Tektronix®
COMMITTED TO EXCELLENCE

5A22N
DIFFERENTIAL AMPLIFIER

INSTRUCTION MANUAL

REPACKAGING FOR SHIPMENT

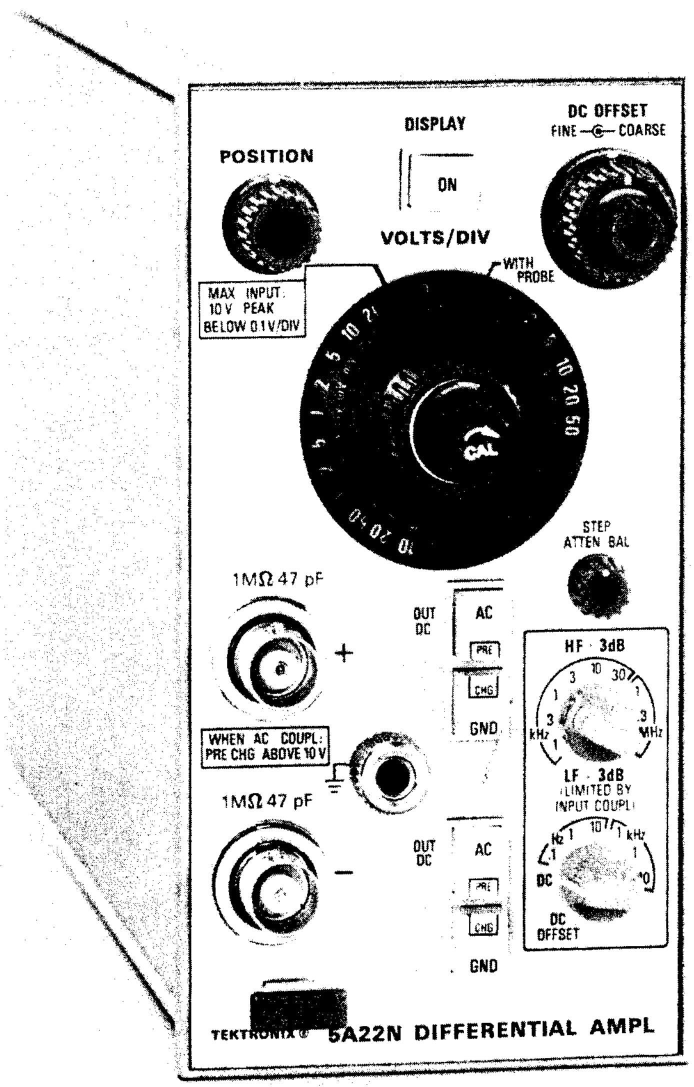
If the Tektronix instrument is to be shipped to a Tektronix Service Center for service or repair, attach a tag showing: owner (with address) and the name of an individual at your firm that can be contacted, complete instrument serial number and a description of the service required.

Save and re-use the package in which your instrument was shipped. If the original packaging is unfit for use or not available, repackage the instrument as follows:

1. Obtain a carton of corrugated cardboard having inside dimensions of no less than six inches more than the instrument dimensions; this will allow for cushioning. Refer to the following table for carton test strength requirements.
2. Surround the instrument with polyethylene sheeting to protect the finish of the instrument.
3. Cushion the instrument on all sides by tightly packing dunnage or urethane foam between carton and instrument, allowing three inches on all sides.
4. Seal carton with shipping tape or industrial stapler.

SHIPPING CARTON TEST STRENGTH

Gross Weight (lb)	Carton Test Strength (lb)
0-10	200
10-30	275
30-120	375
120-140	500
140-160	600



5A22N Differential Amplifier

d. The above procedure matches the probes for use at any sensitivity which employs the particular 5A22N input attenuator (1X or 100X) used in steps b and c. When it is necessary to use the other input attenuator, steps b and c should be repeated for that attenuator.

e. When examining a small differential signal in the presence of relatively large common-mode components, fine adjustment of probe CMRR may be made by temporarily connecting both probes to either of the two signal sources.

f. Movement of the probes should be kept to a minimum after the adjustment.

