

TEKTRONIX OSCILLOSCOPES:

VERTICAL AMPLIFIER CALIBRATION PRINCIPLES WITH SPECIFIC REFERENCE TO THE TEKTRONIX 464 OSCILLOSCOPE SERIAL NUMBERS B200000 AND UP.

Dr. Hugo Holden. Sept. 2014.

Background:

A critical part of an oscilloscope's performance relates to the vertical amplifier's frequency response & fidelity. An oscilloscope requires very well designed and frequency compensated differential amplifiers which have a flat response from DC to their upper specified frequency limits. Generally, if the oscilloscope's bandwidth is specified as 100MHz then this means that the vertical amplifier would have a flat response over this bandwidth and only be 3dB down (0.707 or about 70% reduced in amplitude) at 100MHz. A Tektronix "100MHz rated" 464 oscilloscope for example is 3dB down at 100MHz. However this scope can still display and sync lock a 150MHz wave, even though the vertical calibration is not meaningful at that frequency.

The vertical amplifiers in the 464 and many other oscilloscopes have multiple frequency compensation adjustments to ensure a flat response can be obtained. These take the form of RC networks or RCL networks placed various parts of the differential amplifiers leading to the vertical deflection plates of the cathode ray tube.

While the Tektronix 464 service manual is a very well written document, I did find that the suggested methodology for adjusting the vertical amplifier's frequency compensation adjustments was a little lacking in specific detail and the time-base settings were not ideal to visualize the fine detail on and after the applied square wave's rising edge. The suggestions presented in this paper are "fine adjustments" so as to tweak the vertical amplifiers for best possible frequency response and are not intended as a replacement for the methods in the manual.

So ideally these fine adjustments are performed after the standard service manual calibration.

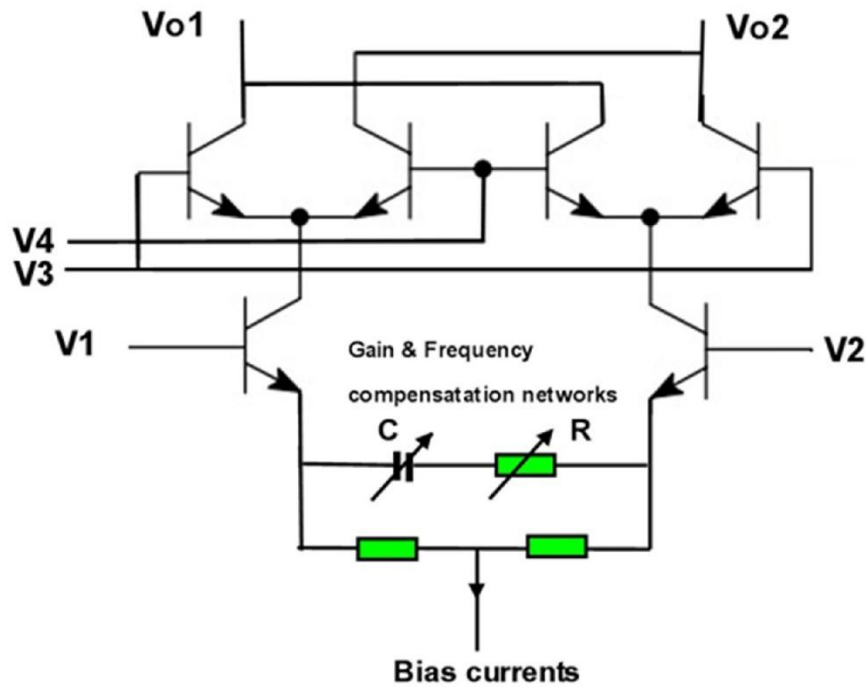
Many people have realised that oscilloscopes such as the Tektronix 464 are extraordinary items of laboratory equipment, with such a quality build that it is not likely to ever be seen again in a world of plastic components and built in obsolescence (now affectionately referred to as life cycling). So any time invested in restoring and adjusting these vintage Tektronix scopes in my view is time very well spent. As stated in other articles I have written about vintage Tektronix oscilloscopes and test equipment: The Tektronix Engineers were masters of circuit design techniques and the physical implementation of their designs were outstanding, impressive, and something to aspire to.

The 464's Vertical Input Circuits:

Before going into the theory and details of how to calibrate the 464's vertical amplifiers, it is worth looking at the input amplifier configuration of the 464. By the time the late model 464 (B200000 and up) appeared on the scene in the 1980's, the input amplifier stages had gone to an IC known as a Gilbert Cell.

Gilbert patented this configuration in the late 1960's or early 70's or thereabouts, but it had actually been invented by a fellow named Jones in the very early 60's. However due to the obscurity of Jones's work, he was largely forgotten. In addition, prior to the Gilbert patent, the Nagra Company of Switzerland were using this exact configuration in their professional audio tape recorders for a phase detector in a capstan servo system to phase lock a tone recorded on the magnetic tape to a crystal reference. This prevented drift of tape speed and ensured good lip synching in the film industry.

The circuit below shows the "Gilbert Cell" configuration with the characteristic crossed collector connection. This circuit configuration is also seen in IC's such as the Motorola MC1495 and MC1496:



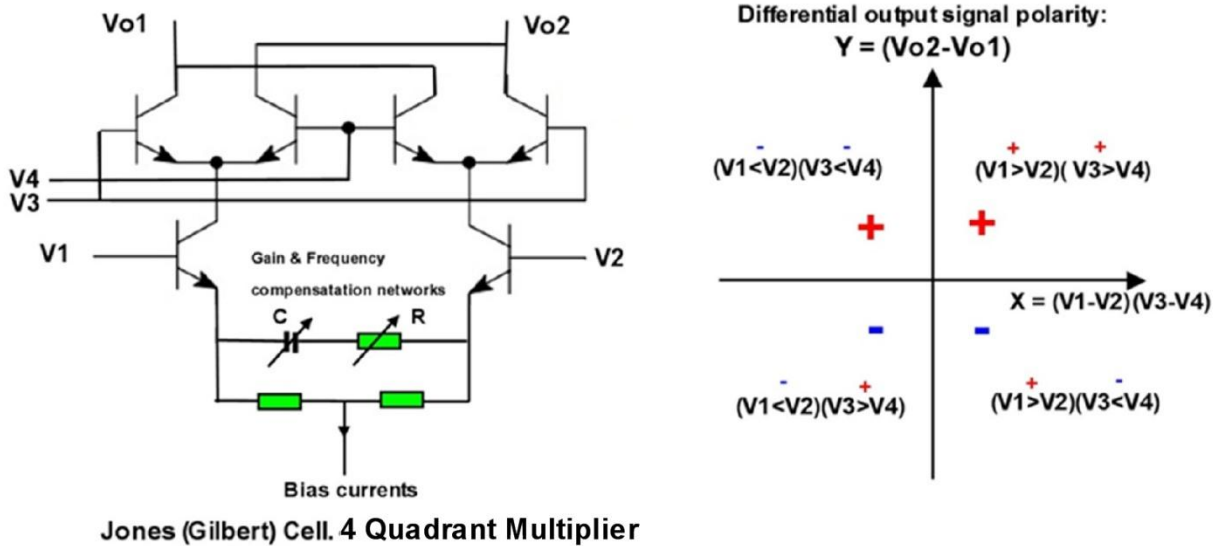
Jones (Gilbert) Cell. 4 Quadrant Multiplier

Sometimes additional transistors can be used to control the bias currents as they do in the MC1496.

The configuration resembles the usual long tailed pair differential amplifier driving the emitters of the next stage, except for the additional pair of output transistors whose collectors pass to the opposite output transistor's collector. The differential output voltage is $V_{o2} - V_{o1}$. There are two differential input voltages; $V1-V2$ and $V3-V4$. Generally for this configuration the lower inputs $V1$ and $V2$ are called the "low level" inputs and $V3$ and $V4$ the "high level" inputs. They are called this because of the signal levels they could tolerate before the transistors saturate. We will assume for this discussion that the levels are low enough all around so that no saturation occurs.

