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INTRODUCTION TO OSCILLOSCOPE DIFFERENTIAL AMPLIFIERS

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This article describes oscilloscope differential amplifiers in terms of their application to measurements. Characteristics such as common-mode rejection ratio, voltage range, and frequency range are explained, and typical figures are given. In addition, the effect of probes and filters as well as the importance of source impedance are discussed and pointed up as factors that can affect measurement capability.

What Is It?

The word "differential" in the amplifier name can be misleading. To some it suggests a relationship to differential calculus while others think of a differentiating network. It is neither of these, but simply a *difference* amplifier. By definition: An oscilloscope differential amplifier is a device that amplifies and displays the voltage difference that exists at *every* instant between signals applied to its two inputs.

With this definition as a departure point, one can get some idea of the oscilloscope display that will result from a variety of input signals. For example, two pulses that differ in both amplitude and coincidence that are applied to a differential amplifier will cause the oscilloscope display to be a complex waveform that represents the instantaneous difference between the two pulses. On the other hand, two signals that are *identical* in every respect will cause no output on the CRT screen (limitations to this statement will be described under *Common-Mode Rejection*).

Several examples of input waveforms as applied to a differential amplifier and the resultant output waveforms are shown in Figures 1, 2 and 3.

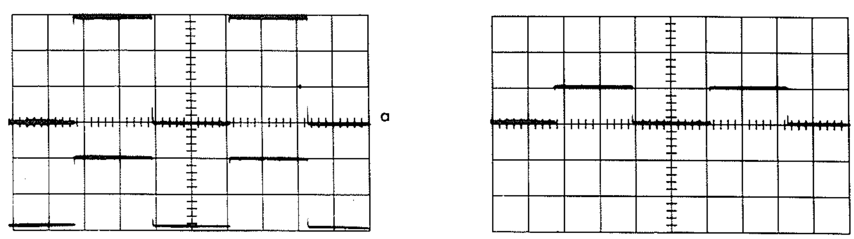


Figure 1. a, Input signals of different amplitude (same phase) applied to a differential amplifier. b, The resultant ouput signal.

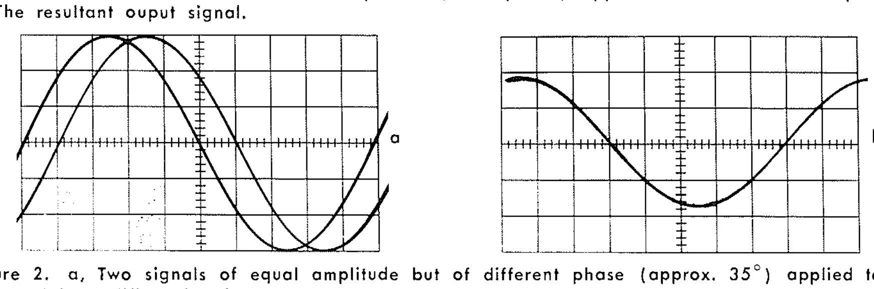


Figure 2. a, Two signals of equal amplitude but of different phase (approx. 35°) applied to a differential amplifier. b, The resultant signal seen on the crt.

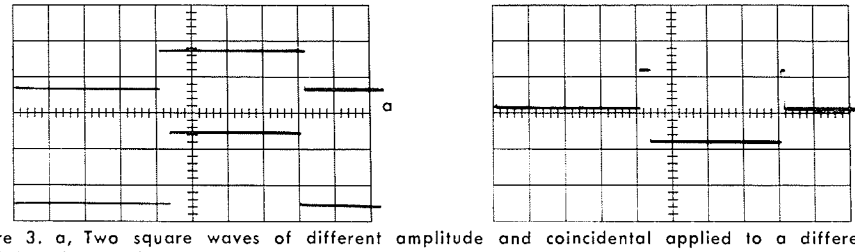


Figure 3. a, Two square waves of different amplitude and coincidental applied to a differential amplifier. b, the difference waveform seen on the crt.

Common-Mode Rejection

The definition of the term differential amplifier implies a rejection of equal amplitude, coincident signals. This implication is correct. However, the degree of rejection depends primarily on the symmetry of the amplifier inputs. Unfortunately, the design and construction of two exactly symmetrical inputs to a differential amplifier cannot be accomplished in practice. Small differences in resistor and capacitor values result in deviations from the theoretical input attenuation ratio. In addition, the capacitance of active elements may not remain the same for each input and this can cause a difference voltage, especially at the higher frequencies. The net result of these variations in component values is an unbalance that causes a *difference* signal, even though the amplifier is driven by identical input signals. The amount of difference signal that one can expect from a particular amplifier is documented with a mathematical relationship that is called the common-mode rejection ratio (CMRR). This ratio and associated terms are defined as follows:

Common-Mode: Refers to signals that are identical with respect to both amplitude and time. Also used to identify the respective parts of two signals that are identical with respect to amplitude and time.

Common-Mode Rejection: The ability of a differential amplifier to reject common-mode signals.

