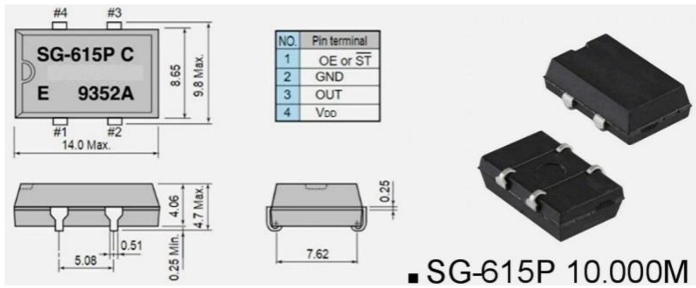
5) Electrolyte leakage on the A5 Board:

https://www.worldphaco.com/uploads/TEKTRONIX_2465b_OSCILLOSCOPE_A5_BOARD_REPAIR.pdf

6) A random CPU lockup issue with corrupt Dallas Nvram but no error reported:

https://worldphaco.com/uploads/TEKTRONIX%202465B%20A5%20RANDOM%20CPU%20LOCKUP%20PROBLEM.pdf

7) One issue which crops up on the occasional late model A5 board with surface mount parts is that the MS0-1 CMOS-Xtal 10MHz Oscillator surface mount module appears to lose activity and fails to start at power up. This original module has become difficult to find. However there is a drop in replacement with the same footprint, it is the Epson SG-615p-10MHz. These are currently available on eBay.

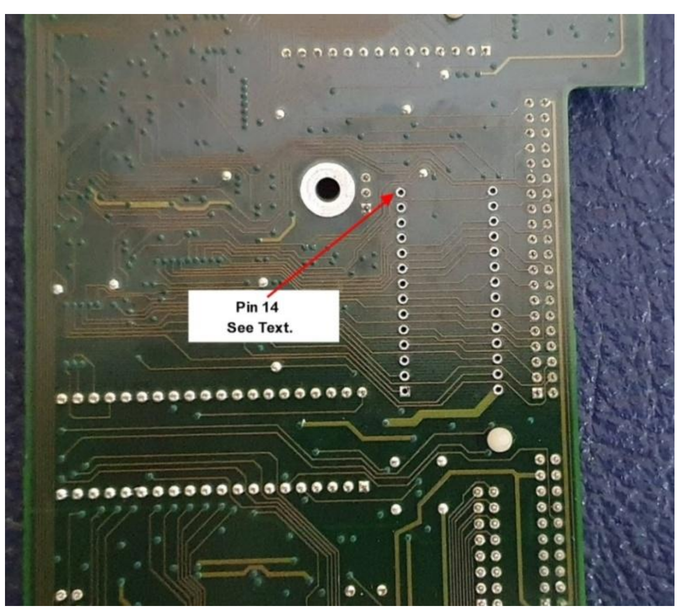


8) Additional notes on removing the original DS1225 from the A5 board and fitting a 28 pin socket to the pcb, to hold either a new DS1225, an Immortalized DS1225 or the FM16w08 FRAM on an adapter or the STK16C68 or equivalent:

Some of these these issues are explained in the random CPU lockup problem article, but I will present some of it again here.

The first thing to do is to remove the original DS1225 without damaging the pcb. Fortunately, much like a dual wipe socket, the pins on the DS1225 are thin and flat and air can easily enter the top surface of the plated through pcb holes and around the pin for efficient solder sucking.

This makes de-soldering, with a good high volume single shot sucker, such as a Hakko SPPON No.20g, relatively easy, on all holes but one. This is pin 14. This passes to a middle board layer and the thermal relief is poor. Once it is certain that all of the other pins are free in their holes, by moving them from side to side, pin 14 is then melted with the Soldering Iron and the socket is removed and then the pin 14 hole is solder sucked after that.



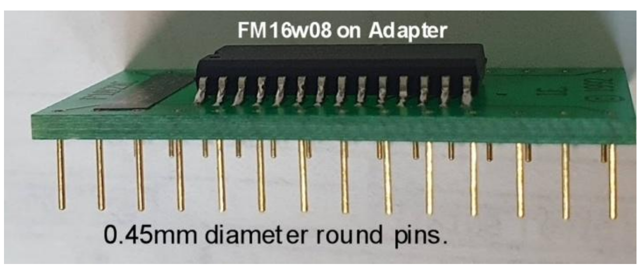
Then the question of what socket to fit comes up. This is more complicated that it appears.