Right away it can be seen that this circuit could have multiple uses. For example a DC level could be placed on the high level inputs to scale up or multiply the low level inputs. Or instead a carrier wave could be placed on the high level inputs and audio modulation applied to the low level inputs to make an amplitude modulator. If the circuit is biased correctly it will form a double sideband modulator with the carrier suppressed. Or the same input signal could be applied

to both differential inputs making a squarer. So this type of circuit is a multiplier, mixer, modulator, squarer etc. It can also function as a phase detector and has other uses. The circuit is often described as a “four quadrant multiplier” The reason for this is shown below:

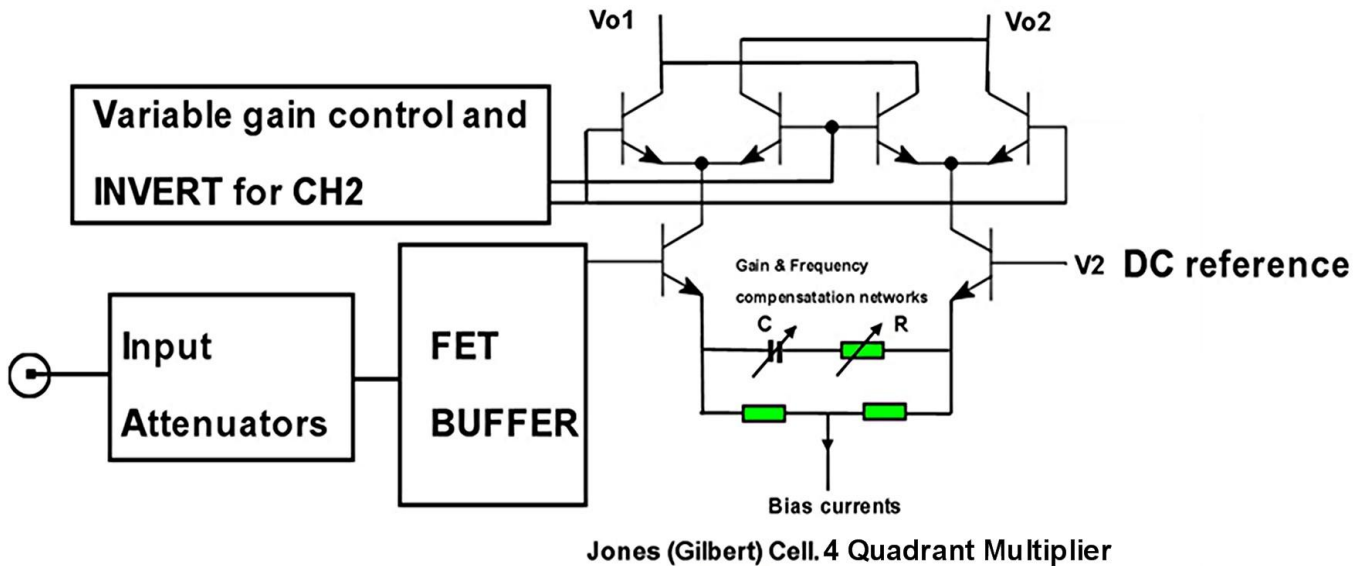


The differential input signals can be positive or negative depending if V1 is greater or less than V2 and if V3 is greater or less than V4. As a result the differential output signal polarity $Vo2 - Vo1$ can be positive or negative depending on the polarities of both the inputs. And there are 4 combinations of input polarities hence the “4 quadrant terminology”.

If for example V3-V4 is a positive DC control voltage ($V3 > V4$) to alter the gain of the V1-V2 input where ($V1 > V2$) so that the output voltage ($Vo2 - Vo1$) is positive, then if this DC control voltage is reversed ($V3 < V4$) then the output voltage $Vo2 - Vo1$ “flips” to a negative polarity as shown. This is the mechanism used in the 464 to invert the channel 2 signal.

The diagram below shows the basic input configuration in the 464:

Basic Configuration Tek 464 U3970:



The Gilbert cell is especially effective when manufactured as a monolithic integrated circuit as Tektronix made it, rather than from discrete components. In the IC the devices are tightly thermally coupled and drifts due to heating are cancelled out. The vertical output amplifier IC, U464 in the 464 scope also uses a Gilbert cell like configuration.

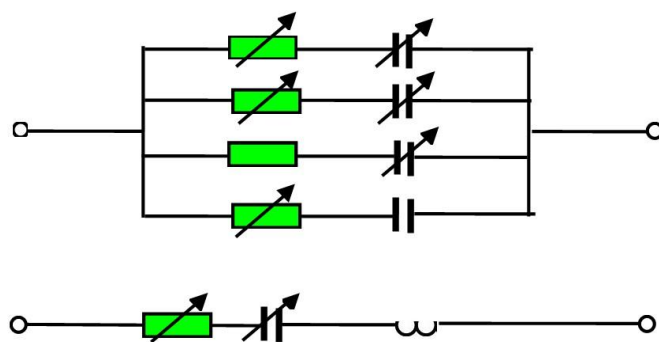
Frequency Compensation Networks:

Throughout the 464's vertical differential amplifiers the frequency compensation components are placed in various parts of the differential amplifier stages leading right up the CRT's vertical deflection plates. Some are fixed combinations of RC networks and RCL networks, other have been made adjustable by Tektronix.

In the instance where differential input voltages are applied to the transistor's bases, then lowering the impedance between the emitters increases the base currents and hence the drive currents to the differential transistor pair. If that "emitter to emitter" pathway is an R-C network, then this lifts the gain of the stage at some specific range of frequencies set by the R & C values and this effect cancels out the R-C based frequency roll off at the stage's collector outputs caused by the resistances and capacitances there.

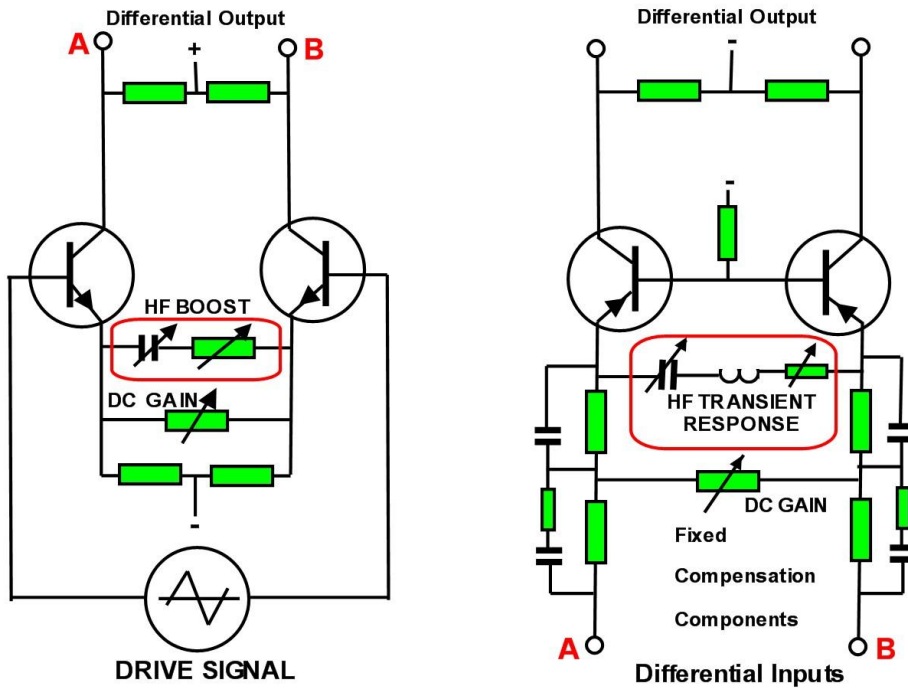
Typical general types of compensation networks in the 464's vertical amplifiers are shown below. They consist of either fixed resistors or capacitors where both or one are adjustable. The frequency ranges over which they act can be roughly estimated from the values, the larger value fixed capacitors with the variable series resistor operate over a lower frequency range than the smaller value trimmer capacitors with fixed or variable resistors.

FREQUENCY COMPENSATION NETWORKS



The circuit on the left below shows the typical location of the R-C compensation network placed between the transistor emitters when the signal drive is applied at the bases:

COMPENSATING DIFFERENTIAL AMPLIFIERS:



In any individual differential stage the HF (high frequency) boost or compensation provided by the R-C network might be a little over or under compensated to make up for the frequency response errors in subsequent stages.

When the drive is applied to the emitters and there is a fixed base voltage, the filter circuit is an LCR resonant filter connected as a shunt peaking filter as shown on the diagram on the right diagram above. The resonant frequency is largely determined by the C & L value and the circuit damping set by the resistor. This type of network affects the transient response and the “ringing” on and around the leading edges of a step waveform like a square wave. In the 464, there are 3 of these networks in the vertical amplifier system:

One in CH1 (C3342,R3335 & L3245), one in CH2 (C3643,R3634 & L3642) and one in the vertical output amplifier (C428,R428 & L428).

These “transient response” adjustments are critical to the correct setup of the vertical amplifiers in the 464. If they are incorrect there will either be a poor high frequency response or excessive ringing and oscillations immediately after the step response and there will be a bumpy non-uniform high frequency response.

I have yet to find these correctly setup in any 464 I have encountered, even though they were said to be “calibrated” recently. Full details on how to adjust these correctly is shown below.

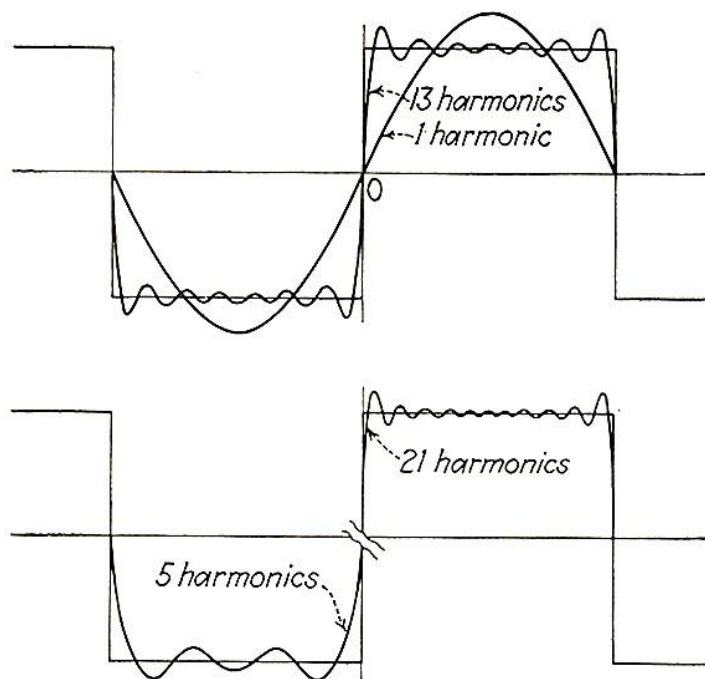
The reason it is necessary to have frequency boosting or “peaking” adjustments is that in any amplifier the circuit resistances and inductances combine with stray capacity and input capacity of the transistors to form LPF’s (low pass filters) which roll off the high frequency response. The Miller capacitance, depending on the specific stage design, can also play a part rolling off the high frequency response. Driving a transistor at its emitter and fixing the base voltage is a good way to avoid the high frequency degenerative feedback induced by the transistor’s Miller capacitance.