Common-Mode Rejection Ratio (CMRR): The ratio between the amplitude of the common-mode input signal to the difference input signal which would produce the same deflection on the CRT screen.

NOTE: Since the differential amplifier in this discussion (and throughout this article) is part of an oscilloscope, the output signal used to calculate the CMRR is measured in the usual way from the CRT screen and volts-per-division switch setting.

Thus, a differential amplifier that produces a .005-volt output when driven by 5.0 volts of common-mode signal has a CMRR of 5/.005 or 1000:1.

Measurements made with a differential amplifier should contain an allowance for the output voltage that is due to common-mode signal. For example, if an amplifier with a CMRR of 1000:1 is used to measure the difference between two similar five-volt signals, the output seen on the oscilloscope screen is the result of two voltages: (1) the *actual* difference between the input signals, and (2) the difference voltage that results from the common-mode signal. Because of this combination, the actual difference voltage cannot be *exactly* measured. Therefore, the voltage measured on the CRT screen should include a tolerance that is equal to the computed, or measured, output voltage due to the common-mode signal.

In the above example, the CMRR of 1000:1 means that the common-mode portion of the five-volt signals will cause an output of 5.0 volt/1000 or .005 volt. If a voltage of, say .015 was measured on the CRT screen, it should be noted as .015 ±.005 volt.

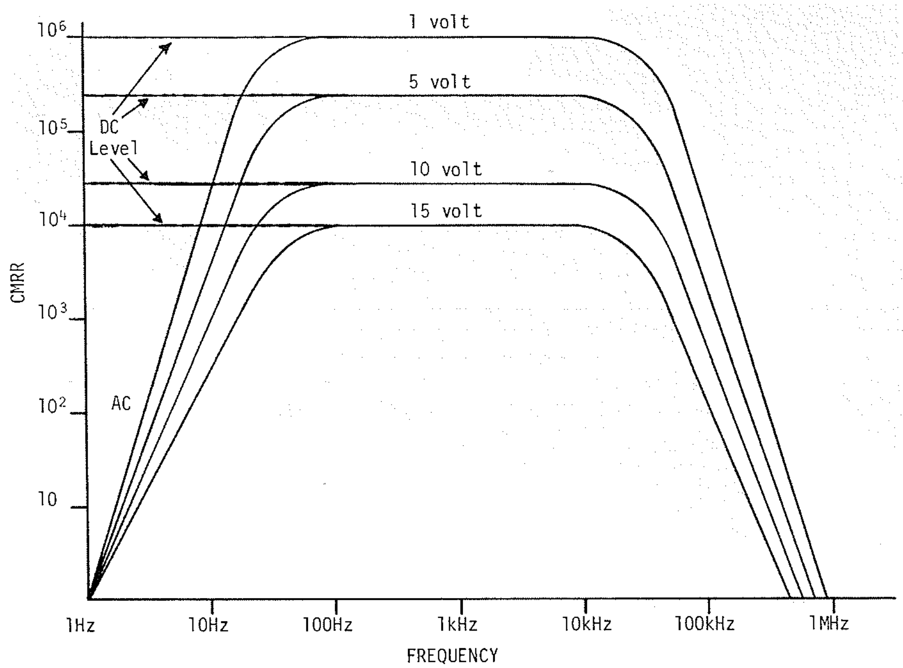


Figure 4. The common-mode rejection ratio related to frequency, voltage level, and input coupling of a typical differential amplifier.

COMMON-MODE REJECTION[1]

0.1 MV/CM to 10 MV/CM[2]

	Referred to Input Connectors		Referred to Input of Properly Adjusted P6023 Probes	
	DC-Coupled Input	AC-Coupled Input With Low-Z Source	DC-Coupled Input	AC-Coupled Input With Low-Z Source
DC to 100 kHz	50,000:1			
500 kHz	1,000:1	1,000:1		
DC to 10 Hz			50,000:1	
15 Hz		500:1		
60 Hz		2,000:1		
100 Hz			10,000:1	
1 to 10 kHz			1,000:1	1,000:1
100 kHz		50,000:1	500:1	500:1
20 MV/CM to 10 V/CM[3]				
DC to 1 kHz	10,000:1			
DC to 100 kHz	1,000:1			
500 kHz	500:1	500:1		
15 Hz		500:1		
60 Hz		2,000:1		

[1] For ground-referenced sine-wave common-mode signals.
[2] With 10 volts peak-to-peak or less in common mode at input connectors.
[3] With common-mode amplitude at input connectors of 100 volts peak-to-peak or less from 20 mv/cm to 0.1 v/cm, and with 600 volts peak-to-peak or less from 0.2 v/cm to 10 v/cm.

These common-mode signals will not overdrive the amplifier:
0.1 mv/cm to 10 mv/cm, ±20 v from gnd (40 v pk-to-pk ac)
20 mv/cm to 0.1 v/cm, ±200 v from gnd (400 v pk-to-pk ac)
0.2 v/cm to 10 v/cm, ±600 v from gnd (1200 v pk-to-pk ac)

Figure 5. Chart for the Tektronix Type 3A3 Differential-Amplifier Unit that outlines the parameters under which certain common-mode rejection ratios can be achieved.