IC socket Dilemmas:

In the past, when the original Dallas DS1225 NVRAM had been removed from this particular A5 pcb and a socket fitted, in one of my 2465B scopes, it was a Dual Wipe type. Considering all of the variables, why would it be better to choose a dual wipe socket over a machine pin type with the Gold inserts?

The answer depends on whether the equipment in question, or any computer, is still under repairs, be it the scope's computer board in this case, or any vintage computer. And if the other repairs are complete yet, or not, is a factor. The Dual Wipe socket is easily damaged. I think the modern ones are not made of the same springy Phosphor Bronze or Beryllium derivatives they once were and some might be plain Brass.

The adapter board in use shown below was fitted with FM16w08 FRAM. These were some of the smallest pin sized adapters I could find at the time. Thin pin adapters, which resemble IC pins, are available and those would have been a superior choice.



This adapter board was from a previous historical project where I fitted FRAM to the scope. After I did this and Web published the paper on it back in 2013, many 2465B scope owners followed suit and converted to FRAM.

You might imagine that the Dual Wipe socket would have put up with 0.45mm pins and later would have still been viable with the pins from an actual Dallas DS1225, but it was not.

On re-inserting a normal programmed Dallas NVRAM (it has 0.27mm x 0.53mm pins) into the socket where the FRAM adapter had been, on one occasion one of the pins did not make contact. This indicated that the spring leaflets in the dual wipe socket do not have much mechanical "memory" at all and they were permanently deformed by nothing more than a 0.45mm diameter round pin.

Many round pins on various adapters and headers are closer to 0.5mm to 0.55mm, aggravating this issue. Of course, in some kind of fault finding scenario, this sort of thing is a disaster, because faults start to compound as more work and investigations are done and the repair spirals down hill. This can happen when RAM/ROM diagnostic adapters with 0.5mm round pins are inserted into vintage computers, such as the PET, to help with diagnosis and repairs. It can result in socket degradation. It is even worse there too, because many of the sockets for the CPU/PIA/VIA & ROMs were only a single wipe type in the PET and they are less hardy to mechanical damage than a dual wipe type.

It gets to the question: If you are fitting an IC socket or replacing one, which might be the better sort, a Dual Wipe or round Machine pin and why? It is an interesting question**:**

DUAL WIPE IC SOCKET:

Advantage; in the case of the dual wipe type, one highly favourable feature is that the pin geometry which passes into the pcb's plated through holes is super thin.

For example on the flat axis these pins are only around 0.15mm thick and about 0.6mm on the wide axis. This means that it makes removing the socket from a pcb a breeze, because there is plenty of air flow and molten solder for the sucker to work brilliantly, especially a single shot high volume sucker such as a 20g Hakko.

The solder is well cleared and not only that the pin does not get stuck to either the upper pcb pad or the side wall of the hole. Once cleared of solder, the pin is easily rocked from side to side in the hole to make sure it is totally free on every pin, before the socket is lifted away and there is no pcb damage.

Disadvantage; some types appear significantly damaged by an over sized pin of as little as 0.45mm thickness or diameter, making insertion of a real IC with a flat pin (typically around 0.25mm thick) unreliable later.

MACHINED PIN IC SOCKET:

Advantage; There is a very favourable feature of the machine pin IC socket I call *"the two chance effect"* This is because of the anatomy of the four prong gold ferrule in the socket. Here is a photo of the typical 4 pronged insert from a machine pin socket:

In the case of fitting a standard IC pin to the machine pin socket (typical geometry 0.25mm x 0.5mm), only the two prongs on the 0.5mm wide axis of the IC pin are pushed apart to any extent and engage the IC pin side edges.

If a round pin is pushed into the socket in the range of 0.45mm or even 0.5mm (at worst) the 4 prongs engage the pin surface equally. If that round pin is then removed, the socket's insert still works for the flat IC pin because the two prongs on either side that are the main operational ones for the flat IC pin and are undamaged. The other two prongs played no significant role anyway for the 0.25mm wide flat faces of the IC's pin.