In some Tektronix oscilloscope circuits “cross coupling” is used from each side of the differential amplifier to phase cancel the Miller effect, but not in the 464.

Also there are component tolerance variables where even the paint on the components can affect their capacitance. So to be sure every scope can be bought into alignment adjustments are required. Tektronix were very generous with the range of adjustments in the 464. This ensures every scope can be bought into electrical alignment, provided the correct test equipment is available.

TEST EQUIPMENT TO CALIBRATE THE 464's VERTICAL AMPLIFIERS & THE HEAVISIDE STEP, TRANSIENT RESPONSE & the FOURIER THEOREM:

It would be a tedious proposition to check the frequency response of an amplifier with a sine wave generator over its full bandwidth. Also making any adjustments which seem correct at one frequency might alter another. The solution to the problem is to check and calibrate a broadband amplifier with a *square wave response test*. 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:



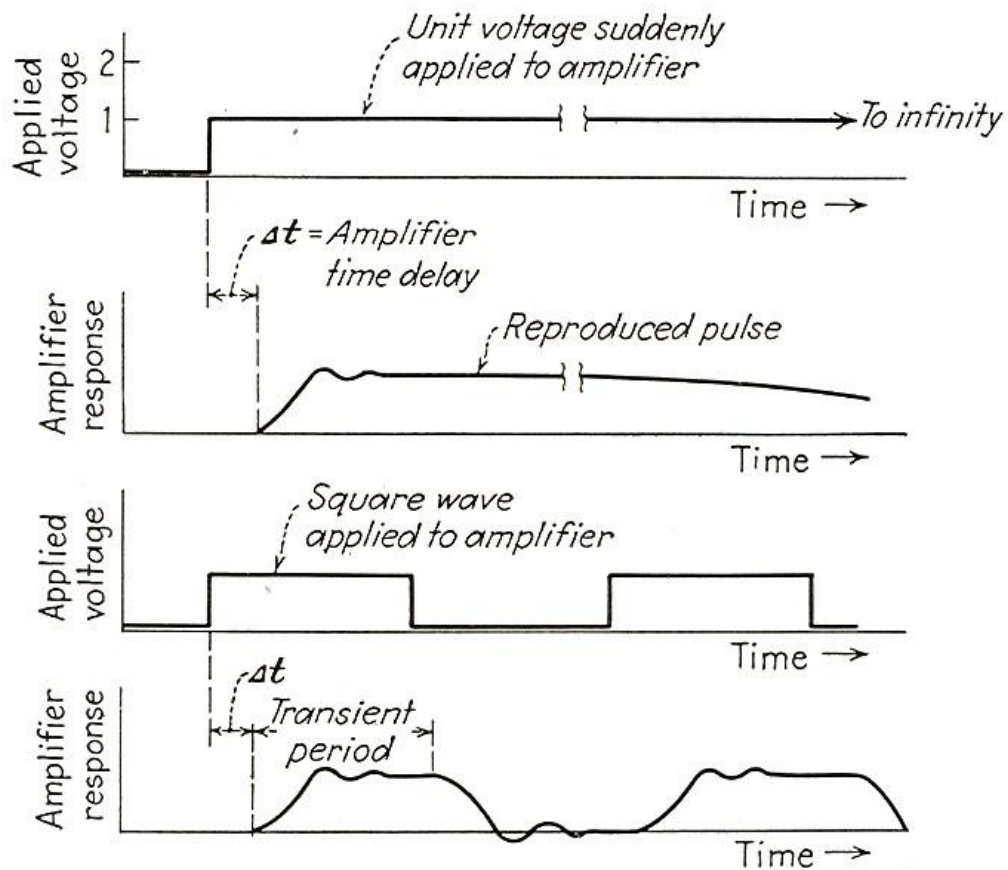
If the frequency response (or gain) for the higher order harmonic frequencies is inadequate then the resultant square wave has rounded corners as shown in the

diagram above where there are only 5 harmonics and not 13. With 21 harmonics the waveform starts to approximate an actual square wave, albeit with some aberrations (overshoots) after the leading edge of the wave. Defects in the low frequency response also show up when a square wave is passed through an amplifier, for example the top of the waveform is not flat and instead tilted up or down.

Notice on the diagram above showing 21 harmonics how the ringing after the rising edges is such that the amplitude of the oscillation after the rising edge is a little smaller after each cycle until it appears to decay to a series of small residual ripples on the flat part of the square wave.

A square wave test signal can therefore assess the performance of an amplifier over a broad range of frequencies. The rising edge and then the stable state of a square wave, stable for half the square wave's period at least, is effectively a "step" waveform similar to a Heaviside function or a step unit voltage. The Heaviside function is an instantaneous step function at some moment in time up to a new fixed voltage which then stays stable over time after that.

The diagram below shows how a square wave is just as useful as a step function as long as its period is at least twice as long as it takes for the output of the amplifier system to attain a stable state. Also a periodic or repetitive test wave is easier to display and visualise on an oscilloscope screen than a single Heaviside step function. This is why square wave testing from a fast rise square wave source, from a device like a PG506 generator (+/- a Tunnel Diode Pulser) is used to calibrate the frequency response of oscilloscope vertical amplifiers.



There is always a phase or time delay, Δt , as shown in the diagram above, in that the output signal from the amplifier arrives later than the input signal. This is due to cumulative delays throughout a multistage amplifier.

One other thing about a square wave composed of harmonics is that the amplitudes of the harmonics comprising a square wave are such that they are inversely proportional to their frequencies. For example the amplitude of the 3rd harmonic is 1/3 of the fundamental's amplitude, the 5th harmonic 1/5 of the fundamental's amplitude and the amplitude of the 21st harmonic is 1/21 of the fundamental amplitude and so on. So to attain a square wave from a combination of sine waves: The relative amplitudes of the harmonics that comprise it must be correct **and** the waves must have the correct phase relationship.

So, as often is the case, there is another way to view the concept of the "fidelity" of an amplifier to faithfully reproduce the input signal:

Provided that every frequency over the range that the amplifier is expected to operate is amplified the same amount and that every frequency is phase delayed by the same amount the output will be correct. This concept is summarized in the diagram below taken from a Tektronix manual:

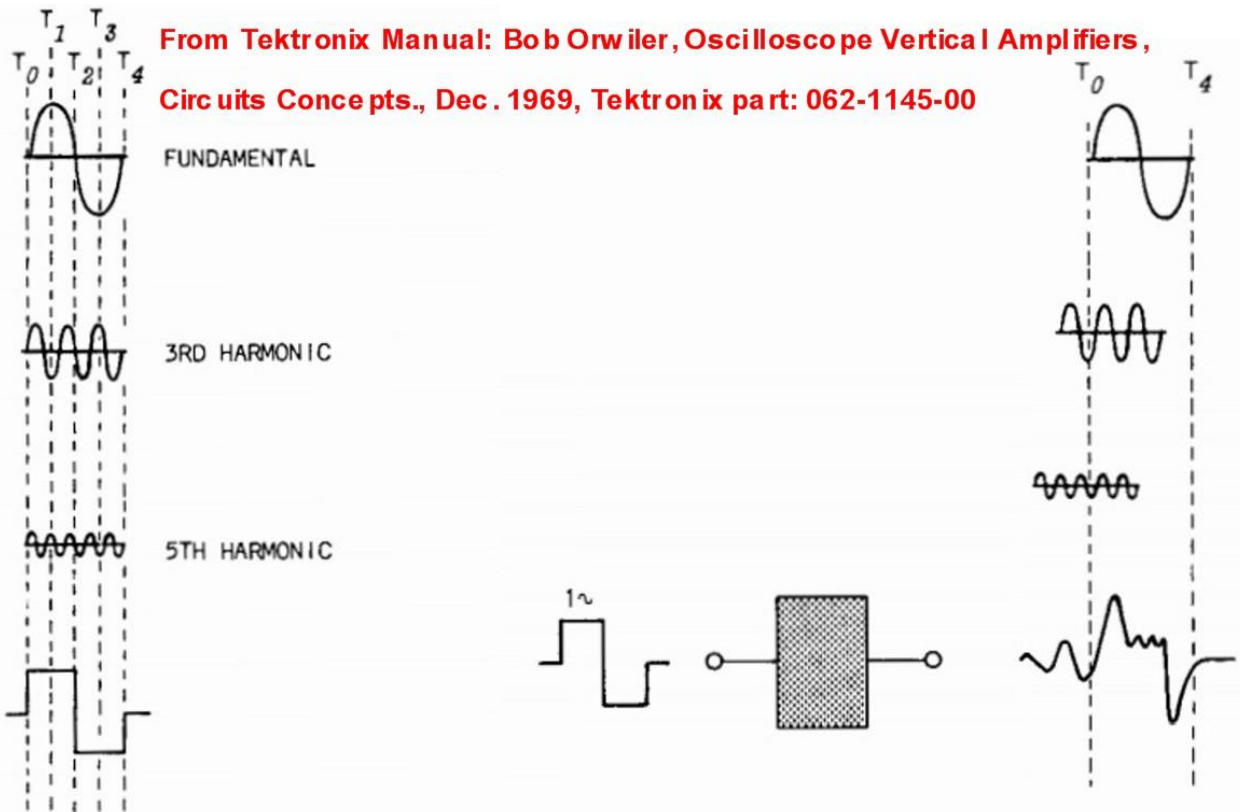


Fig. 1-27. Equal group delay.