Amplitude, Frequency and Input Coupling

To this point, no mention has been made of common-mode rejection in terms of amplitude, frequency, or type of input coupling. The importance of these factors is graphically illustrated in Figures 4 and 5. From these figures one can formulate some general rules as to expected changes in common-mode rejection when amplitude, frequency or input coupling are changed.

1. The specified common-mode rejection becomes *lower* as the common-mode signal amplitude is *increased.*
2. The specified common-mode rejection becomes *lower* as the input attenuators (within the amplifier) are switched into the amplifier input circuit.
3. The specified common-mode rejection becomes *lower* as the frequency of the common-mode signal increases. (Exception: with AC-coupled input the CMRR can become higher as frequency is increased within the 1 Hz to 100 Hz range).
4. Generally, the addition of components such as probes, attenuators, or even extra cable to the amplifier inputs will lower the *apparent* common-mode rejection. (Note: the actual CMRR of the instrument cannot be changed by added external components.)

Where precise quantitative data is needed, one should measure the CMRR of the instrument at the specific frequency or repetition rate and amplitude of the signals being used and use this measured CMRR as a tolerance figure in difference measurements.

Amplitude and Common-Mode Rejection

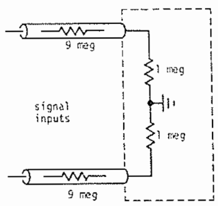
In the text to follow, the term maximum *common-mode input voltage* means the maximum voltage that will not overdrive the amplifier. This should not be confused with the *maximum non-destructive input voltage* which is related to the breakdown limits of the amplifier components.

Figure 4 shows that the CMRR decreases as the input voltage increases. If the voltage applied to the input is raised beyond the maximum common-mode input voltage specified for the amplifier, at some point the input circuit will be overdriven and the common-mode rejection ratio becomes meaningless. Once this occurs, further increase of the common-mode voltage will cause a disproportionate increase in the amplitude of the CRT display.

This discussion of input voltage also applies to pulses and square-waves as well as sine-waves. But because these waveforms contain components of many frequencies, it is difficult to predict the shape of the resultant waveform that a differential amplifier may display.

Probes and Common-Mode Rejection

Attenuator probes extend the usable voltage range of a differential amplifier by reducing the input signals to a level that is below the *maximum common-mode input voltage*. In doing this, however, the probes may cause a reduction in the *apparent* CMRR due to component value differences within the probes. For example, Figure 6 illustrates the change in CMRR (apparent) due to X10 probes that are within 1, 2, and 3% of their attenuation value. Bear in mind that the reduction in apparent CMRR can also be caused by different values of the input resistor. Also, probes with cables of different length may introduce enough signal delay between them to cause a difference voltage at the inputs. A good rule, especially with probes, is to try to make conditions at both inputs identical.



Probe	Tolerance	CMRR (Apparent)
A	+1%	50:1
B	-1%	50:1
C	+2%	25:1
D	-2%	25:1
E	+3%	16:1
F	-3%	16:1

Figure 6. Simplified input circuit and table that shows the change in CMRR (apparent) due to X10 probes that are within 1, 2, and 3% of their attenuation value.

A typical test was run on four Tektronix Type 6006 probes to illustrate what might be expected in practice. The differential amplifier was a Tektronix Type 3A3 Dual-Trace Differential Amplifier in a Tektronix Type 561A Oscilloscope and the source voltage was from a Tektronix Type 190B Sine-Wave Generator set at 1 kHz.

	CMRR
Probes 1 and 2	56:1
Probes 1 and 3	40:1
Probes 2 and 3	68:1
Probes 4 and 1	8:1
Probes 4 and 2	7:1
Probes 4 and 3	8:1

This test pointed out two additional features of probe use: (1) by reversing the probe connections to the amplifier inputs the CMRR was changed. For instance, when probes 1 and 2 were reversed, the CMRR changed from 56:1, as shown above, to 46:1; and (2) the test showed probe number 4 to be defective, as indicated by the low CMRR (8:1).

In measurements where attenuator probes must be used because of voltage levels, and at the same time a high (above 1000:1) CMRR must also be achieved, the Tektronix Type P6023 Probe is suggested. This is a X10 low capacitance probe with variable attenuator ratio that is adjustable over a ±2.5% range. As pointed out earlier in Figure 5, these probes, when used with a Tektronix Type 3A3 Differential-Amplifier Unit, can be adjusted for CMRR's of 50,000 at certain frequencies.

Filters and Common-Mode Rejection

Some differential amplifiers use filters, but this technique is not considered to be common-mode rejection since difference signals are also rejected by filters. In effect, the filters set the bandwidth of the amplifier and reject signals that are above or below the filter passband. For example, a 60 Hz sine-wave modulated by high-frequency noise can be "cleaned up" considerably by using a filter whose passband centers on 60 Hz. Conversely, to eliminate line-frequency hum, a filter that restricts the hum frequency should be used.