Coded Probes. The 5A22N is designed for compatibility with coded probes, such as the Tektronix P6060 or P6052 1X/10X Passive Probe. The + and − input connectors have an outer ring to which the coding ring on the probe connector makes contact. This type of probe allows the vertical deflection factor indicated by the readout to correspond with the actual voltage at the probe tip, eliminating the need to consider the attenuation factor when measuring the signal amplitude on the graticule scale.

Attenuation on the P6052 probe is selected by a sliding collar on the probe barrel. When the collar is pulled back (away from the probe tip), 1X attenuation is selected; when the collar is pushed forward (nearest the probe tip), 10X attenuation is selected. Input resistance for 1X attenuation is 1 megohm; for 10X, 10 megohms. Probe compensation is obtained in the usual manner (see probe manual for details).

ELECTRICAL CHARACTERISTICS

In this manual the word Volts/Div or division refers to major graticule division.

Performance Conditions

The following characteristics apply when the 5A22N is operating within the environment described in the 5100-Series Oscilloscope System manual. In addition, the 5A22N must have been calibrated at an ambient temperature between +20°C and +30°C.

Bandwidth (−3 dB)

DC (DIRECT) COUPLED: DC to at least 1 MHz independent of deflection factor. Selectable high- and low-frequency limits.

AC (CAPACITIVE) COUPLED: 2 Hz to at least 1 MHz.

High and Low −3 dB Frequencies

HF −3 dB: Selectable from 0.1 kHz to 1 MHz in a 7 step, 1-3-10 sequence.

LF −3 dB: Selectable from DC to 10 kHz in a 7 step, 1-10-100 sequence. Limited to 2 Hz when AC-coupled.

Deflection Factor

10 μV/div to 5 V/div within 2% in an 18 step, 1-2-5 sequence.

Uncalibrated, continuously variable between steps and to 12.5 V/div.

Common-Mode Rejection

DC (DIRECT) COUPLED: At least 100 dB, DC to 30 kHz at 10 μV/div to 0.1 mV/div with up to 20 V P-P sine wave, decreasing by 20 dB/decade or less on lower deflection factors up to 50 mV/div. At least 50 dB, 0.1 V/div to 5 V/div with up to 100 V P-P sine wave. At least 50 dB at any deflection factor with two P6060 probes.

AC (CAPACITIVE) COUPLED: At least 80 dB at 5 kHz and above, decreasing to 50 dB at 10 Hz.

DC Offset Range

At least + and −0.5 V from 10 μV/div to 50 mV/div. At least + and −50 V from 100 mV/div to 5 V/div.

Input RC

1 MΩ within 0.1% paralleled by ≈ 47 pF.

Overdrive Recovery

Unit recovers to within 0.5% of the quiescent level, in 5 μs after overdriving signal has been applied for 1 s.

Maximum Input Gate Current

100 pA (100 μV depending on external loading) at 25°C.

Maximum Safe Input Voltages

DC (DIRECT) COUPLED: 10 V (DC + peak AC) from 10 μV/div to 50,mV/div. 350 V (DC + peak AC) from 100 mV/div to 5 V/div.

AC (CAPACITIVE) COUPLED: 350 VDC + 10 V peak AC from 10 μV/div to 50 mV/div with coupling capacitor precharged. 350 V (DC + peak AC) from 100 mV/div to 5 V/div.

DC Stability

DRIFT WITH TEMP: 100 μV/°C.

Displayed Noise

20 μV or less measured tangentially at full bandwidth (DC to 1 MHz) with 25 Ω source resistance.

SECTION 1
OPERATING INSTRUCTIONS

Instrument Description

The 5A22N Differential Amplifier is a high-gain differential amplifier plug-in unit for use with Tektronix 5100-Series Oscilloscopes. The unit features high sensitivity with direct-coupled inputs, high common-mode rejection, and variable DC offset. An illuminated knob skirt provides deflection factor readout. The unit has a maximum bandwidth capability of DC to one megahertz with selectable high and low-frequency limits for increasing the signal-to-noise ratio at low frequencies.