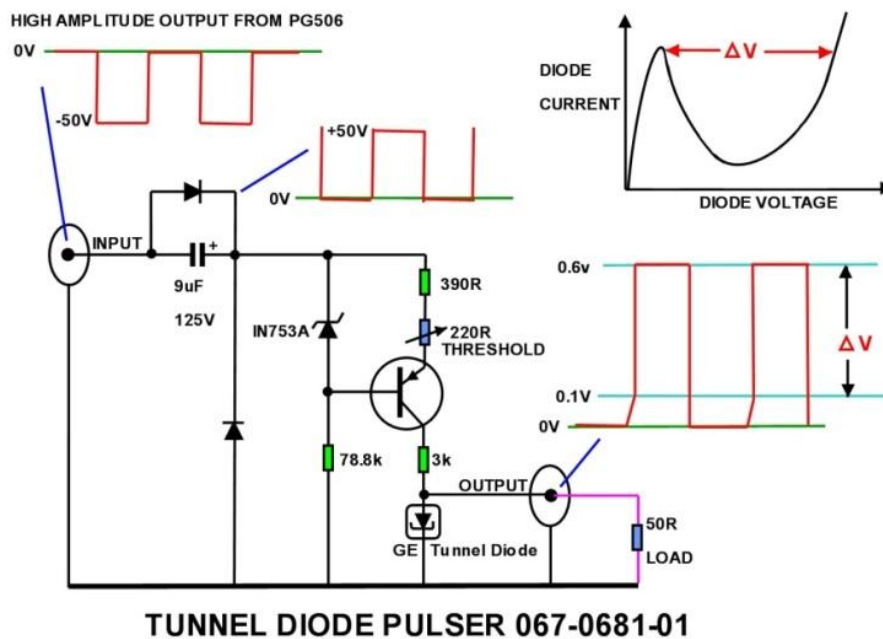
Fig. 1-28. Unequal group delay.

If all the frequency components making up a square wave arrive with the correct amplitude at the correct time the square wave will be faithfully reproduced as shown in figure 1-27. However, if there are different phase lags for different frequencies (or different amplification of different frequencies) they will combine at the output to produce a distorted wave as shown in figure 1-28. So the terminology for amplifier fidelity is that of *Amplitude distortion & phase distortion*. Ideally any amplifier is as free from these as possible.

Required Square Waves to Calibrate a Tektronix 464:

The square waves required to calibrate the 464 are 100Hz, 1KHz, 10KHz, and 1MHz square waves which have a very fast rise and no overshoot. These are available as outputs from the Tek PG506 calibration generator. However the fastest rise step waveform, which is as mathematically as close as possible to a Heaviside Step, comes via a Tunnel Diode Pulser (TDP) in conjunction with the PG506, and the TDP is required for optimal adjustment of the 464 oscilloscope or any scope's vertical amplifiers.

A Tunnel Diode Pulser (TDP) has the general configuration shown below:



Once the voltage applied to the Tunnel diode reaches a threshold, around about 100mV, the diode moves into its negative resistance region and the quantum mechanical process of electron tunnelling begins. There is a sudden (almost instantaneous) voltage step ΔV as the current attains a new stable state. This

rapid voltage transient is only limited by the Tunnel diode's small junction capacitance and its peak current rating. The waveform also has a perfectly flat top.

The square edge waveform produced by the TDP is as close as possible to an ideal Heaviside step and is perfect for checking the fidelity of oscilloscope vertical amplifiers. The input arrangement on this TDP allows for it to work with either positive or negative going square wave inputs. The PG506 high amplitude output produces a negative going square wave, the 9uF input capacitor AC couples this and the diodes DC restore it to a positive going wave as shown in the diagram above.

CALIBRATING THE 464's VERTICAL AMPLIFIERS:

In general the calibration for each channel is performed with the attenuators on the 5mV/division setting and with a 50 Ohm termination at the scope's input. This bypasses the attenuators. Once the vertical amplifier calibration is complete the attenuators can be calibrated after that according to the manual. Prior to the vertical signal switching circuitry the calibration controls on channel 1 and 2 are identical, albeit with different numbering. The vertical output amplifier's adjustments are common to both channels.

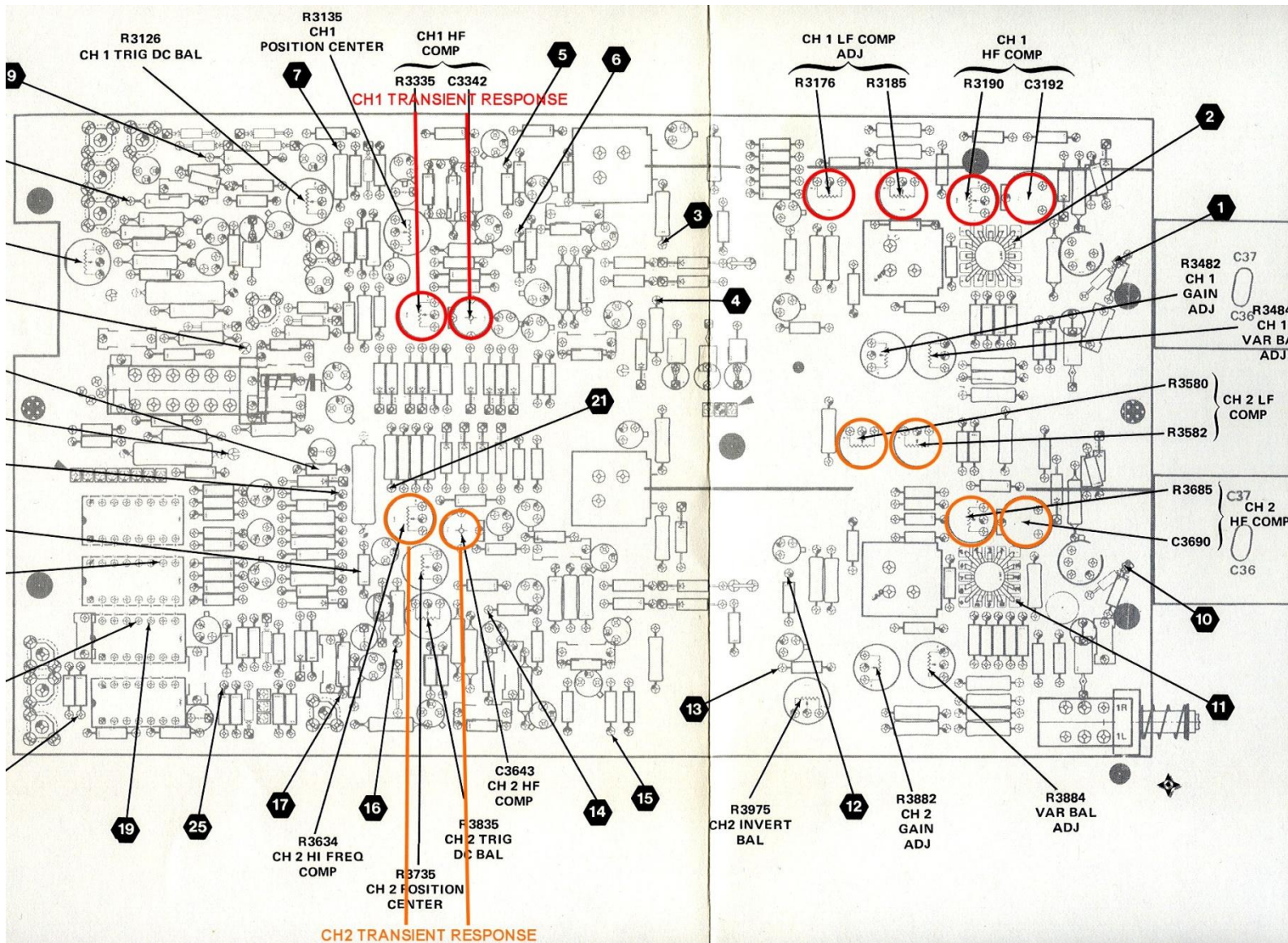
The required equipment is the PG506 calibration generator and a x10 attenuator and a feed through 50 ohm termination (a x2 attenuator) and the TDP. The SG503 levelled sine wave generator is useful for a final bandwidth check and to adjust the vertical output amplifier bias, R478.