Several differential amplifiers, such as the Tektronix Type 2A61 Low-Level Differential Amplifier and Tektronix Type 1A7 High-Gain Differential Amplifier, have a series of internal filters that are adjusted by frequency-response controls on the instrument front panel. These controls allow the amplifier passband to be centered on the frequency of the desired signal. One note of caution—too severe restriction of the passband may cause distortion of non-sinusoidal signals.

Signal Source Impedance and Common-Mode Rejection

The common-mode rejection ratio specified for a differential amplifier is obtained by applying the same signal to both inputs. Since the signals are from the same generator, the source impedance of the signals is the same. (In the discussion that follows, the signals are 100 Hz sine waves.)

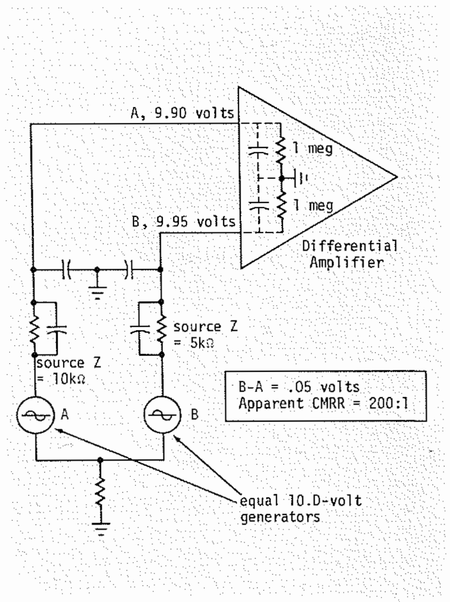


Figure 7. Schematic that shows the relationship of test-point source impedance to the amplifier-input impedance, and also shows the apparent CMRR caused by large value difference between test-point impedances.

If the two inputs to a differential amplifier are connected to circuits that do not have the same source impedances, the *apparent* CMRR will be lower than expected, even though the voltages from both sources are the same. (Note: This assumes a finite resistance such as 1 megohm from grid to ground at each input of the differential amplifier). The reason for this lower CMRR is: the source impedance of the circuit under test and the amplifier input impedance form a divider (both R and C) and the ratio between these two impedances determines the amount of signal presented to the grids.

For example, in Figure 7, the source impedance of generator A is 10 kilohms and the input impedance of input A is 1 megohm. The actual voltage present at the input A is 99.0% of the source or 9.90 volts.

Generator B has a source impedance of 5 kilohms which is in series with the 1 megohm input impedance of input B. This results in 99.5% or 9.95 volts applied to input B.

With 9.90 volts applied to input A and 9.95 volts applied to input B, the net difference between the two inputs is 0.05 volt. This difference voltage of 0.05 volt would be amplified and appear on the CRT screen. If one considered this voltage as the result of a common-mode 10.0-volt signal the ratio would be 200:1. However, as the illustration shows, the difference voltage of 0.05 volt was present at the input to the amplifier and because of this, cannot be considered as a common-mode voltage. In addition, the illustration shows that the difference voltage present at the amplifier input was a direct result of the difference in source impedance of the two signal sources.

One way to reduce inaccuracy due to different source impedance is to select test points with low source impedance. Figure 8 shows a difference voltage of .0005 volt applied to a differential amplifier when the source voltage is 10.0 volts and the source impedances are 50 Ω and 100 Ω respectively. In this case, the apparent CMRR is 20,000:1 (assumes infinite CMRR of the amplifier).

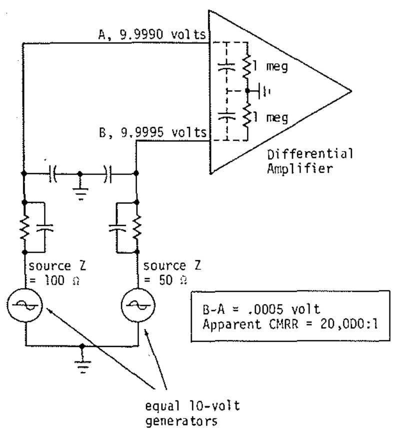


Figure 8. Schematic that shows the small affect on CMMR caused by low-impedance test points compared to that of Figure 7.

If a measurement must be made from two different high impedance points the source impedances can be calculated and allowance made for the difference voltage although this calculation can be quite difficult. A second way to handle this measurement is to use a differential amplifier with an infinite input resistance. The Tektronix Type W Plug-In Unit can be set by a front panel control to have 10,000 megohms input resistance. The remaining input capacitance of 20 pf will present approximately 80 megohms to the 100 Hz signal. When two dividers are calculated between 80 megohms and the 5-k and 10-k source impedances, the difference voltage from a 10-v signal is .0006 v.

As the frequency of signals increases, the error due to different source impedances also increases. There is really no solution to this problem other than to avoid the conditions that produce it. Thus, one should: (1) select low source impedance test points whenever possible, and (2) where high impedance test points must be used, try to use points of equal source impedance.