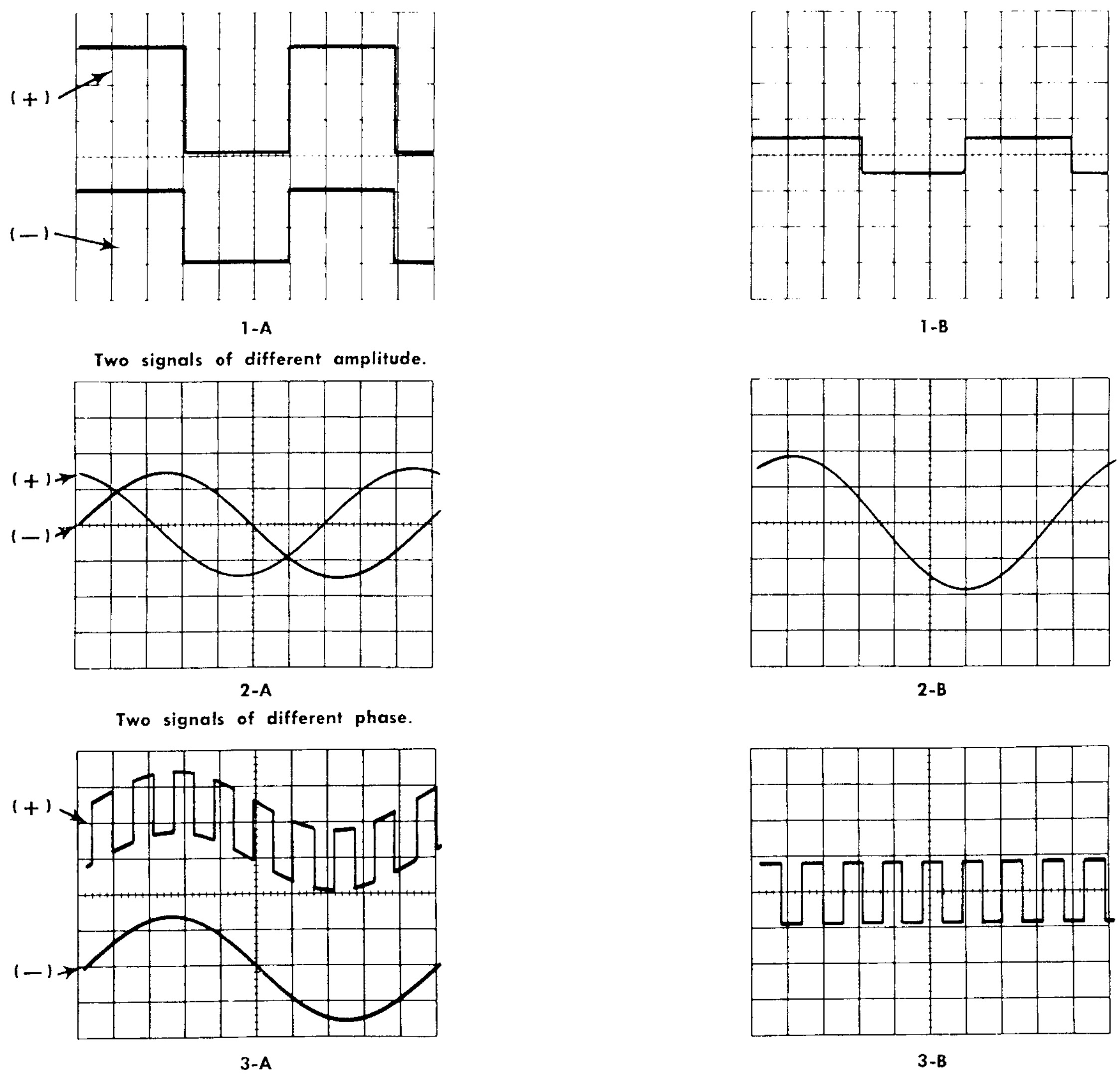
CONTROLS AND CONNECTORS

This is a brief description of the function or operation of the front-panel controls and connectors. More detailed information is given under General Information.