The TDP is fed from the high amplitude output of the PG506 via a 50 ohm cable, and then from the TDP's output via the x10 attenuator and 50 ohm terminator to the scope's channel 1 input set to 5mV/division.

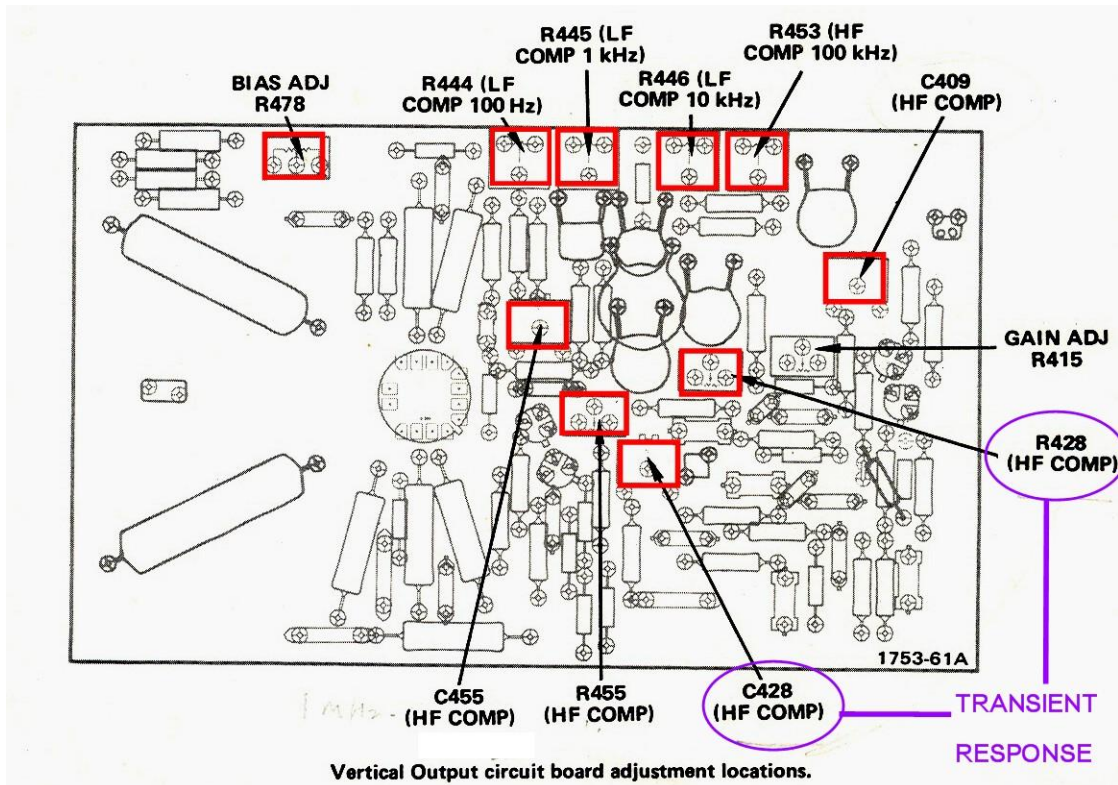
The PG506 output level and the control knob on the TDP are set to just activate the tunnel diode to produce the rectangular wave and just a little more to keep the tunnel diode reliably tunnelling.

Firstly the adjustment locations:

It is worthwhile printing out the adjustment locations and having them near the oscilloscope being calibrated. This speeds up finding them and reduces the chances of errors.



The channel 1 adjustments and the vertical output amplifier adjustments are outlined in red, the channel 2 in orange. Once the amplifier calibration is complete for channel 1 and the vertical output amplifier is also adjusted, the scope is switched to channel 2 to perform the adjustments shown in orange on the diagram above. At that point the **vertical output amplifier** is not touched.



In general, if it is thought that the particular 464 being worked on is grossly out of vertical frequency response calibration it would be best to set it up exactly according to the service manual first before applying the fine adjustments shown here on the different time-base settings.

For example if the transient response adjustments are grossly out, this places extreme ringing on the leading edge of the square wave or a slow rising shape, and it becomes a little more difficult to interpret the correct settings for the other HF compensation adjustments. However it is still possible to observe the average

value of the ringing waveform and work with that, or simply repeat the processes below twice.

If the scope is in basically satisfactory alignment already, skip step 1.

STEP 1.

Calibrate the vertical amplifiers according to the manual with special attention to R478, the vertical output amplifier bias adjustment which is done with a 100MHz signal from the SG503 levelled sine wave generator, 50 Ohm cable & termination for a 4 division display, on CH1, 0.2V/div and adjusting R478 for a maximum amplitude signal. The gain controls, invert balance controls and variable balance controls are all set according to the manual.

STEP 2.

Set up the scope with DC coupling Channel 1 and set 5mV/division vertical sensitivity, fed via the TDP output and a x10 and a x2 attenuator to the CH1 input. Set the scope's time-base for 50us/div and trig source to CH1, sync coupling AC, A time-base selected, Auto mode, BW limit switch out, x10 MAG out, adjust A trigger level & position control and CH1 vertical position to see the fast rise. The amplitude is approx 5 div pp. Set the PG506 to 100Hz:

ADJUST R444 for the flattest wave over the first 50us (one H division) immediately after the fast rise as shown in Figure 1 below:

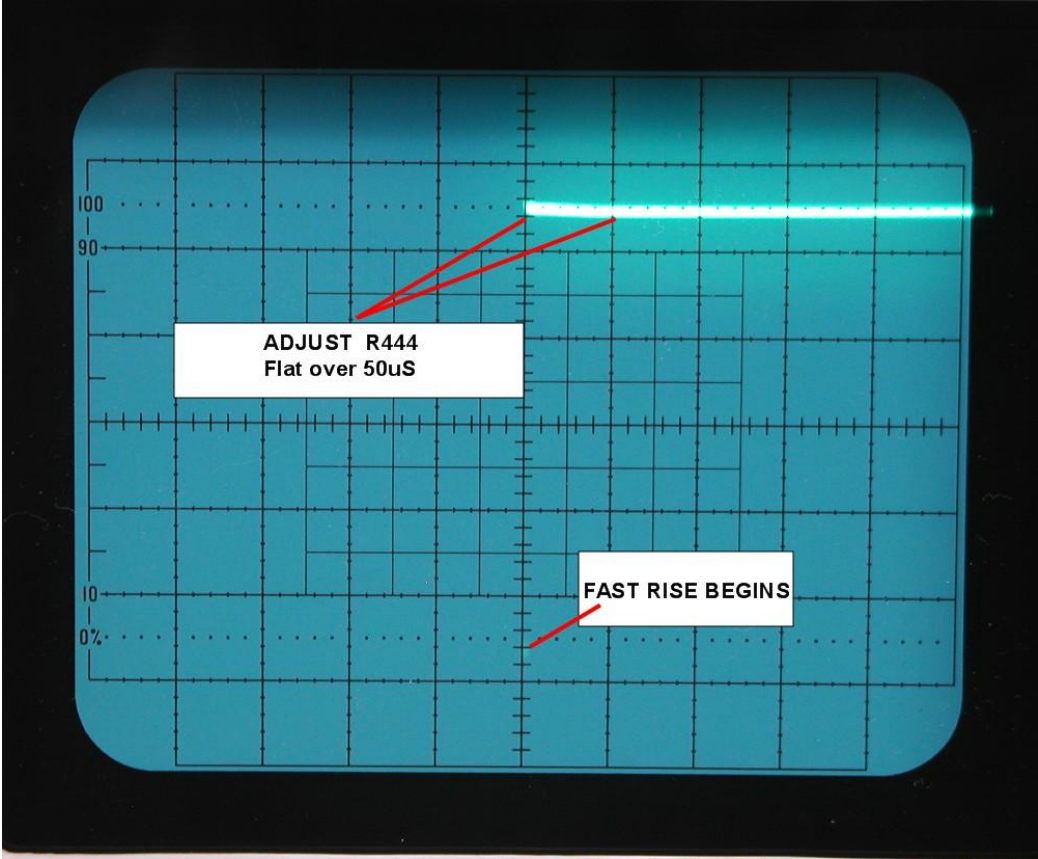


FIGURE 1.

STEP 3.

Set the PG506 to 1KHz, all else stays the same. Adjust the A trigger level and H position control as required to see the fast rise.