In other words: *the machine pin socket is better able to tolerate both types of pins, and work for both and switching between both, especially if the round pin is not above 0.5mm in diameter.*

This is not the case for the dual wipe socket because they grab the IC pin over the flat axis which is only in the region of 0.25mm for a real IC pin.

Disadvantage; The machine pin socket is somewhat diabolical in one respect. It has a conical area where the diameter of the metal pin tapers down to the part of the pin that passes though the pcb's holes.

What this does is that it often occludes the mouth of the plated through hole on the top surface of the pcb. That blocks the flow of air which allows a solder sucker to work effectively. And it really needs to work effectively, because the round pin occupies a greater cross sectional area inside the plated through hole compared to the dual wipe sockets pin (0.19 mm^2 vs 0.09 mm^2) thereby leaving more opportunity for the round pin to remain stuck to the inner wall of the plated through hole, around some part of its circumference.

These are the reasons why many people who try to remove machine pin sockets sometimes end up ripping pads/tracks and pcb plated through holes.

The above are some considerations of Dual wipe versus Machine Pin sockets. Howevers ome might think...why get worried about it, why would I need to replace a new IC socket that I just fitted?

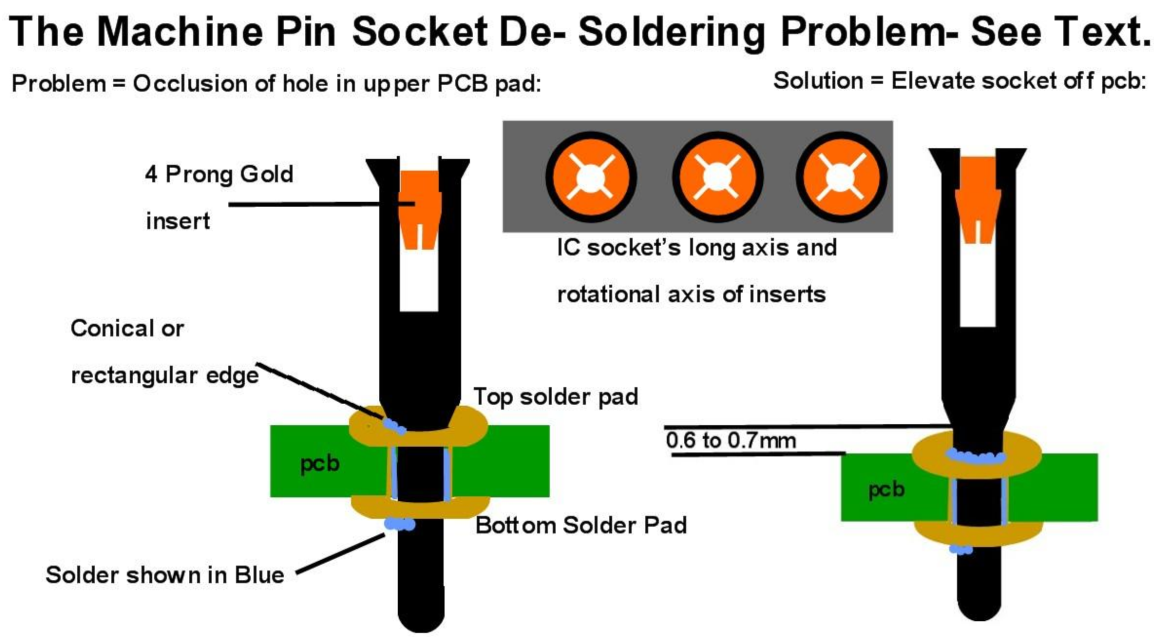
The answer is that unless the board is fully repaired yet, you may end up damaging that socket with adapter boards for other IC's, or with some kind of diagnostic adapter later. In reality if the board is not fully fixed yet, the risk of socket damage remains through diagnostic interventions and the use of various adapters. The IC might need removing a number of times too. The socket needs to be resilient to wear and damage from alternate sized pin insertions.

One other disadvantage, though it is not too common, some have reported that occasionally an IC's pin will become trapped in a machine pin socket and it won't release. This can happen for two reasons. One is if the IC pin is bent and rotated 45 degrees. Or there was a manufacturing error at the factory and the Gold insert was 45 degrees off axis. Possibly some of the cheaper sockets might be more affected here. When this happens the edges of the wider axis of the IC's pin are forced between two opposing slots in the 4 prong insert. The arrangement then becomes not dissimilar to a Chinese Finger Trap. Pulling on the pin causes the prongs to tighten down on the pin, preventing the pin's release.

CONCLUSION – THE IC SOCKET DILEMMA:

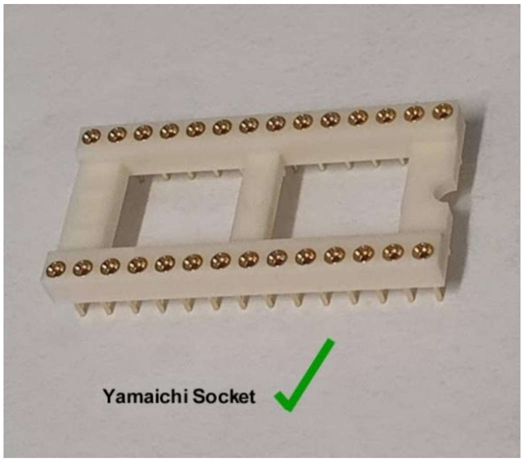
The machine pin socket is better and more resilient to a range of pin geometries, if only the problem of difficult de-soldering could be solved.

After a number of experiments with this problem, I found that the answer was simple. All that is required, when fitting the machine pin socket to the pcb, is to simply elevate it a little off the pcb surface. 0.7mm is plenty to allow good solder sucking if required.



But what about the brand of the machine pin sockets? Unfortunately a lot of poor quality machine pin sockets have flooded the market.

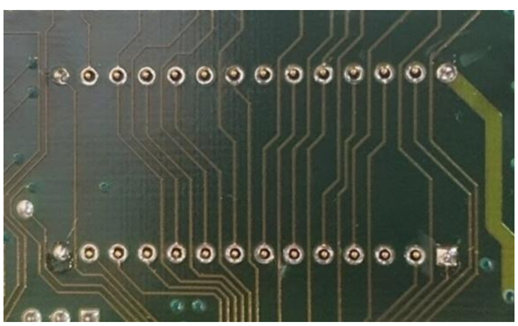
It is best to go with a known brand from a specific manufacturer even if they cost five times as much as a cheap generic part. Generally even superior sockets will be below $10. I use sockets from Yamaichi. These sockets make an excellent and resilient firm connection to an IC's pin:

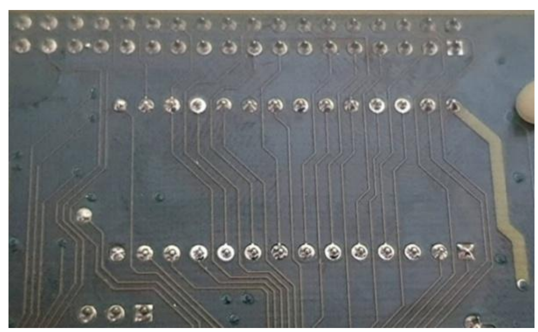


Fitting the socket- important details:

Make sure the socket is around 0.7mm lifted from the board surface before soldering. Also, ideally, the socket is positioned so that the pins are in the middle of the plated through holes with an air gap around them, prior to soldering. As shown in the photo below left. This way, if the socket is later removed, excellent results are obtained with the Solder Sucker and each pin is easily freed up from the plated through hole.

If no thought is given to this issue and the socket is pushed hard sideways and the socket's pins are pushed hard up against the side walls of the plated through holes, it is more difficult to completely disconnect them with the Sucker if that is again required in the future.





When these sockets are mounted correctly and a little elevated from the pcb, the rounded ends of the pins of the Yamaichi socket, as shown in the photo above right, project just a little above the pad surface.

All of the above issues relating to IC sockets may seem like "small details" but the Devil is always in the detail and these issues are all important in pcb preservation.

****