DISPLAY	Applies and removes logic levels to the oscilloscope system to enable or disable plug-in operation. Switch is functional only when plug-in is operated in one of the vertical plug-in compartments.
POSITION	Positions display.
HF −3 dB	Allows reduction of the upper bandwidth frequency limit to increase the signal-to-noise ratio for low-frequency applications.
LF −3 dB	Allows lower bandwidth frequency to be increased, thus reducing bandwidth and increasing the signal-to-noise ratio. Also, low-frequency drift can be reduced by restricting frequency response. When AC coupled, the lower bandwidth frequency is limited to 2 hertz by the coupling capacitor. This control also provides DC offset operation when in the DC OFFSET position.
VOLTS/DIV	Volts per major graticule division. Selects calibrated deflection factor in a 1-2-5 sequence, from 10 µV/Div to 5 V/Div in 18 steps. Knob skirt is illuminated to indicate deflection factor, and X10 scaling of readout is provided automatically when a 10X coded probe is used.
Variable (Volts/Div)	Provides uncalibrated, continuously variable deflection factor between calibrated steps; extends range to 12.5 V/Div.
DC OFFSET	COARSE and FINE controls provide on-screen display of small signal variations on relatively large DC levels. LF −3 dB switch must be in the DC OFFSET position.
STEP ATTEN DC BAL	Balances the input amplifier for minimum trace shift throughout the deflection factor gain-switching range.
Input Coupling Pushbutton	AC-DC: Button pushed in selects capacitive coupling of signal applied to associated input connector; button out selects direct coupling of input signal.
Input Coupling (cont) Pushbutton	GND: Disconnects the input signal and provides ground reference to the amplifier input stage.
	PRE CHG: Both AC-DC and GND buttons pushed in permits precharging of the coupling capacitor to the input signal DC level. Release GND button for measurement.

Double exposure photographs of the waveforms applied to the (+) and (—) input connectors.

Photographs of the resultant display.



A composite waveform of a desired signal (square wave) with an interfering line-frequency component is applied to the (+) input. The interfering signal (sine wave) is also applied to the (—) input connector.

NOTE: The waveform of the signals applied to the (—) input connectors will appear inverted when viewed alone.

Fig. 1-1. Three examples of differential applications.

Tektronix P6023 probes for differential measurement. (This probe type does not have the coding feature to be discussed later.)

a. Connect one probe for DC-coupled single-ended input. Obtain a triggered display of an appropriate square wave, such as that from a calibrator or square-wave generator. Adjust the probe DC Atten Calibration control for correct deflection sensitivity, then compensate the probe square-wave response using the AC Fine Comp adjust and the AC Coarse Comp adjust if necessary.

b. Connect a second probe for DC-coupled operation. Apply the square wave to both probes at 100 volts peak to peak. Free run the sweep and adjust the DC Atten Calibration of the second probe for maximum low frequency cancellation (minimum signal amplitude, or elimination of the two-trace appearance).

c. Adjust the AC Fine Comp and AC Coarse Comp, if necessary, of the second probe to minimize the amplitude of the differential pulses on the displayed trace.

+ and – Input Connectors — BNC connectors for application of external voltage signals. Connector labeled + indicates that a positive-going signal will cause upward deflection; connector labeled – indicates that a positive-going signal will cause downward deflection. Connectors include coded-probe input rings for activation of X10 readout.

BASIC OPERATION

Preparation

The 5A22N is calibrated and ready for use as it is received. It can be installed in any compartment of the 5100N-Series Power Supply/Amplifier module, but it is intended for primary use in vertical compartments (the center and left compartments). For X-Y operation, the 5A22N may also be installed in the horizontal (right) compartment (refer to the Oscilloscope System instruction manual for information on X-Y operation).

NOTE

The Power Supply/Amplifier module is designed so that in the absence of DISPLAY logic levels from the vertical plug-ins, it will display the output of the unit in the left compartment.

To install, align the upper and lower rails of the 5A22N with the plug-in compartment tracks and fully insert it (the plug-in panel must be flush with the oscilloscope panel). To remove, pull the release latch to disengage the 5A22N from the oscilloscope.

The first few steps of the following procedure are intended to help place the trace on the screen quickly and prepare the instrument for immediate use. The remainder of the steps demonstrate some of the basic functions of the 5A22N. Operation of other instruments in the system is described in the instruction manuals for those units.

1. Insert the unit all the way into the oscilloscope system plug-in compartment.

2. Turn the oscilloscope Intensity control fully counterclockwise and turn the oscilloscope system Power On. Preset the time-base and triggering controls for a 2-millisecond/division sweep rate and automatic triggering.

3. Set the 5A22N front-panel controls as follows:

DISPLAY

DISPLAY	ON (readout illuminates)
POSITION	Midrange
LF and HF –3 dB	Full bandwidth
VOLTS/DIV	.1 V
STEP ATTEN BAL	Midrange
+ Input Coupling	DC, GND
– Input Coupling	DC, GND

NOTE

About five minutes is sufficient time for warmup when using the 5A22N for short-term DC measurements. For long-term DC measurements using the lower deflection factors, allow at least 15 minutes.

4. Adjust the Intensity control for normal viewing of the trace. The trace should appear near the graticule center.

5. Move the trace two divisions below the graticule centerline with the POSITION control.

CAUTION

If the maximum input voltage rating at the gates of the input FET's is exceeded, the gates are diode-clamped at about + or – 12.0 volts. If the signal source can supply more than 1/16 A, the input protective fuse(s) will open.

6. Apply a 400-millivolt peak-to-peak signal (available at the oscilloscope Calibrator loop) through a test lead or 1X probe to the + input connector.

7. For DC-coupled, single-ended operation, release the + input GND button. The display should be a four division square wave with the bottom of the display at the reference established in step 5. Rotate the Variable Volts/Div control counterclockwise out of its detent position, observing reduction of the display. Return the Variable control to the detent (CAL) position.

8. For AC-coupled, single-ended operation, re-position the display with the POSITION control to place the bottom of the display at the graticule centerline.

9. Push in the AC button and note that the display shifts downward about two divisions to its average level.

The range of the Variable control is at least 2.5:1. It provides uncalibrated deflection factors covering the full range between the fixed settings of the VOLTS/DIV switch. The control can be set to extend the deflection factor to at least 12.5 volts/division.

To reduce noise at higher frequencies and drift at lower frequencies and obtain a more usable display when the VOLTS/DIV switch is set to the more sensitive positions, reduce bandwidth with LF and HF −3 dB switches.

Voltage Comparison Measurements

Some applications require deflection factors other than the fixed values provided by the VOLTS/DIV switch. One such application is comparison of signal amplitudes by ratio rather than by absolute voltage. To accomplish this, apply a reference signal to either input of the 5A22N, and set the VOLTS/DIV switch and Variable control so that the reference display covers the desired number of graticule divisions. Do not change this setting of the Variable control throughout the subsequent comparisons. The settings of the VOLTS/DIV switch can be changed, however, to accomodate large ratios. In doing so, regard the numbers which designate the switch positions as ratio factors rather than voltages.

Differential Operation

Single-ended measurements often yield unsatisfactory results because of interference resulting from ground-loop currents between the 5A22N and the device under test. In other cases, it may be desirable to eliminate a DC voltage by means other than the use of a DC-blocking capacitor, which could limit the low-frequency response.

These limitations of single-ended measurements are effectively eliminated using differential measurements. Differential measurements are made by connecting each input (+ input and − input) to selected points in the test circuit. Since the chassis of the 5A22N need not be connected in any way to the test circuit, there are few limitations to the selection of these test points. In any case, do not exceed the maximum safe input voltages listed in Electrical Characteristics.

Both Input Coupling switches should be set to the same position, AC or DC, depending on the method of signal coupling required.

Only the voltage difference between two signals is amplified and displayed in differential measurements, while the common-mode signals (common in amplitude, frequency, and phase) are rejected. See Fig. 1-1.

The ability of the 5A22N to reject common-mode signals is indicated by the common-mode rejection ratio (CMRR). CMRR is at least 100,000:1 at the input connectors for the lower deflection factors (10 μV/DIV and 20 μV/DIV) when signals between DC and 30 kHz are DC coupled to the inputs. To illustrate this characteristic, assume that a single-ended input signal consists of an unwanted 60 Hz signal at 1 volt peak to peak, plus a desired signal at 1 mV peak to peak. If an attempt is made to display the described signal (single-ended measurements) at .2 mV/DIV, the 60 Hz signal will produce a deflection equivalent to 5000 divisions and the 1 mV signal will be lost.

If the same 1 mV signal is measured differentially with the 60 Hz signal common to both inputs, no more than one part in 100,000 of the common-mode signal will appear in the display. The desired signal will produce a display of 5 divisions, with not more than 0.1 division of display produced by the common-mode signal (CMRR not specified when residual display is 0.1 division or less).

There are a number of factors which can degrade common-mode rejection. The principal requirement for maximum rejection is for the common-mode signal to arrive at the input FET gates in precisely the same form. A difference of only 0.01% in the attenuation factors of the input attenuators may reduce the rejection ratio to 10,000:1. Likewise, any difference in source impedance at the two points in the source under test will degrade the rejection ratio. Attenuator probes which do not have adjustable R and C may reduce the rejection ratio to 100:1 or less (swapping probes may improve the rejection ratio).

Outside influences such as magnetic fields can also degrade the performance, particularly when low level signals are involved. Magnetic interference may be minimized by using identical signal-transporting leads to the two inputs and twisting the two leads together over as much of their length as possible.

Voltage Probes

In general, probes offer the most convenient means of connecting a signal to the input of the 5A22N. Tektronix probes are shielded to prevent pickup of electrostatic interference. A 10X attenuator probe offers a high input impedance and allows the circuit under test to perform very close to normal operating conditions. See your Tektronix, Inc., catalog for characteristics and compatibility of probes for use with this system.

Differential Measurement. The following adjustment procedure is recommended when preparing to use two

10. Disconnect the coaxial cable from the + input connector. Connect a dual input cable to the + and − input connectors, then connect the coaxial cable from the Calibrator to the dual input cable.

11. For AC-coupled differential operation, set the − input to AC (AC button in, GND button out). The calibrator signal is now coupled to both inputs as a common-mode signal. A straight line display should be observed, since the common-mode signal is being rejected.

Step Attenuator Balance Adjustment

If this control is not properly adjusted, the CRT zero reference point (trace or spot) will shift vertically due to differential DC imbalance in the amplifier as the VOLTS/DIV switch is rotated throughout its range. The shift is more noticeable on the most sensitive positions.

a. With the instrument operating, ground both the + and − inputs (GND buttons pushed in), set the VOLTS/DIV switch to 5 V, and move the trace to graticule center with the POSITION control.

b. Adjust the STEP ATTEN BAL control for minimum trace shift as the VOLTS/DIV switch is rotated throughout its range.

Gain Check

Whenever the 5A22N is inserted into a plug-in compartment other than the one in which it was calibrated, the amplifier gain may be checked and, if necessary, adjusted. See the Calibration Procedure in this manual for complete instructions.

GENERAL INFORMATION

Applying Signals

CAUTION

If the 5A22N input is connected to a large DC voltage source without using the pre-charge provision, the peak charging current (into a 0.1 µF capacitor) will be limited only by the internal resistance of the signal source, and this source may be damaged.

When measuring DC voltages, use the largest deflection factor (5 V/Div) when first connecting the 5A22N to an unknown voltage source. If the deflection is too small to make the measurement, switch to a lower deflection factor. If the input stage is overdriven, a large amount of current might flow into the input and open the protective fuse. See CAUTION after item 5 of the Basic Operation.

Pre-charging. When only the AC component of a signal having both AC and DC components is to be measured, use the Input Coupling switches (AC and GND pushbuttons) to take advantage of the pre-charging circuit incorporated in the unit. The pre-charging circuit permits charging the coupling capacitor to the DC source voltage when the AC and GND buttons are pressed in. The procedure for using this circuit is as follows:

a. Before connecting the 5A22N to a signal containing a DC component, push in the AC and GND buttons. Then connect the input to the circuit under test.

b. Wait about one second for the coupling capacitor to charge.

c. Remove the ground from the coupling capacitor (GND button out). The display will remain on-screen, and the AC component can be measured in the usual manner.

The above procedure should be followed whenever a signal having a different DC level is connected.

Signal Input Connectors

When connecting signals to the + and − input connectors on the 5A22N, consider the method of coupling that will be used. Sometimes unshielded test leads can be used to connect the 5A22N to a signal source, particularly when a high level, low-frequency signal is monitored at a low impedance point. However, when any of these factors is missing, it becomes increasingly important to use shielded signal cables. In all cases, the signal-transporting leads should be kept as short as practical.

When making single-ended input measurements (conventional amplifier operation), be sure to establish a common ground connection between the device under test and the 5A22N. The shield of a coaxial cable is normally used for this purpose.

In some cases, differential measurements require no common ground connection,[1] and therefore are less susceptible to interference by ground-loop currents. Some problems with stray magnetic coupling into the signal-transporting leads can also be minimized by using a differential rather than a single-ended measurement. These considerations are discussed later in this section under Differential Operation.

It is always important to consider the signal source loading (and resulting change in the source operating characteristics) due to the signal-transporting leads and the input circuit of the 5A22N. The circuit at the input connectors can normally be represented by a 1 megohm resistance to ground paralleled by the 47 pF. A few feet of shielded cable (20 to 40 pF per foot) may increase the parallel capacitance to 100 pF or more. In many cases, the effects of these resistive and capacitive loads may be too great and it may be desirable to minimize them through the use of an attenuator probe.

Attenuator probes not only decrease the resistive capacitive loading of a signal source, but also extend the measurement range of the 5A22N to include substantially higher voltages. Passive attenuator probes having attenuation factors of 10X, 100X, and 1000X, as well as other special-purpose types, are available through your Tektronix Field Engineer or Field Office.

Some measurement situations require a high resistance input to the 5A22N with very little source loading or signal attenuation. In such situations, a passive attenuator probe cannot be used. However, this problem may be solved by using an FET Probe or the high impedance input provision of the 5A22N.

High Impedance Input

In the 50 mV through 10 μV positions of the VOLTS/DIV switch, where the input attenuator is not used, the internal gate return resistors alone establish the 1 megohm input resistance. The removal of the strap from the circuit board disconnects these resistors from ground and permits the input FET gates to float, providing a very high input impedance. The signal source must then provide a DC path for the FET gate current.

The input signal must be kept to relatively low amplitudes, since the deflection factor is restricted to 50 mV/Div through 10 μV/div, and DC coupling must be used.

[1] **The DC plus AC voltages on the test points (with respect to the chassis potential of the 5A22N) should be limited to the levels listed in Electrical Characteristics under Common-Mode Rejection. Higher levels will degrade the common-mode rejection ratio and exceed the input voltage rating of the unit.**

NOTE

In the 0.1 V to 5 V range of the VOLTS/DIV switch, the input impedance is paralleled by the resistors in the attenuator. When the link is removed, the attenuation ratio is affected, causing the deflection factors in this range to be incorrect. To determine the deflection factor, check the deflection with an input signal of known amplitude.

The signal source impedance is an important factor, since gate current will produce a DC offset. For example, a 100 picoampere gate current through 10 megohms produces a one-millivolt offset, which may result in significant error where small voltages are of concern.

The high frequency response will also depend upon the signal source impedance, since various shunt capacitances between the source and the input gate must charge and discharge through that impedance.

Gate Current Compensation

The leakage current associated with the gates of the input FETs may be as high as 100 picoamperes. This leakage current will produce an offset voltage which, at the higher input sensitivities, is not acceptable. For example, 100 picoamperes through a one-megohm input resistance to ground produces an offset voltage of 100 microvolts which could drive a display off-screen at 10 microvolts per division. To compensate this effect, the gates of the input FETs may be adjusted to zero volts by returning R120 and R126 through potentiometers R121 and R127 to a slightly negative supply voltage.

Display Polarity

Single-ended signals applied to the + input connector produce a display in phase with the input signal. Signals applied to the − input connector will be inverted.

A similar polarity relationship exists for differentially applied signals, but it pertains to the direction of voltage change at one input with respect to the other, rather than with respect to chassis potential.

Deflection Factor

The amount of trace deflection produced by a signal is determined by the signal amplitude, the attenuation factor (if any) of the probe, the setting of the VOLTS/DIV switch, and the setting of the Variable control. The calibrated deflection factors are indicated by the VOLTS/DIV switch only when the Variable control is rotated fully clockwise into the detent position.