ADJUST R3176 for a flat response over 2.5 divisions (125uS) and R445 over 0.5 divisions (25uS) as shown in Figure 2 below:

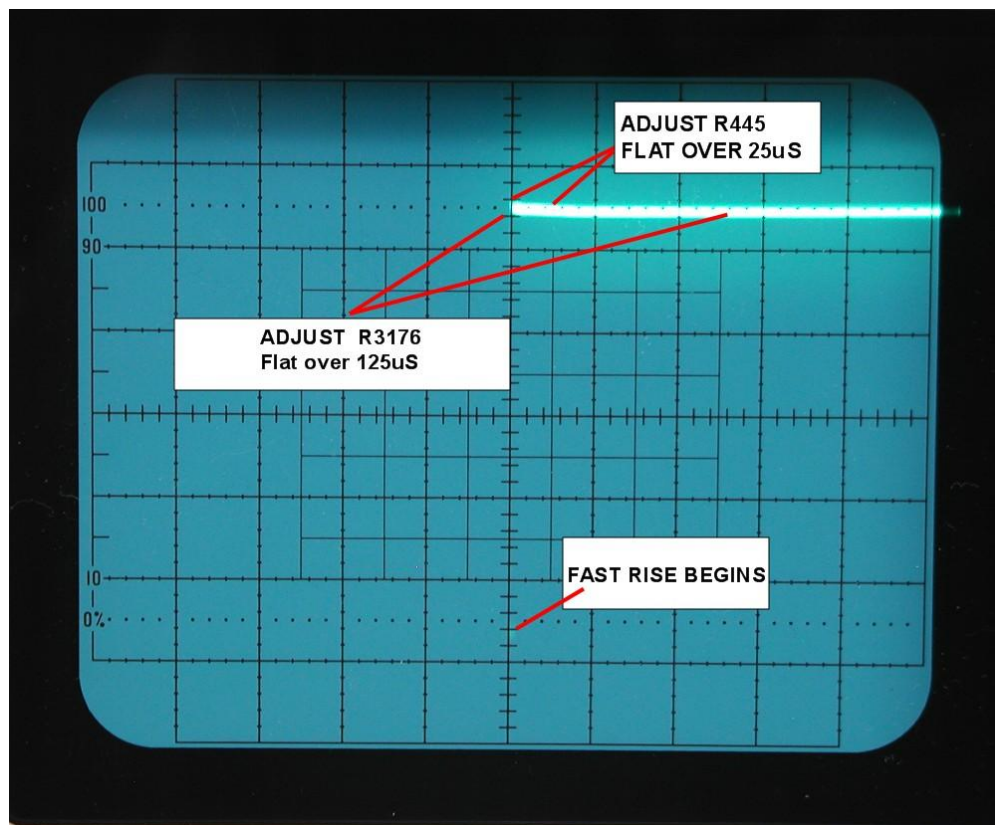


FIGURE 2.

STEP 4.

Set the PG506 to 10KHz. Set the oscilloscope's the time-base to 5uS/division. All else stays the same.

ADJUST R3185 for a flat response over 10uS and R446 for a flat response over 2.5uS as shown in Figure 3 below:

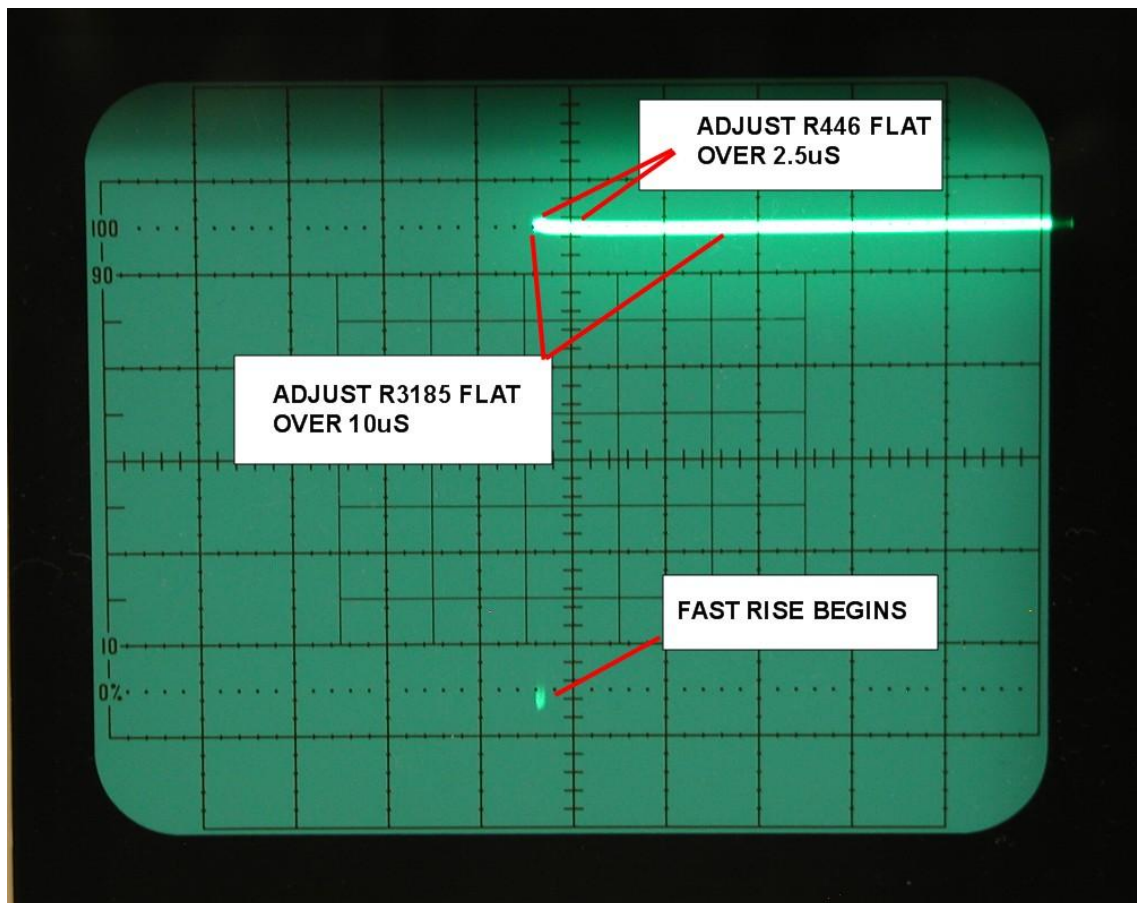


FIGURE 3.

STEP 5.

Set the oscilloscope's A time-base to 0.1 μ S and press the x10 MAG button. The Horizontal display is now 0.01 μ S/division. Set the PG506 to the 1Mhz setting. All other settings stay the same. Adjust the trigger level and H position control and CH1 vertical position control to see the fast rise from the TDP and increase the beam brightness as necessary.

(Note: If extreme ringing is seen on and after the fast rise initially, then roughly adjust R3335/C3342 and R3190/C3192 to minimise this ringing, OR pass through the process below once and repeat it. If the ringing is extreme, it is harder to set the adjustments on the vertical output board to the correct positions as the average level immediately after the fast rise is more difficult to interpret)

ADJUST R453 for an average flat response (ignoring oscillations) over 4 divisions (0.04 μ S) and adjust C409 for an average flat response over 1 division (0.01 μ S). Then adjust C455 and R455 for the flattest response over 0.7divisions (0.007 μ S) as shown in Figure 4 below:

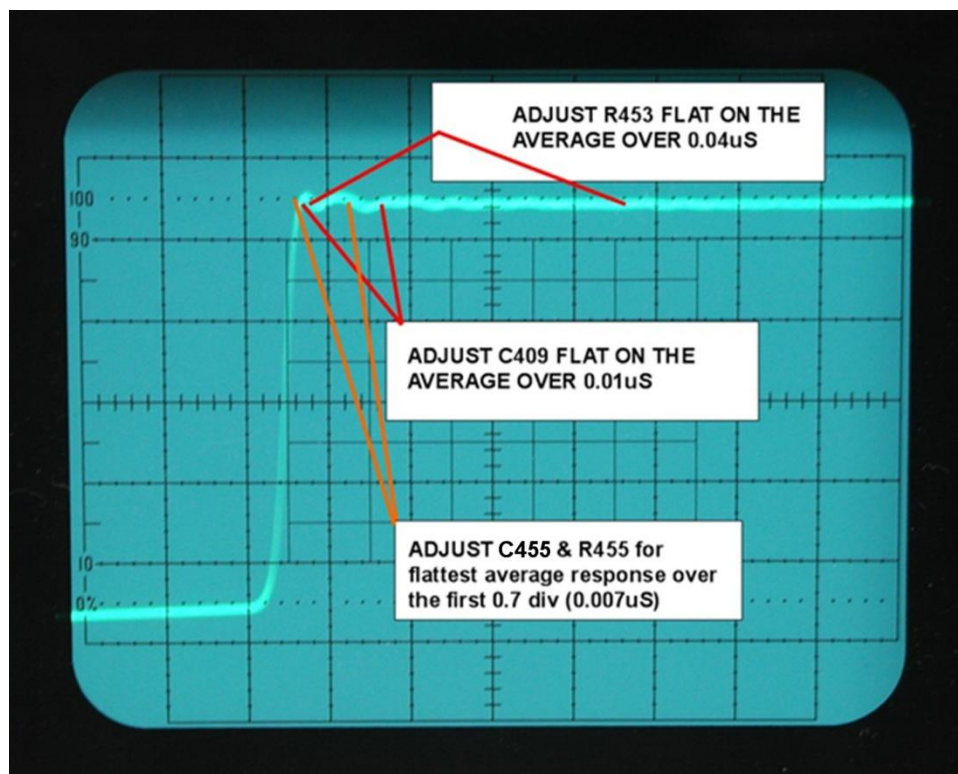


FIGURE 4:

STEP 6.