Ground Connections

Because differential amplifiers are capable of measuring difference signals at microvolt levels they are also sensitive to unwanted signals that may be present in the instrument environment. Proper grounding can often reduce these unwanted signals to a point where they do not interfere with a measurement. Figures 9a, b, and c illustrate the right and wrong way to connect a differential amplifier into a circuit.

Figure 9a is wrong because each probe shield acts much like an antenna in picking up stray signals from the environment. These signals will differ in both phase and amplitude between the two probe shields and will induce currents in the center conductors which result in small signal differences at the input to the amplifier. Figure 9b is wrong since a ground connection between the junction of the probe shields and the instrument under test would allow ground currents to flow through the shields. The presence of these ground currents increases the possibility of erroneous measurement due to resultant voltage differences applied to the inputs of the amplifier.

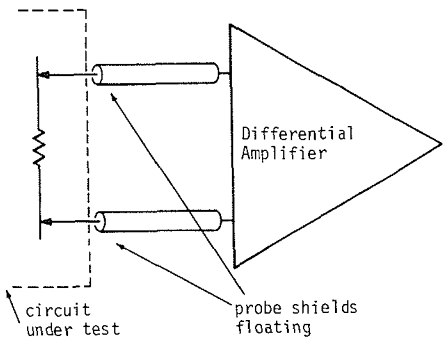


Fig. 9a. Wrong

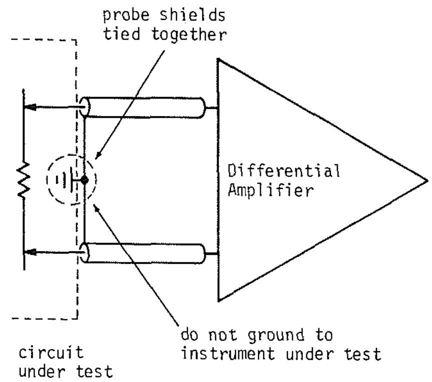


Fig. 9b. Wrong

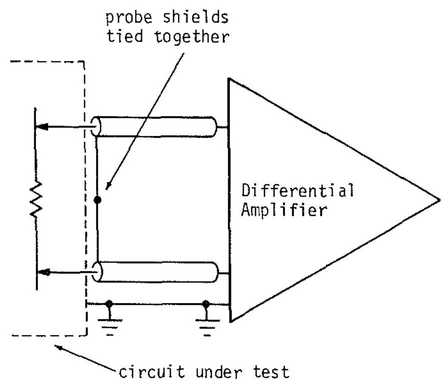
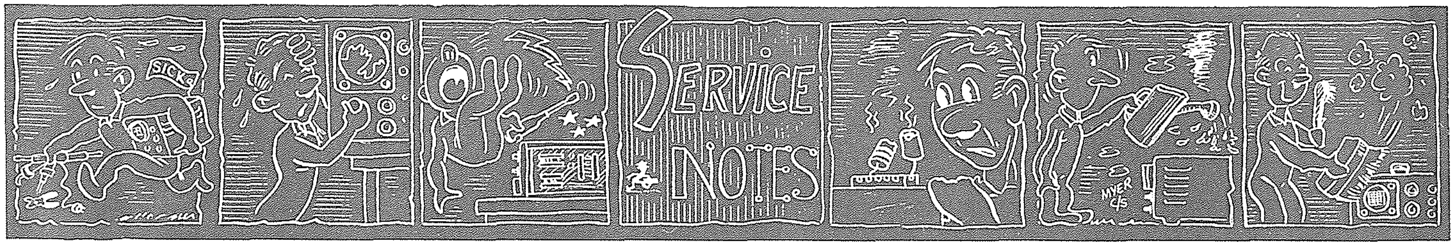


Fig. 9c. Right

Figure 9. The right and wrong way to connect a differential amplifier into a circuit. The ground shown in c is for safety purposes and not essential to the measurement.

Figure 9c shows that the correct way to connect the probes is to couple the shields together at the probe body (but not to instrument ground). This reduces interference by (1) reducing the impedance of the loop formed by the shield, and (2) equalizing the currents through the loop to allow the CMR of the amplifier to reject them. The chassis ground shown in Figure 9c is provided for safety between instruments; it is not essential to the measurement.

(Part 2, which concludes this article, will appear in the forthcoming October, 1965 issue of SERVICE SCOPE.)



TYPE 543B AND TYPE 545B OSCILLOSCOPES — IMPROVEMENT OF AUTOMATIC INTERNAL AND EXTERNAL TRIGGER

TRIGGER

	TRIGGER MODE	TRIGGER REQUIREMENTS
INTERNAL	AC	2-mm deflection from 150 cps to 10 Mc, increasing to 1 cm at 30 Mc. Will trigger below 150 cps with increased deflection.
	AC LF REJECT	2-mm deflection from 30 kc to 10 Mc, increasing to 1 cm to 30 Mc. Will trigger below 30 kc with increased deflection.
	DC	6-mm deflection to 10 Mc.
	AUTOMATIC	5-mm deflection at 150 cps. With increasing deflection, to 10 Mc. Will trigger to 50 cps with increased deflection.
EXTERNAL	AC	0.2 v from 150 cps to 10 Mc, increasing to 1 v at 30 Mc. Will trigger below 150 cps with increased signal.
	AC LF REJECT	0.2 v from 30 kc to 10 Mc, increasing to 1 v at 30 Mc. Will trigger below 30 kc with increased signal.
	DC	0.2 v to 10 Mc, increasing to 1 v at 30 Mc.
	AUTOMATIC	0.5 v at 150 cps. With increasing deflection, to 10 Mc. Will trigger to 50 cps with increased deflection.

Chart 1. Manual specifications of trigger requirements for Type 543B and Type 545B (Time Base A only) Oscilloscopes.

Some Type 543B and Type 545B Oscilloscopes, both conventional and RM models, offer a difficulty in meeting the 5 mm and 0.5 v Manual specifications, respectively on automatic internal and external trigger. (In the Type 545B Oscilloscope the difficulty is confined to the Time Base "A" trigger circuit). A nonsymmetrical trigger-output signal when the TRIGGER MODE control is in the AUTO position, will cause erratic auto triggering. Changing the resistor R38 from a value of 12 k to 18 k (1 w, 5%—Tektronix part number 303-0183-00) will improve the symmetry of the signal and allow stable triggering on the latest Manual specifications. See Chart 1.

After making the change, be sure to note the new value for R38 in the parts list and on the schematic in the Instruction Manual for the instrument.

This improvement is applicable to Type 545B Oscilloscopes, s/n 101 to 1235; Type RM545B Oscilloscopes, s/n 101 to 247; Type 543B Oscilloscopes, s/n 101 to 267; and Type RM543B Oscilloscopes, s/n 101 to 120.

TYPE G PLUG-IN UNIT — INTERMITTENT OSCILLATIONS IN TYPE 544, TYPE 546, AND TYPE 547 OSCILLOSCOPES

Some Type G Plug-In Units will, on occasion, exhibit intermittent oscillation when used in some Type 544, 546, and 547 Oscilloscopes.

A cure for this problem is the addition of two 0.01 μh ferrite cores (Tektronix part number 276-0528-00); one to the lead of L3977 (an 0.18 μh inductor) located between pin 1 of the Type G Unit's amphenol connector and ceramic strip #2, and the other to the lead of L4977 (an 0.18 μh inductor) located between pin 1 of the amphenol connector and ceramic strip #4. Install the ferrite cores on the leads that run between the ceramic strip and the inductors. Give the designation L3978 to the ferrite core added to the lead of L3977. Give the designation L4978 to the ferrite core added to the lead of L4977. Be sure to make the necessary corrections to the schematic and parts list in your Type G Unit's Instruction Manual.

TWO TYPE 3A1 PLUG-IN UNITS X-Y — POWER SUPPLY UNDERLOAD AT HIGH LINE

Type 3A1 Plug-In Units (s/n below 7930 only) will, under certain conditions shunt a little more current around the —100 v power-supply series regulator than the plug-in can actually use.

With two 3A1's installed, the —100 v in the Type 561, Type 561A or Type 564 Oscilloscopes (either conventional or rack mount versions) may fail to regulate when the power source (line voltage) exceeds 115 v. The Type 3A1/Type 3A1 is the only plug-in combination where the underload is significant.

Replacing the wire strap between pin 22 of the Type 3A1's amphenol connector and ground with a 1 k, 2 w, 10% resistor (Tektronix part number 306-0102-00) will reduce the power supply shunting to a level which will allow the use of Two Type 3A1's X-Y. Designate the new resistor R393 and make the necessary addition to the parts list and correct the schematic in your Type 3A1 Instruction Manual.

Generally speaking, two 3A1's is a rather unusual combination for dual-trace X-Y presentations. Type 3A1's have no facility for channel pairing,* phase characteristics do not match for the entire bandpass and the X-axis unit is limited to 8 cm scan (6 cm in units with serial number below 7930). However, in X-Y applications where these limitations are not serious, Type 3A1's below serial number 7930 will operate satisfactorily if modified as noted above. Type 3A1 Units with serial numbers 7930 and higher incorporate the modification.

*For single-trace X-Y presentations or for dual-trace X-Y presentations using a common signal applied to only one channel of one of the axis units, the lack of channel pairing does not present a problem.

INPUT TIME-CONSTANT STANDARDIZER — USE OF UHF-TO-BNC ADAPTERS NOT RECOMMENDED

Tektronix input Time-Constant Standardizers are available for standardizing the input time constant of plug-in having a nominal capacitance of 12 pf, 15 pf, 20 pf, 24 pf, and 47 pf. The individual standardizers for each time constant (except 15 pf X 1 meg) can be obtained with either

UHF or BNC connectors; the standardizer for 15 pf X 1 meg time constant is available with BNC connectors only.

The use of a UHF-to-BNC *adapter* with a Tektronix Time-Constant Standardizer equipped with UHF connectors will add one or two picofarads of capacitance to the plug-in input. This additional capacitance will have an effect on the accuracy of high frequency measurements. The higher the frequency of the applied signal the greater the effect of the additional capacitance.

Use a standardizer of the correct time constant equipped with connectors that match those of the plug-in whose input time constant you wish to standardize.

Listed below are the available Tektronix Time-Constant Standardizers:

	Tektronix Part #	
Input Cap.	UHF	BNC
12 pf X 1 meg	011-0051-00	011-0065-00
15 pf X 1 meg		011-0073-00
20 pf X 1 meg	011-0022-00	011-0066-00
24 pf X 1 meg	011-0029-00	011-0067-00
47 pf X 1 meg	011-0030-00	011-0068-00

TYPE 544, TYPE 546, TYPE 547 OSCILLOSCOPES — MODIFICATION FOR BETTER COMPATIBILITY WITH TYPE W HIGH-GAIN DIFFERENTIAL-COMPARATOR* AND TYPE Z DIFFERENTIAL COMPARATOR PLUG-IN UNITS

The Type W and Type Z Units are capable of more signal-output swing than other plug-in units used with these oscilloscopes.

Off screen signals saturate one or more of the two delay-line-driver transistors (Q1014 or Q1024). This raises the emitter voltage to an excessive level. When the signal waveform comes back on screen, a transient oscillation occurs in the lumped LC formed by L1018, C1035 and C1153. The oscillation-energy excursion diverts emitter current from the delay-line drivers and causes amplifier distortion as shown in Figure 1. The size of the aberration depends on the vertical position of the waveform.

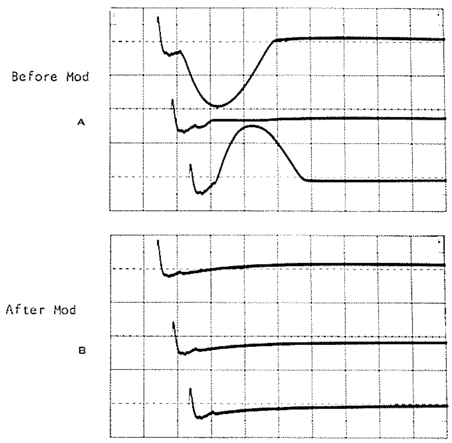


Figure 1. A—Waveform aberration before addition of R1020. B—After addition. Signal Source: 1 Volt Cal, Sweep Rate 1 μs/cm. Type W Unit Control Settings: V_c + 11, INPUT ATTEN 1, DISPLAY A-V_c, MILLIVOLTS/CM 5. (Triple exposure photos.)

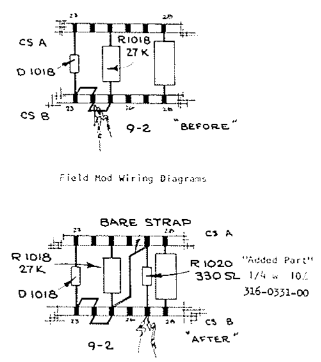


Figure 2. "Before" and "After" sketches showing how to install the 330 Ω resistor R1020.

A 330 Ω, ¼ w, 10% resistor (Tektronix part number 316-0331-00) connected effectively between the junction of the inductor, L1018, and the two capacitors, C1035 and C1153, will act as an oscillation damper and overcome this problem. The "Before" and "After" sketches in Figure 2 show how to install the 330 Ω resistor.

Designate this new resistor R1020 and make the necessary corrections to the parts list and on the schematic of your instrument's Instruction Manual.

This modification is applicable to the following instruments:

TYPE	SERIAL NUMBER
544	101-210
RM544	101-210
546	101-449
RM546	101-150
547	101-940
RM547	101-180

*In conjunction with this modification, Type W Units with serial numbers 101 through 169 will require the addition of an 0.1 μf discap (Tektronix part number 283-0057-00). Type W Units with serial numbers 170 and up have the additional capacitor installed at the factory.

The new capacitor is installed in parallel with R283, a 2-k, 5-w, wire-wound resistor.

To install the new capacitor, turn the Type W Unit upside down on the bench with the front panel facing you. R283 is located on the rear of the chassis to the left and just under the Amphenol connector. Solder one lead of the new 0.1 μf capacitor to the top lug of R283. Solder the other lead to the bottom lug of R283.

Designate the new capacitor C283 and add it to the parts list and schematic of the Type W Unit's Instruction Manual.

NEW FIELD MODIFICATION KITS

TYPE 310 OSCILLOSCOPES — SILICON RECTIFIERS

This modification replaces the selenium rectifiers SR601 or SR660 and SR630 with silicon rectifiers, offering more reliability and longer life.

The modification involves the removal of the old selenium rectifiers and the installation of a new silicon rectifier assembly. The new assembly includes three resistors (R601, R630, and R660), which compensates for a lower voltage drop across the twelve silicon diodes in the new assembly.

This modification is applicable to Type 310 Oscilloscopes, serial numbers 101-10000. Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0195-00.

TYPE 551 OSCILLOSCOPE—SILICON RECTIFIERS

This modification replaces the selenium rectifiers with silicon diodes which offer more reliability and longer life.

The modification involves the removal of selenium stacks SR690, SR660, SR640, SR700 and SR740 and the installation of a new silicon rectifier assembly. The new assembly includes resistors which compensate for a lower voltage drop across the 20 silicon diodes in the new assembly.

This modification is applicable to Type 551 Oscilloscopes, serial numbers 101-2357.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0206-00.

TYPE 551 OSCILLOSCOPES—MULTI-TRACE COMPATIBILITY

This modification assures compatibility between the Type 551 Oscilloscopes and Multi-Trace plug-ins (i.e., 53C, 53/54C, C, CA, M, 1A1, 1A2, etc).

The "Multi-Trace Units Sync Amplifier" V154 (a 6AU6 tube) is replaced with a 6DJ8 duo-triode which supplies Alternate Trace sync pulses to each plug-in.

The isolation of the two sync pulses prevents the differences in the plug-in Alternate-Trace switching circuitry and input impedances from locking up the switching circuitry in one or both of the plug-ins when they are in the Alternate Mode.

This modification is applicable to Type 551 Oscilloscopes, serial numbers 101-5953. A few instruments in the serial number range 5575-5950 were factory modified. Instruments within this range should be checked before the modification is ordered. If V154 is a 6DJ8, the instrument has been modified.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0398-00.

TYPE 524D TELEVISION OSCILLOSCOPES — HIGH-VOLTAGE POWER SUPPLY

This modification includes a new High-Voltage Power Supply which has been redesigned mechanically on a larger chassis.

With the new chassis, one can replace a defective part rather than replace the entire supply and the new layout provides greatly improved ventilation.

The modification is applicable to Type 524D instruments, serial numbers 101-1429.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0058-00.

TYPE 524AD OSCILLOSCOPES — PROBE POWER

This modification supplies the instructions and components for converting the Probe Power Supply in the Type 524AD from AC to DC filament voltage. The DC filament voltage reduces hum to a minimum when the instrument is used with a P500CF cathode-follower probe.

The modification is applicable to Type 524AD instruments, serial numbers 1843-6649.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0274-00.

TYPE 531 AND TYPE 535 OSCILLOSCOPES — B+ DELAY RELAY CONVERSION

This modification provides long-term reliability for K701, the B+ Delay Relay, by installing a more expensive relay designed around tighter specifications.

The modification is applicable to Type 531 Oscilloscopes, serial numbers 101-1280 and Type 535 Oscilloscopes, serial numbers 101-1703.

Order through your local Tektronix Field Office, Field Engineer, Field Representative or Distributor. Specify Tektronix part number 040-0085-00.

TYPE 540 SERIES AND TYPE 551 OSCILLOSCOPES — VERTICAL AMPLIFIER BIAS

This modification increases the bias on the 6DK6 tubes in the distributed amplifiers. This imparts a greater reliability to the tubes and a better stability to the Vertical Amplifier.

It is applicable to the following instruments:

Type	Serial Numbers
541	6475 - 7022
543	101 - 181
545	9292 - 11691
RM41	101 - 142
RM45	101 - 205
551*	101 - 291

*The Type 551 instrument has two identical main amplifiers. Order two modification kits for this instrument.

Order through your local Tektronix Field Office, Field Engineer, Representative, or Distributor. Specify Tektronix Part Number 040-0191-00.

TYPE RM567 OSCILLOSCOPES — IMPROVED FRAME PLATES

This modification supplies improved frame plates for the Type RM567 Oscilloscopes. The new left-hand frame plate contains a removable panel for ease of access to the Vertical plug-in unit during calibration. The new right-hand frame plate provides better access to the 6R1A Digital Unit's plug-in cards and their Bendix connectors.

Please note that, in order to accommodate the above improvements, the chassis tracks are relocated on both frame plates. The rack-mounted portion of the tracks must be relocated in the rack in order to maintain the same position of the instrument in the rack.

This modification is applicable to Type RM567 instruments with s/n's 101-2029.

Order through your local Tektronix Field Office, Field Engineer, Representative, or distributor. Specify Tektronix Part Number 040-0378-00.

TYPE 524D AND TYPE 524AD OSCILLOSCOPE — IRE RESPONSE NETWORK

In this modification a new IRE Response Network installed in the oscilloscope changes the roll-off characteristics to conform with the Revised Standard '58 IRE 23.1 as amended July 1, 1961.

This modification kit is applicable to Type 524D Oscilloscopes, s/n's 1400 - 1842 and Type 524AD Oscilloscopes, s/n's 1843 - 6835. It is also suitable for Type 524D's with s/n's below 1400 that have the four-position VERTICAL RESPONSE switch installed (Tektronix Field Mod Kit 040-057). It is *not* for use with instruments which have Tektronix Field Mod Kit 040-271 (Four - Position Vertical Selector Swtch) installed.

Order through your local Tektronix Field Office, Field Engineer, Representative, or Distributor. Specify Tektronix Part Number 040-0343-00.

Service Scope

USEFUL INFORMATION FOR

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