ADJUST transient response: R428/C428 (on the vertical output board) and R3335/C3342 on the channel one vertical board to minimise the ringing and overshoot immediately after the fast rise. Also adjust R3190 and C3192 to attain the exact appearance shown below. There should be a mild initial upward overshoot after the fast rise, with decaying oscillation after that as shown and the overshoot should not exceed 0.2 vertical divisions. While it is possible with these controls to nearly eliminate the overshoot and ringing, at that setting, the rise time is a little slower and the bandwidth a little reduced. Therefore aim for the adjustment to give the response shown Figure 5 below:

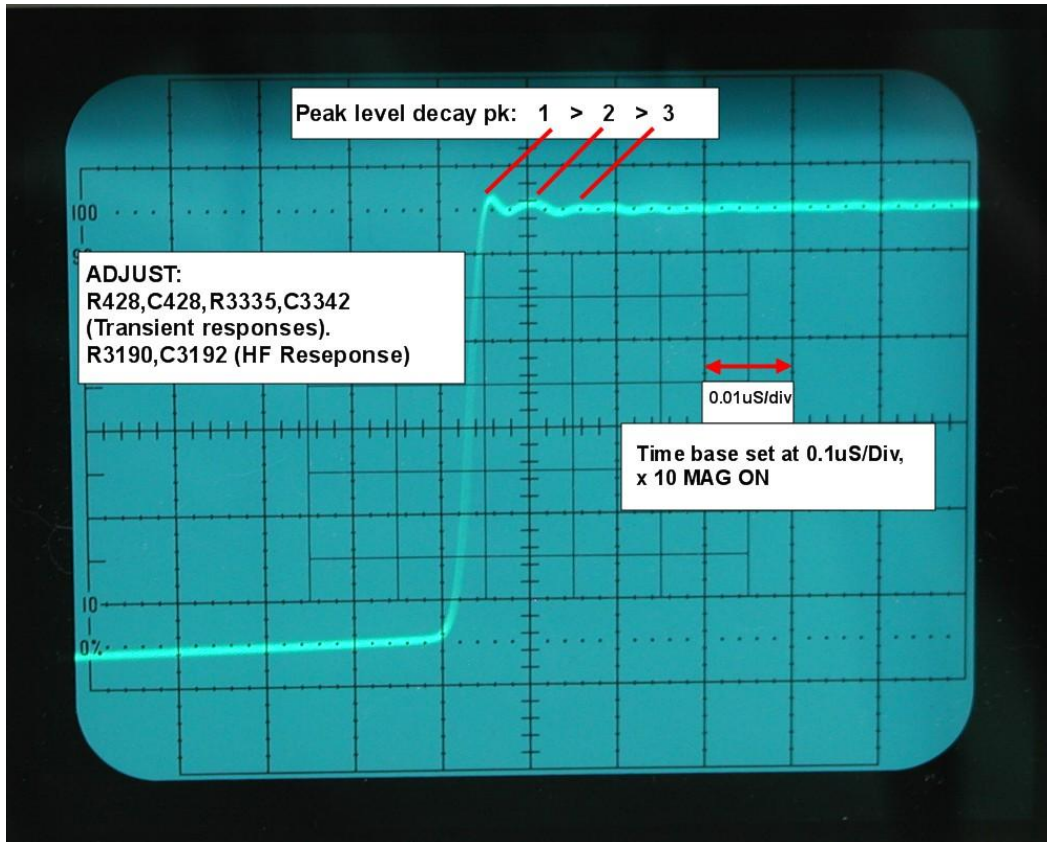


FIGURE 5.

NOTE: When set correctly the peak of the first overshoot is a little higher than the second which is a little higher than the third and the peak to peak aberration of

the first positive and second negative peak is well inside the spec of % div +/- 0.2 divisions as set out in the manual.

Repeat step 5 and step 6 if the response above is not obtained the first time.

Now the channel 1 vertical board and vertical output amplifier frequency compensation is correct.

The vertical output board does now not need to be touched again.

Switch off Channel 1.

Calibrating Channel 2:

Switch on Channel 2 again DC coupling and 5mV/div sensitivity. Move the input signal to Channel 2 & select the sync source to channel 2. Adjust the trigger level, H position and CH2 vertical position control to see the fast rise signal. Perform adjustments on the fellow controls in channel 2 under the same time-base setting conditions as they were when channel 1 was calibrated. The two CH2 LF compensation controls R3580 & R3582 in Ch2 are again set with the PG506 on 1KHz or 10KHz respectively and the time-base set as it was when the CH1 LF controls were adjusted on 50uS/div and 5us/div respectively. The CH2 transient response controls C3643 and R3634 and the CH2 HF compensation controls R3685,C3690 are adjusted to ensure that the channel 2 response is matched closely as possible to the channel 1 response (shown in figure 5 above). Again with the scope's time-base on 0.1uS/div and the x10 MAG switch pushed in, the display is 0.01uS/div as shown in Figure 5. Figure 6 below is a photo of the Channel 2 result after adjustment:

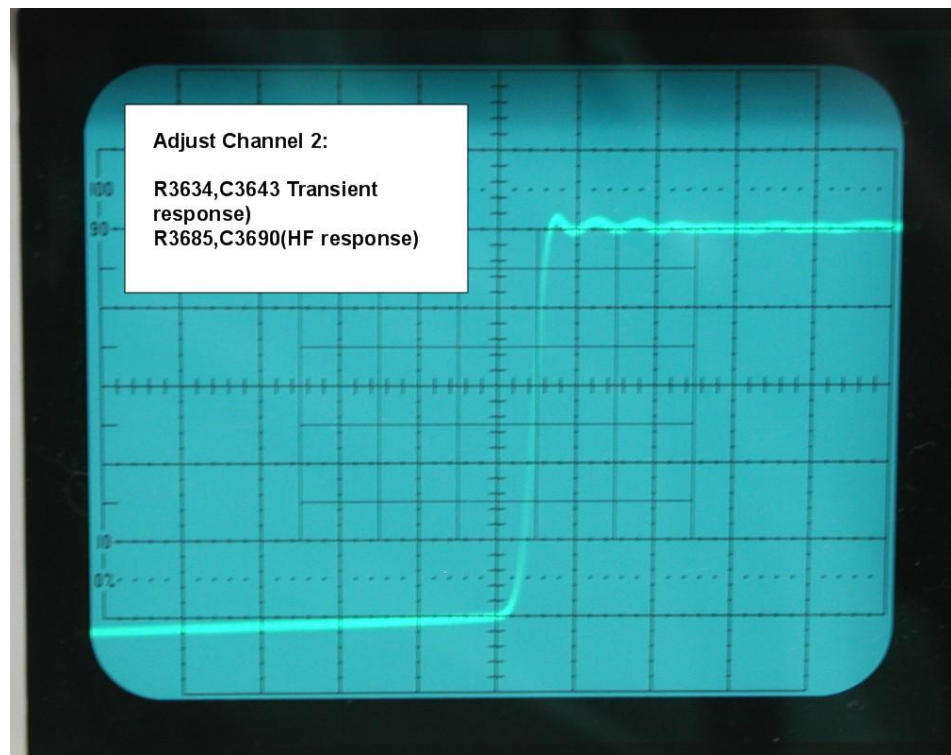


FIGURE 6:

(Again ensure that the ringing has the same format of peak 1 >peak 2 >peak 3).

CHECK BANDWIDTH:

Set the SG503 levelled sine wave generator to the reference 0.05Mhz output. Select the X.1 amplitude multiplier and the output voltage to 2.4 on the Vernier output scale. Pass the output via a 50R cable to a x10 then a x2 attenuator and feed this to the channel 1 input again set on 5mV/div.

Adjust the output voltage of the SG503 to give an exact 6 vertical division peak to peak display. Set the SG503 to 100MHz. The displayed peak to peak amplitude should be close to $0.707 \times 6 = 4.2$ divisions. This indicates that the vertical amplifier frequency response is 3dB down at 100MHz.

With the transient & HF responses adjusted as shown above in figure 5 (and figure 6 for channel 2), the measurement shows the peak to peak amplitude to be 4.4 divisions, so the response is just a little less than 3dB down @ 100MHz easily meeting the manufacturer's specification. Perform the same bandwidth check on channel 2 it should be identical or very close to the channel 1 result if the transient & HF adjustments were adjusted as indicated in figure 6.

Some practical considerations:

The grey plastic top ceramic base calibration adjustment resistors/potentiometers on the 464's CH1 & CH2 vertical amplifier board are prone to go noisy & intermittent as they are not sealed to the ingress of dust. To avoid this problem spray them on their edges with CO contact cleaner with a cloth on the opposite side to collect the overspray and rotate them throughout their full range of motion 5 or 6 times and this helps to flush out any fine particulate matter from the wiper & carbon track . After that they tend to run a little dry and I have found the addition of a small amount of potentiometer lubricant helps, WD40 in a small quantity will also work for this application. The plastic encased rectangular trimmers typical of the ones on the vertical output amplifier board very seldom if ever give any problems as they are well sealed units.

Other remarks and optional adjustment methods for the 464's V amplifiers:

The net result achieved in the calibration of the entire vertical amplifier's frequency response described above is the result of the combination of adjustments on the CH1 and Ch2 vertical amplifier boards and the vertical output amplifier board. Since the transient adjustment controls and the LF & HF adjustment controls in the CH1 & CH2 circuits and the vertical output amplifier PCB induce similar effects, and since the vertical output board is common to both channels, it raises the question whether or not it would be better to have a standard correct frequency response setup on the vertical output board to start with.

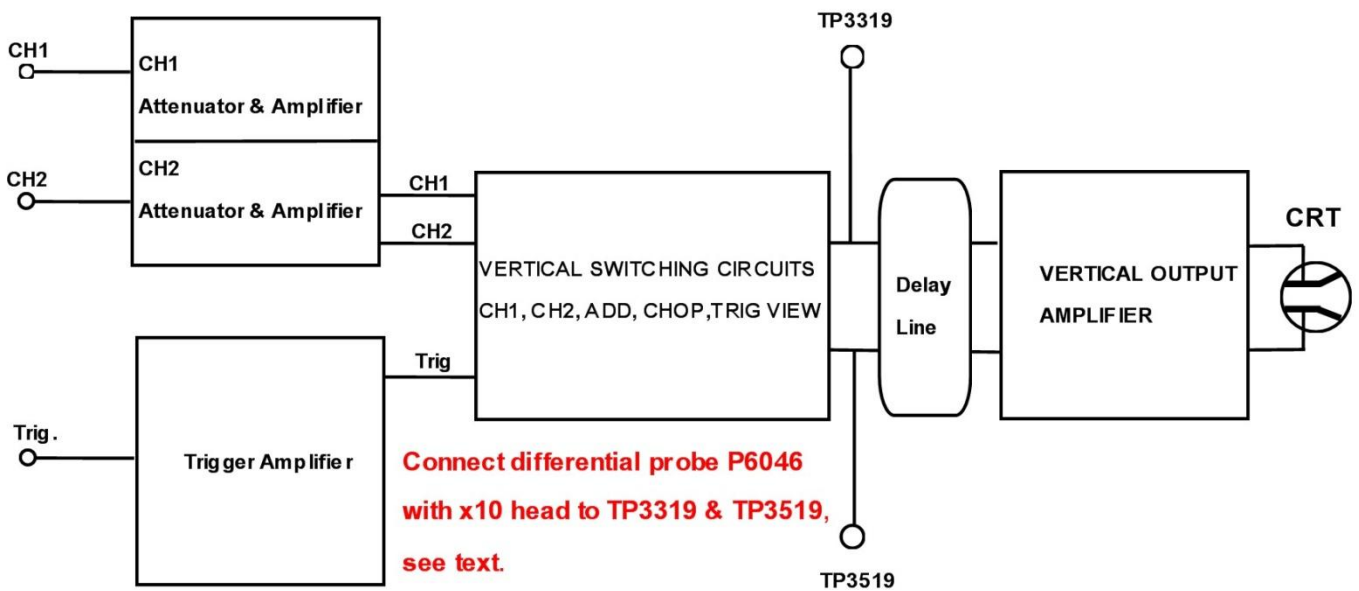
To do this would require a standard test signal applied to the delay line & vertical output board that was correctly compensated and free from aberrations so that the vertical amplifier board on its own, could be correctly set up. No provisions have been made for such a system of adjustment in the 464.

However, with the use of the Tektronix P6046 Differential probe, with the x10 head, the very low loading capacitance, of 3pF or less, then the application of this probe to the delay line input area has a negligible effect on the transient response & HF settings of the entire amplifier (see below photos of the aberrations with the probe connected & not connected).

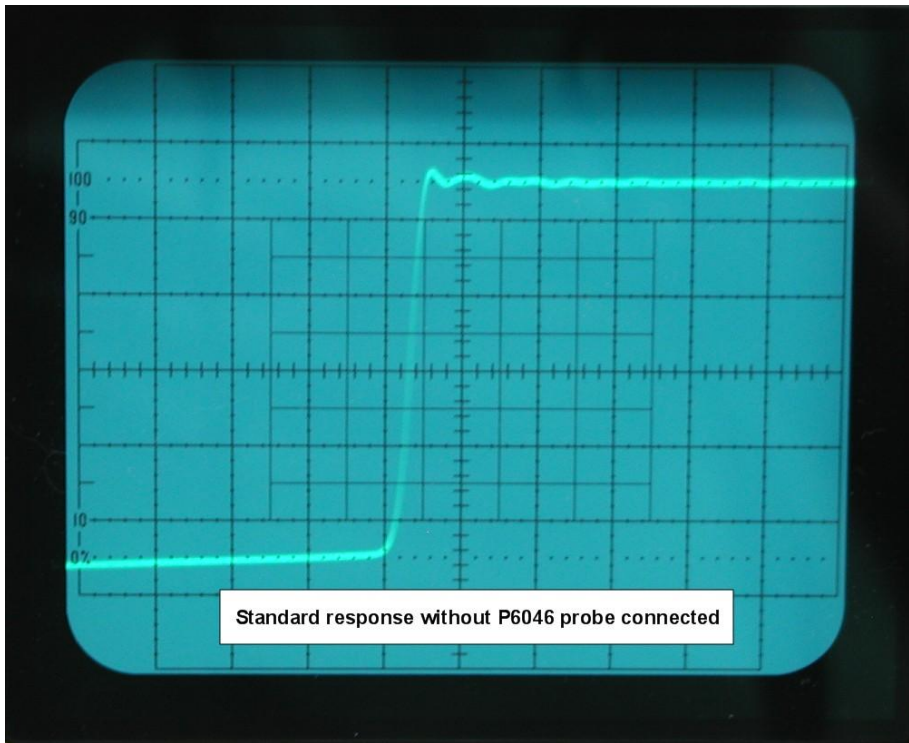
Therefore with the probe applied then the CH1 and CH2 frequency compensation & transient response adjustments on the channel 1 and channel 2 amplifier board can be set for minimum aberrations on these test points as observed on another oscilloscope connected to the P6046 probe. This effectively creates a "standard drive signal" to the 464's vertical output amplifiers which can then have its LF & HF compensation and transient response adjustments made for the best result on the 464's display.

After that the differential probe can be removed, and the small error from that eliminated by fine adjustment and the combination of adjustments on the CH1 & vertical output board checked in the usual manner as described above and a final adjustment of channel 2 to match up. This method could be helpful if all the initial adjustments were wildly out due to adjustment tampering by an unskilled worker etc. Positive of the differential probe goes to TP3519, negative to TP3319.

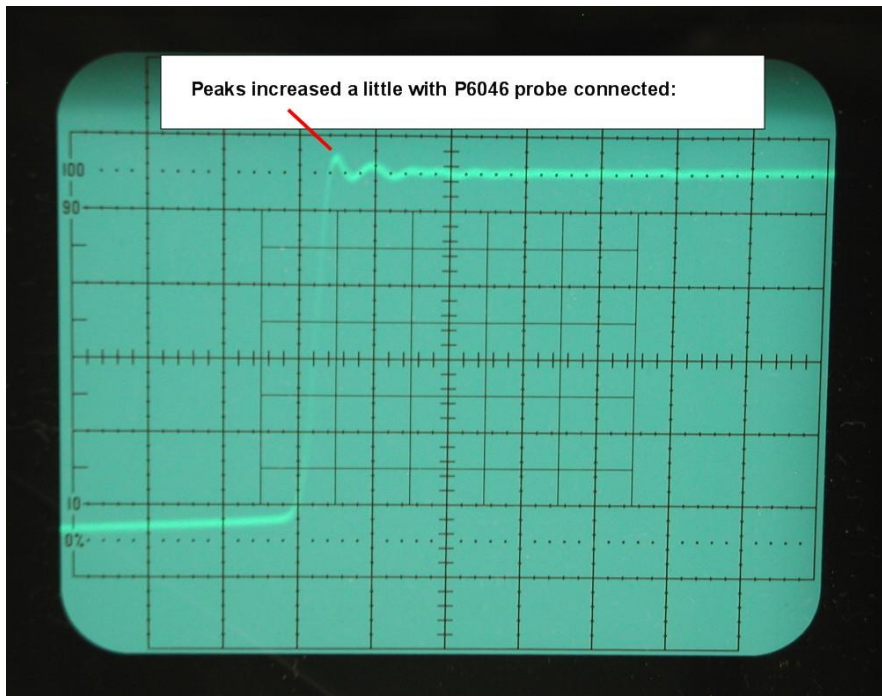
STANDARDISING THE DRIVE TO THE VERTICAL OUTPUT AMPLIFIER:



The photo below shows a calibrated scope transient response (as shown above in figure 5) without the differential probe attached:



The photo below shows the alteration in aberrations with the probe attached, as can be seen the peaks are just a little higher and the frequency response not grossly altered:



The P6046 probe output feeds a 2465B scope via a 50R cable and terminated by the 50R load within the 2465B. The photo below shows the probe hooked on by two of its standard accessory clips to the test points on the CH1 & Ch2 vertical amplifier board:



The Probe's attenuator on the P6046 amplifier was set on 1mV division. The 2465B set on 100mV/division and the 2545B's time-base set on 20nS/Division.

The results shown below (2465B screen photo) are only possible if the P6046 probe is in correct calibration and being used with Tektronix's P6046 amplifier/attenuator assembly.

Output from P6046 probe fed to 2465B oscilloscope:

