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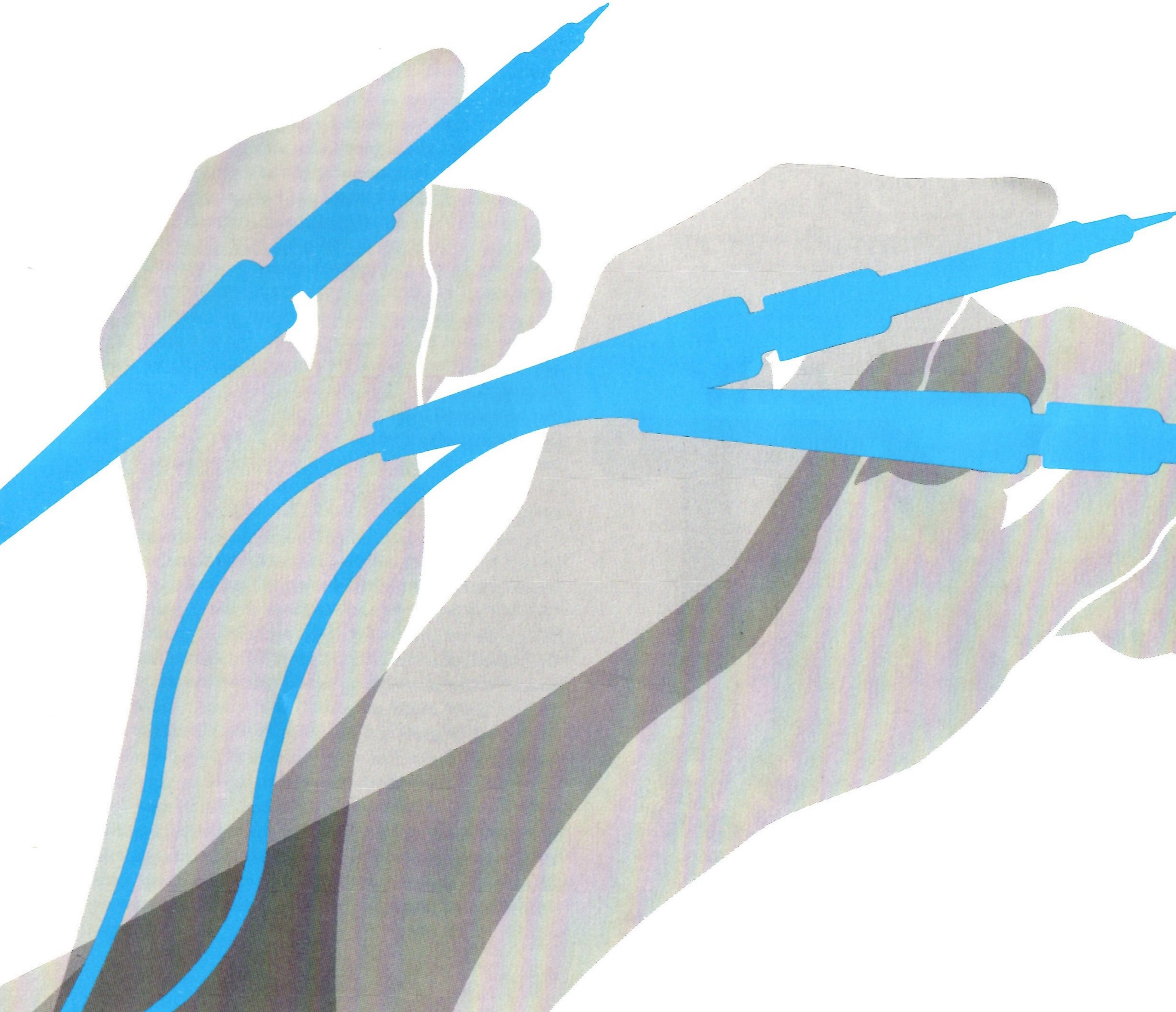
Using your oscilloscope probe

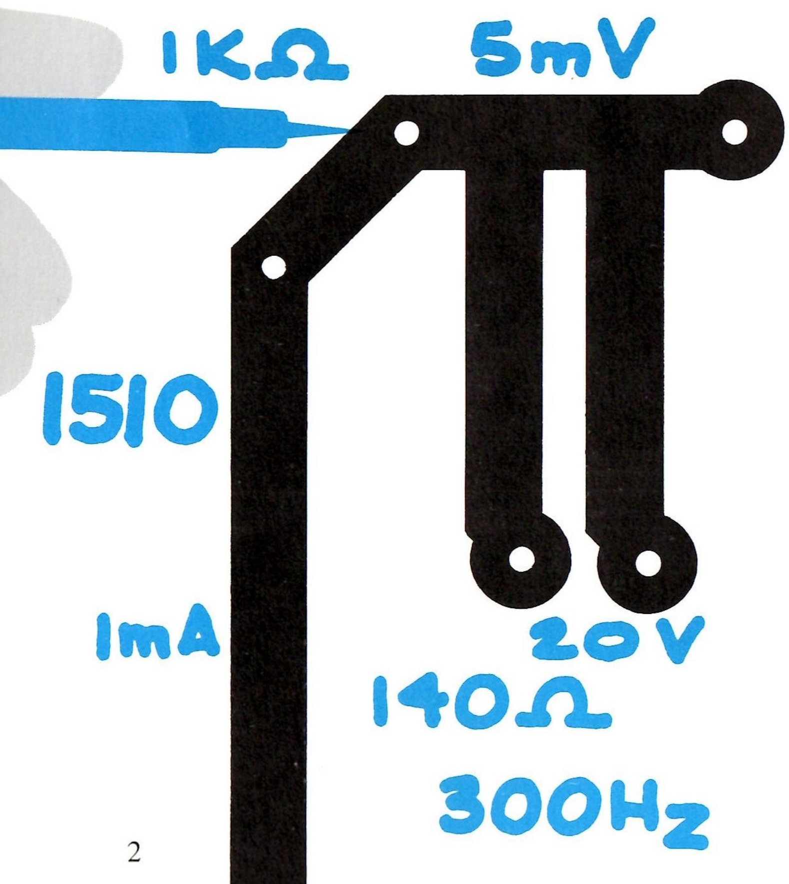


PART I The passive voltage probe

Seeing is believing. Or is it? No doubt there have been times when the signal you viewed on your oscilloscope didn't measure up to what you expected. After thoroughly checking out your circuitry you turned a suspicious eye on the scope—but did you stop to consider the probe?

The function of the ideal probe is to couple the signal of interest to the oscilloscope without affecting the signal source or the signal waveshape. As is often the case, the ideal probe for every measurement doesn't exist. However, a knowledge of probe characteristics and how they affect the circuit under test will help you approach the ideal for your particular application.

The passive probe is, by far, the most common type in use today and provides the greatest convenience for general purpose work. It is also the least expensive. The term "passive" is used to distinguish this type of probe from one that uses active devices, such as FETs, to achieve high input impedance and low input capacitance, even in a 1X mode.



Passive probes come in a variety of sizes and shapes, with differing characteristics. The typical probe consists of a probe assembly, a ground lead and a shielded cable equipped with a suitable connector for the oscilloscope input. Most probes feature interchangeable tips and ground leads for easy connection to various test points. A unique feature of most Tektronix probes is the Tektronix-patented coaxial cable with a resistance-wire center conductor. This distributed resistance suppresses ringing due to the mismatch between the cable and its terminations, when viewing fast pulses on wideband oscilloscopes.

Probes load the circuit

Low and medium frequency oscilloscope inputs are usually one megohm shunted by 8 to 50 pF of capacitance. Many instruments with bandpass above 200 MHz have a 50-ohm input impedance and some have both a 50-ohm and one-megohm input.

When the scope is applied to the circuit under test, the input capacitance and resistance loads the circuit and may alter the signal to be viewed. Sometimes, the loading alters the operation of the circuit itself. These loading effects can be minimized by using an appropriate probe. If the signal amplitude permits, an attenuator probe can be used, reducing both dc loading and capacitive loading. Figure 1 shows a schematic representation of an attenuator probe and oscilloscope input. The probe and scope input essentially form an RC divider. Since R_1 C_1 must equal R_2 C_2 for equal attenuation at all frequencies, we can see that as R_1 increases, C_1 must decrease. Thus, the capacitance at the probe tip can be reduced by going to higher values of attenuation. Common probe attenuations are X10 and X100, with some probes having provision to switch between X1 and X10. Others have plug-on attenuators covering a wide range of attenuation from X1 to X100.

Now, just what changes occur when we attach a probe, how will these changes affect the signal, and can we determine the desired information from the display? One of the primary considerations in determining what the probe will do to the signal and circuit under test, is the impedance of the signal source. In modern circuitry source resistance varies from a fraction of an ohm to greater than hundreds of kΩ and source capacitance from 1 pF to greater than 100 pF. To minimize probe loading effects, a low impedance test point should be selected for viewing when possible.

Two types of signals should be considered when dealing with probe loading effects: (1) pulse or step-function sources dealing with amplitude, risetime (t_r) and transient response; and (2) sine wave sources concerned with amplitude and phase relationship distortion.

Measuring pulse signals

Let's consider what happens to a typical pulse signal source (Figure 2 (a) when we apply a probe. If the generator had a t_r of 0, the output t_{r1} would be limited by the integration network of R_s and C_s and would be equal to 2.2 R_sC_s, or 8.8 ns. If a typical passive probe, such as the P6053B (10X, 9.5 pF, 10 MΩ) is used to measure this signal, the probes' input capacitance and resistance are added to the circuit (Figure 2 (b)). Since R_p is $>>R_s$, R_p may be disregarded. Using the risetime formula, 2.2 R_s (C_s+C_p), the circuit risetime, t_{r2} becomes 13 ns. The loading effect of the P6053B to this signal source is the percentage change in risetime:

$$\frac{t_{r2}-t_{r1}}{t_{r1}}\times 100=\frac{13\text{ ns}-8.8\text{ ns}}{8.8\text{ ns}}=48\%$$

The percentage change that results from adding a passive probe to this pulse source is directly related to the capacitance added. The calculation to determine the amount of change in risetime would be:

$$\frac{C_p}{C_s}\times 100=\frac{9.5\text{ pF}}{20\text{ pF}}=48\%$$

This is a valid approach if the probe resistance, R_p, is large when compared to the source resistance.

Now let's see what happens if we use a probe such as the P6048 (10X, 1 pF, 1 kΩ) to measure this same signal source. In this instance R_p is not ten times greater than R_s and must be considered. R_p and R_s form a dc divider, reducing the amplitude and modifying the source impedance. Using Thevenin's theorem a new generator source voltage and a new source resistance (Figure 2(c)) is calculated resulting in: $t_{r3}=2.2\ R_2\ (C_s+C_p)\ =7.7$ ns. Note that in relating this risetime to the risetime of Figure 2 (a), our original circuit, the P6048 caused a change from 8.8 ns to 7.7 ns. The percentage of change is less than that caused by the P6053B.

$$\text{Percent change}=\frac{7.7\text{ ns}-8.8\text{ ns}}{8.8\text{ ns}}\times 100=-12\%$$

It is interesting to note that rather than degrading the signal by slowing the risetime, the probe modified the source resistance and decreased the risetime making it faster than it should be. But take a look at the output amplitude; it has been decreased to 83.3% of the value without the probe, due to the voltage divider formed by R_p and R_s. In the first example, there was no change in the signal source amplitude when the probe was applied.

And so we see that the choice of probe depends to a large extent on which signal parameter we desire to measure. Low capacitance is desirable when measuring risetime, but high resistance is more important when measuring amplitude. Choosing a low impedance test point is desirable for both risetime and amplitude measurements.

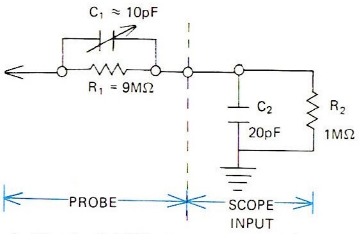


Fig. 1. Typical 10X attenuator and scope input.

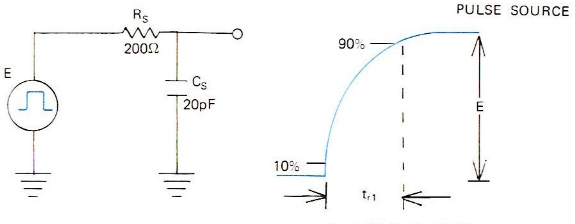


Fig. 2 (a). Typical pulse signal source.

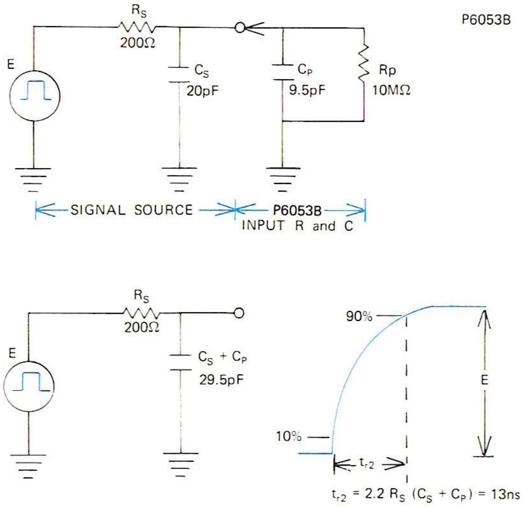


Fig. 2 (b). P6053B probe added to typical pulse source.

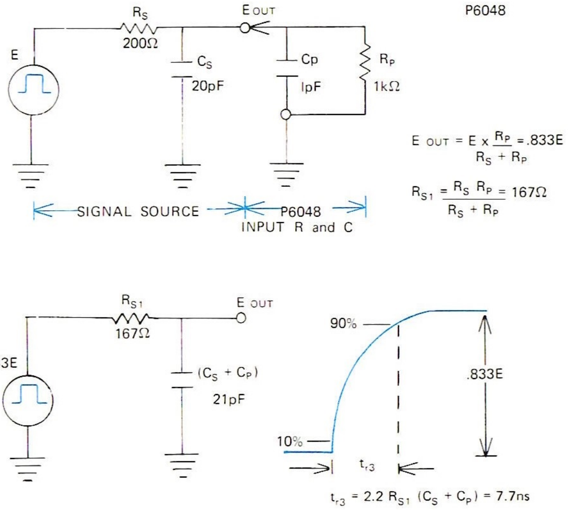


Fig. 2 (c). P6048 probe added to typical pulse source.

Measuring sine wave signals

Now let's consider the effects of using the same probes and the same source resistance and capacitance, with the generator supplying sine waves rather than pulses. Here we will be concerned with amplitude changes and phase relationships.

We should keep in mind that the specified probe input capacitance and resistance, e.g., 10 MΩ and 10 pF, were measured at dc or low frequency (<1 MHz). However, as signal frequency increases, the equivalent probe input impedance changes. Figure 4 shows how the input X_p and R_p of the P6053B probe change with frequency.

Let's assume a source frequency of 10 MHz and a generator voltage of one volt, and see what the source output voltage will be before any probe is applied (Figure 3 (a)). We see that E_{out} of the source only, is 97% of the generator voltage. Now let's apply the P6053B (10X, 9.5 pF, 10 MΩ) probe and see the effect on the source voltage. (See Figure 3 (b)). From the graph in Figure 4 we find that R_p is 40 kΩ and X_p is 1.7 kΩ. Since R_p is $>>R_s$, it can be disregarded in the calculations. X_p is in parallel with X_s giving us a total reactance, X_{ct}, of 545 Ω. From Figure 3 (b) we see that with the P6053B applied, the source output voltage has decreased to 94% of the generator voltage. This represents a 3% change from the unloaded source output voltage.

Now let's see what happens to the source voltage when we apply the P6048 (10X, 1 pF, 1 kΩ) probe. (See Figure 3 (c)). Since R_p is 1 kΩ and $<10R_s$, we must consider it in our calculations as in the case of the pulse signal source. X_p is 16 kΩ and in parallel with X_s resulting in X_{ct} of 760 Ω. We find that with the P6048 applied, the source output voltage is 81% of the generator voltage, for a change of 16% from the unloaded source voltage.

Comparing Figures 2 (b) and (c) with Figures 3 (b) and (c), we can see that for risetime measurements, the low-capacitance P6048 yields better accuracy than the P6053B, while for sine wave amplitude measurements the dc loading of the P6048 causes a larger error than the capacitive loading of the P6053B. Note from Figure 2 (c) that the P6048 also causes a substantial amplitude error.

Phase relationships

Since most attenuator probes have a capacitive element it is evident that the probe will introduce phase shift in the signal being viewed. Source impedance is an important factor in determining the amount of phase shift that occurs. For example, consider an amplifier driven from a 10 MHz, 50 Ω source and having an output impedance of 2 kΩ. (See Figure 5 (a)). Let's look at the input and output using two 10 MΩ, 10 pF probes. Referring to Figures 5 (b) and (c) we see there is a difference in phase of about 49° due to the impedance difference in the points being measured.

Now let's look at the same two points using two 1 kΩ, 1 pF probes. (See Figures 5 (d) and (e)). The phase difference has been reduced to about 2°. However, the 1 kΩ probe causes a 67% signal loss due to resistive loading. Depending on the application, it may be desirable to select a probe which offers a better compromise between phase shift and signal loss, or we may use a different probe for the respective measurements.

Summing it up

From this brief discussion we can see that what seemed a relatively unimportant part of our measurement system, actually determines to a large extent what we see displayed on our oscilloscope screen. All probes do not have the same effect on the signal. And one probe is not the ideal for all measurements.

Here are some general rules we can follow to make better measurements when using a probe:

1. Always check the probe compensation on the oscilloscope being used to make the measurement.
2. Choose the lowest impedance test point possible to view the signal.
3. When making risetime measurements:
   a. Choose a probe with R and C as low as possible.
   b. Scope and probe risetime should be short relative to the signal risetime.
   c. Observed risetime is approximately equal to the square root of the sum of the squares of all the risetimes in the system. These risetimes include the risetime of the signal source, the specified probe risetime, the specified scope risetime, and the calculated risetime of the scope/probe input system, including the effect of the source impedance.
4. When making amplitude measurements:
   a. For sine wave measurements, choose a probe which has the highest input impedance at the frequency of interest. Remember, loading error changes with frequency.
   b. For pulse measurements, choose a probe which has a large input resistance relative to the source impedance. Input C is of no concern if pulse duration is about five times longer than the input RC.

In the second part of this series we will discuss active probes and current-measuring probes. While not as widely used as the passive voltage probe, they provide a valuable extension to the signal measuring capabilities of your oscilloscope.

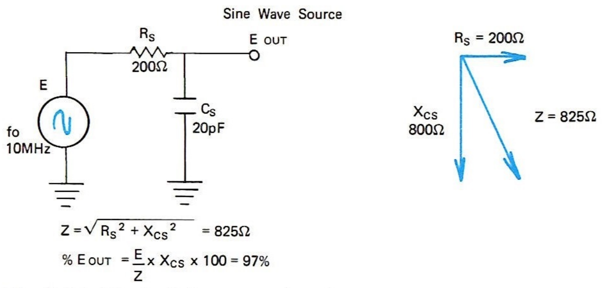


Fig. 3 (a). Typical sine wave signal source.

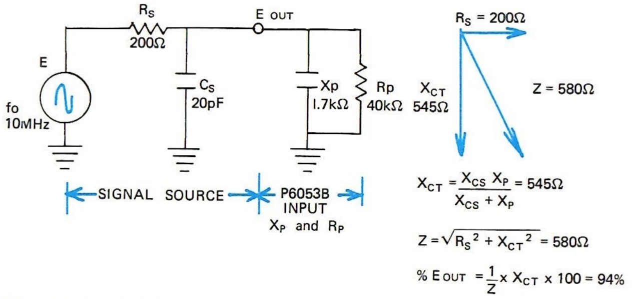


Fig. 3 (b). P6053B probe applied to typical sine wave source.

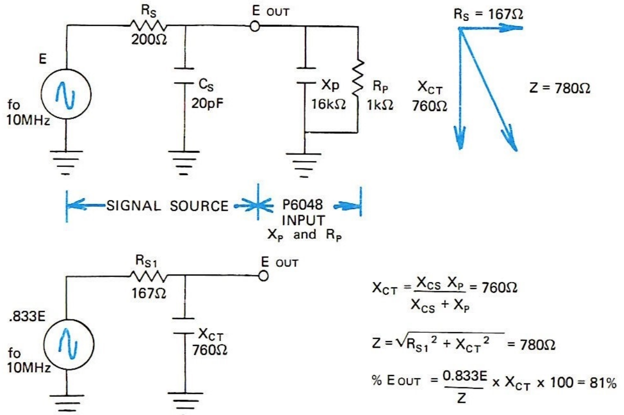


Fig. 3(c). P6048 probe applied to typical sine wave source.

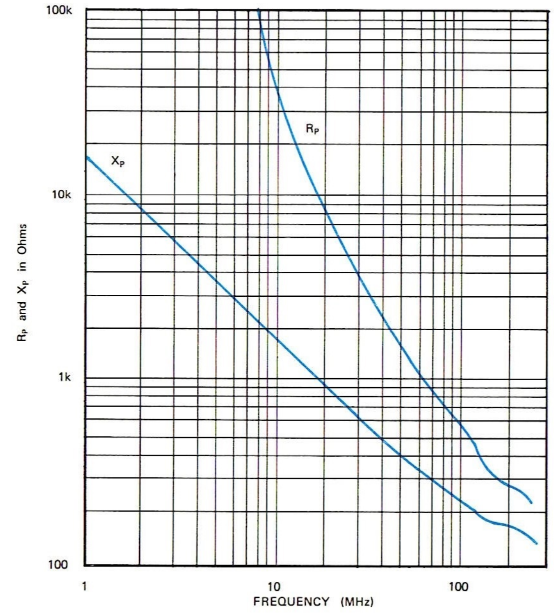


Fig. 4. P6053B probe (3.5 foot cable), typical X_p, R_p versus frequency curves.

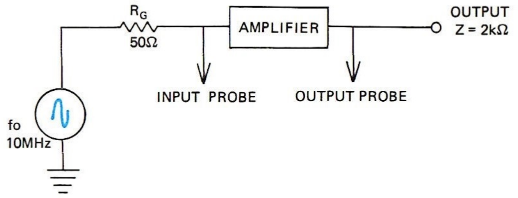


Fig. 5 (a). Typical amplifier circuit with differing input and output impedances.

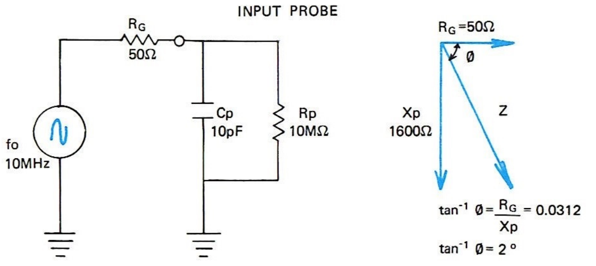


Fig. 5 (b). Phase shift caused by applying P6053B probe to the amplifier input.

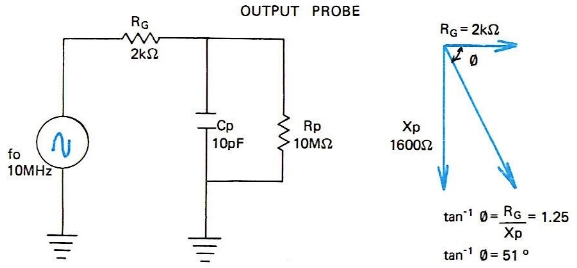


Fig. 5 (c). Phase shift caused by applying P6053B probe to the amplifier output.

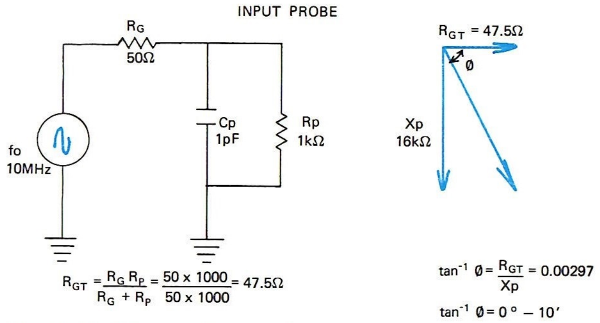


Fig. 5 (d). Phase shift caused by applying P6048 probe to the amplifier input.

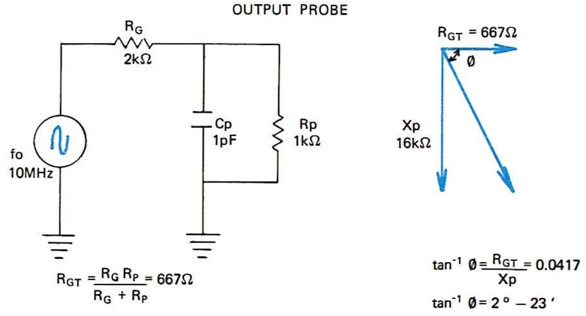


Fig. 5 (e). Phase shift caused by applying P6048 probe to the amplifier output.

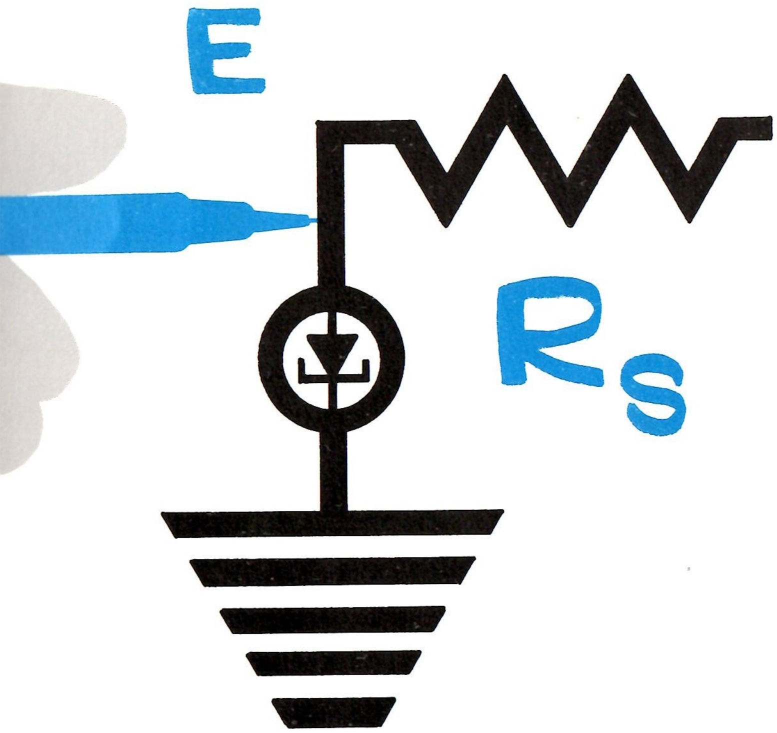
PART II Active and Current Probes

Active probes

Two prime advantages of active probes are: the isolation provided between the measurement point and the probe cable and scope, allowing high input resistance and low capacitance to be achieved; and full bandwidth without input signal attenuation.

Most active probes are compatible with either 1MΩ or 50Ω scope inputs without using external adapters. When working in the 50Ω mode, a 50Ω cable can be used to extend the probe length without increasing capacitive loading. However, longer cables will slow the risetime.

The typical active probe uses a FET input and contains both ac coupling capability and voltage offset for observing signals riding on top of a dc level. The active probe used in this discussion is the TEKTRONIX P6201 probe. It uses a FET input and has a probe only bandwidth of dc to 900 MHz with a risetime of 0.4 ns or less. Other active probes will provide similar advantages within their frequency capability. For example, the P6045 will handle signals up to 230 MHz.



Measuring pulse signals

To provide for a common basis of comparison with the passive probe, the same signal source used in Part I is used for this discussion of active probe performance. The source consists of an ideal step-function generator providing a voltage step of infinitely fast risetime. The source impedance is 200Ω shunted by 20 pF, resulting in a source risetime of 8.8ns (Figure 1(a)).

As we noted in Part I, the capacitive loading caused by applying a probe to the circuit under test can significantly alter the risetime of the signal we desire to measure. If the probe resistance approaches that of the signal source (within two orders of magnitude) risetime can also be affected.

In Figure 1(b) we see the effect of applying the P6201, with 10X attenuator head (1.5pF, 1MΩ), to our signal source. The capacitive loading of the P6201 has increased the pulse risetime from 8.8 ns to 9.5 ns. In Part I of this article we noted that the loading effect of the probe on the signal source could be stated as the percentage change in risetime. In this instance the loading effect is:

$$\frac{t_{r3} - t_{r1}}{t_{r1}} \times 100 = \frac{9.5 - 8.8}{8.8} = 8\%$$

This is a considerable improvement over the 48% increase in risetime caused by the typical high impedance 10X passive probe, and somewhat better than the 12% decrease in risetime caused by the low-resistance, low-capacitance P6048 passive probe.

We also noted that loading is directly related to probe capacitance, assuming the probe resistance (R_p) to be much larger than the source resistance (R_s). When the probe resistance approaches that of the source, the source impedance is effectively reduced, causing a decrease in the risetime and a considerable reduction in signal amplitude.

Measuring low-level signals

One of the prime advantages of an active probe is full bandwidth at 1X attenuation with minimum circuit loading. This is essential when viewing fast signals in the millivolt region. The P6201 (X1) probe has an input resistance of 100KΩ and a capacitance of 3pf. Let's see what happens to the risetime and amplitude when we apply it to our typical signal source.

Figure 1(c) shows the risetime increased from 8.8 ns to 10 ns for a change of 14%. Though somewhat greater than the 8% of the P6201 (X10) the error is comparable to the 12% error caused by the low-resistance, low-capacitance P6048 passive probe. And note that the P6201 (X1) has negligible effect on signal amplitude.

From the graph in Figure 2 we see that the active probe provides a more accurate risetime measurement than does the passive probe, over a wide range of source risetimes. However, at lower values of source impedance or slower risetimes the small differences in measurement error may not justify the difference in cost between the passive and active probes.

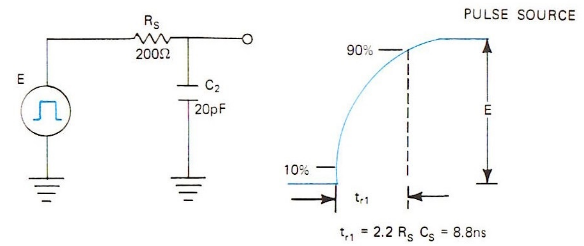


Fig. 1(a). Typical pulse signal source.

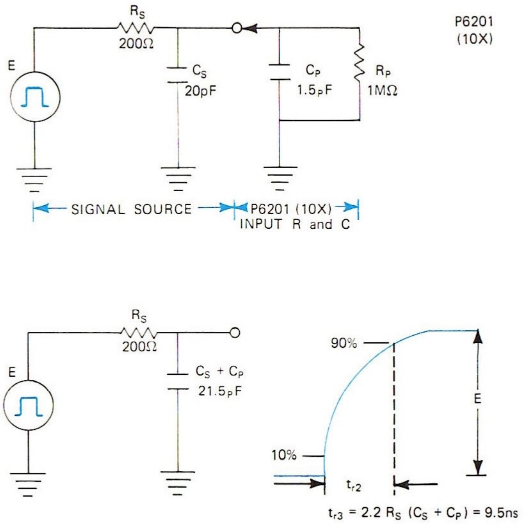


Fig. 1(b). P6201 (10X) probe added to typical pulse source.

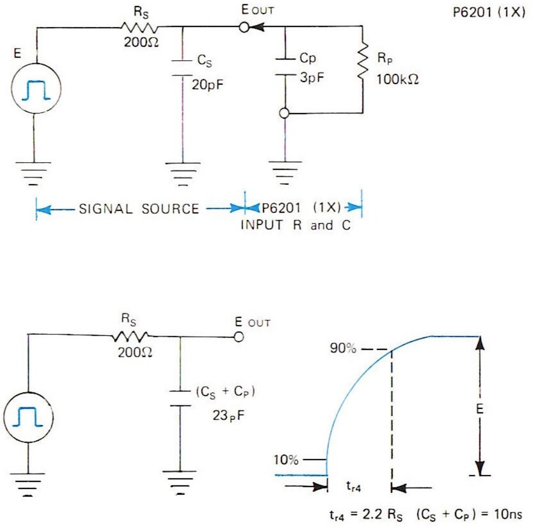


Fig. 1(c). P6201 (1X) probe added to typical pulse source.

Measurement of sine wave signals

Now let's see how the active probe performs when measuring sine wave signals. Figure 3(a) shows the same 10 MHz sine wave source used in Part I. Applying the P6201 (10X) probe we find the source is loaded by a probe resistance (R_{p3}) of 1 MΩ and a capacitive reactance (X_{p3}) of 11 kΩ. This compares with an R_p of 40 kΩ and X_p of 1.7 kΩ for the typical high impedance passive probes (See Figure 4).

Since $R_{p3} >> R_s$ it can be disregarded. However, the shunting effect of X_{p3} in parallel with X_s yields a total reactance, X_{ct}, of 790Ω. The resulting impedance is $Z = \sqrt{R_s^2 + X_{ct}^2} = 815\Omega$. E_{out} with the P6201 (10X) applied becomes $\frac{790}{815} \times 100 = 97\%$ (Figure 3(b)). We see that at the 10 MHz frequency the P6201 has negligible effect on the signal output amplitude.

The advantages the active probe offers for measuring sine wave signals are: a more gradual decrease of R_p with increasing frequency, and a lower input capaci-

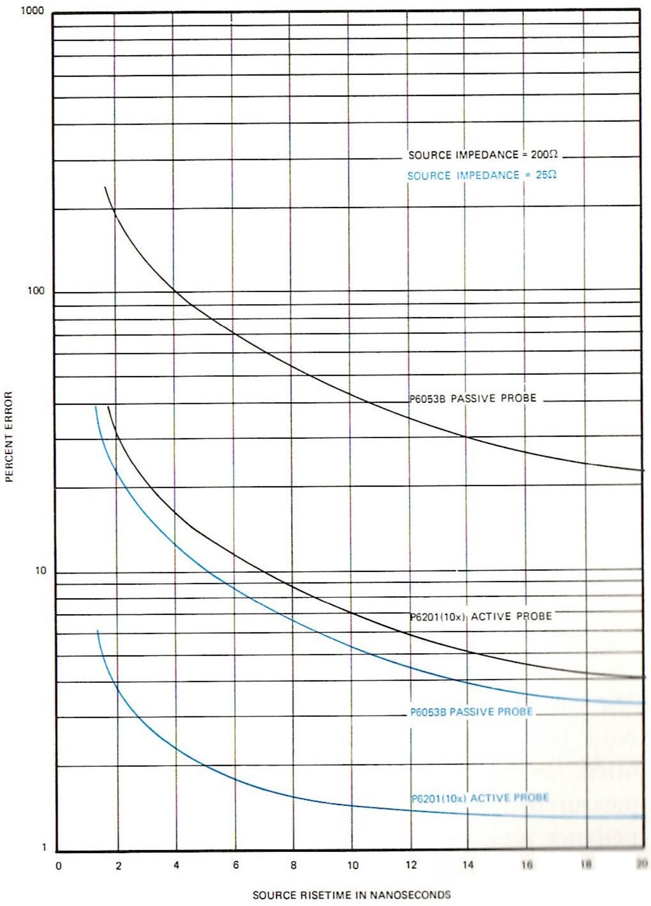


Fig. 2. Relative performance of the P6201 and P6053 when measuring various risetime signals from a 200Ω source and a 25Ω source.

tance providing higher X_p. These characteristics become even more important as the signal frequency increases. For example, if the frequency of our typical source is increased to 50 MHz, the P6201 (10X) causes a change in source output voltage of 3%, while the typical passive probe causes a change of 20%.

Summing it up for active probes

Active probes can provide definite advantages when viewing signals from high impedance and/or low capacitance sources. They provide the best obtainable combination of high input resistance and low capacitance, without signal attenuation; they therefore can be considered capable of providing the best general-purpose measurement capability.

Following is a summary of some general considerations for selecting an active probe:

1. Full bandwidth is provided with no signal attenuation using the 1X configuration.
2. The active nature of the probe provides the high input impedance characteristics of most passive probes and the low input capacitance of passive probes designed to work into 50Ω inputs. These features yield the best of two worlds—minimum risetime and minimum pulse-amplitude error.
3. Impedance selection to permit use with either 50Ω or 1 MΩ inputs is usually provided.
4. Probe length can be extended through the use of 50Ω cable without increasing probe loading.
5. Over-voltage capability is typically provided. However, to minimize the likelihood of over-voltage, the highest attenuation configuration should always be used when probing unknown voltages.
6. Dynamic signal range of the active probe is not as great as that of a passive probe. For example, the P6201 (1X) can handle signals up to ±600 mV. This can be extended to ±60V using the 100X attenuator. DC offset provides a measurement window of ±5.6V using the probe alone, with the range extended to ±200V using the 100X attenuator.

The current probe

Now let's turn our attention to a measurement tool often overlooked—the current probe. Current probe measurements are particularly applicable for high impedance measurement points where the voltage probe would significantly alter the circuit characteristics.

The current probe offers the lowest circuit-loading of any available probe. There is, however, an insertion impedance reflected into the circuit under test, which consists of a series resistance shunted by a small induc-

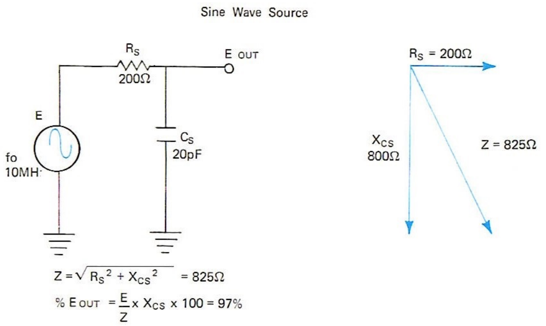


Fig. 3(a). Typical sine wave signal source.

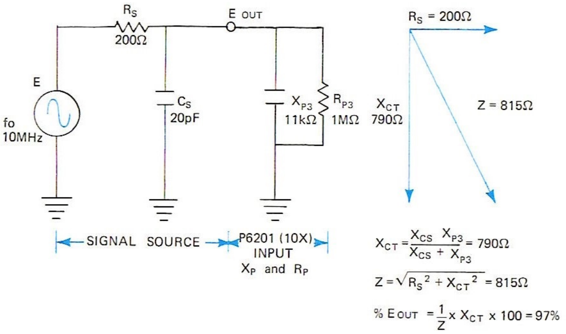


Fig. 3(b). The P6201 (10X) probe to typical sine wave source.

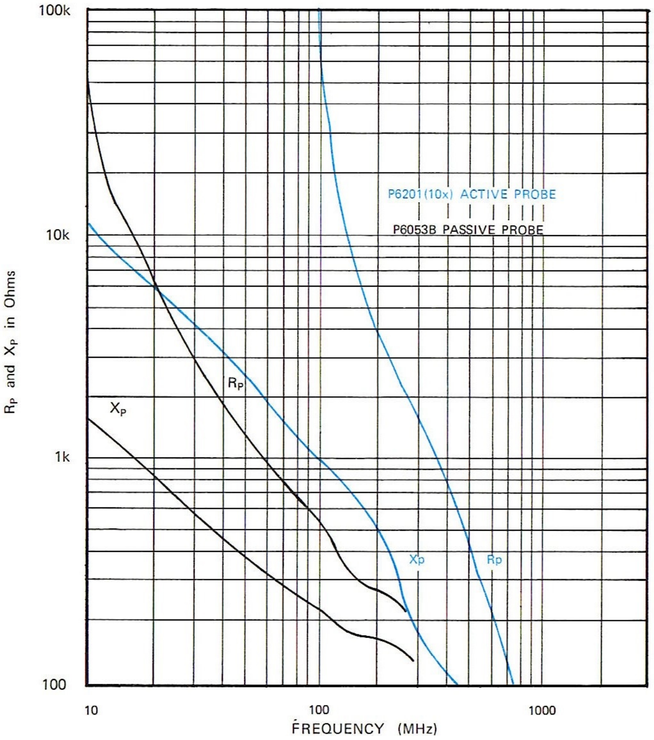


Fig. 4. Typical X_p, R_p vs. frequency curves for the P6053B and P6201 probes.

tance. The value of this inserted impedance is associated with the design of the current-sensing unit in the probe head. In the instance of the TEKTRONIX P6042 (dc to 50 MHz current probe) the insertion impedance is 0.1Ω at 5 MHz. Thus, to realize an amplitude measurement error of less than 2%, the signal source impedance should be 50 times the insertion impedance or, in this case, 5Ω.

A second consideration in the use of the current probe is the capacitive coupling from the probe to the circuit. This coupling is the only shunt loading placed on the circuit by the probe and will vary depending upon the size and type of material of the current conductors. For example, with No. 20 AWG wire the capacitance will be ≈0.6pF and with No. 14 AWG it will be ≈1.5pF. The majority of this capacitance is to a shielding can placed about the current-sensing unit, and its effect can be minimized by using the probe ground lead when working with large voltage swings of high-frequency signals. Another technique is to select a current-monitoring point to minimize voltage swing; for example, monitoring the current on the dc supply side of a load resistor.

Some typical applications

One of the measurements for which a current probe is ideal, is looking at the output required of a generator driving a capacitive or partly-capacitive load. An example would be the gain requirements of an output stage driving the beam-blanking structure of a cathode ray tube. If voltage were monitored, a square wave would be observed. However this is not at all indicative of the current spike that the transistor needs to provide. In this particular measurement, the current probe disturbs the functioning circuit very little, whereas, the capacitive loading of the voltage probe causes a severe disturbance.

A few of the many other areas of usage include transformer design, where the current distribution is the most important parameter; the design of electric motors and generators including looking at starting currents, generated transients, and checking commutation currents; numerous SCR-oriented applications including balancing SCR currents, as well as measuring rate-of-change and peak currents.

Think current measurement

After one becomes accustomed to thinking "current," there are many areas where better measurements can be made and the resultant data is in a more useful form. For example, in evaluating transistor performance, the current probe is ideal for measuring base drive, collector current and even emitter current if the impedance is not too low. You can determine many of the operating characteristics of the transistor through analysis of the collector current waveform.

Differential measurements simplified

If differential measurements are required, the current probe is inherently a high CMRR device. The addition or subtraction of currents by passing two or more wires through the probe sensing unit provides an unsurpassed differential probe. There are no amplifiers, only the opposing or reinforcing flux fields determine the probe output. Similarly, added sensitivity may be obtained by looping the current conductor through the probe more than once.

Another useful technique is to make simultaneous voltage probe and current probe measurements to determine incircuit capacitive or inductive characteristics. If the system is compensated, i.e., has no net reactive components, the voltage and current waveforms will be congruent.

Two styles of current probes

Two styles of current-sensing probes are available. The closed-core unit, such as the CT-1, requires the current-carrying wire to be threaded through the unit. These devices are designed to allow permanent mounting within the circuit to provide continuous monitoring within a controlled electrical environment, for example, a 50Ω strip line. The second style available is the split-core unit which provides for a portion of the core to slide back allowing the current-carrying lead to be inserted without breaking the circuit.

Operational characteristics

The typical current probe has its operational capabilities described by a different set of terms than is characteristic of voltage probes. The **Amp-Second Product** is directly related to the flux saturation of the transformer core. Effectively, the Coulomb charge under one pulse is integrated to determine whether it will place the current transformer into saturation or not.

The **RMS current** indicates the power handling capability of the probe. This power limit may be the wattage capability of the terminating resistance, the wire size of the secondary winding, or a similar power-sensitive component.

The **maximum peak pulse current** rating is indicative of the voltage breakdown characteristics of the weakest component in the system.

Summing up the current probe

Though the use of a current probe may require a slight change in how we customarily evaluate circuit performance, the advantage of using a current probe in certain aspects of circuit design and evaluation make the effort well worthwhile.

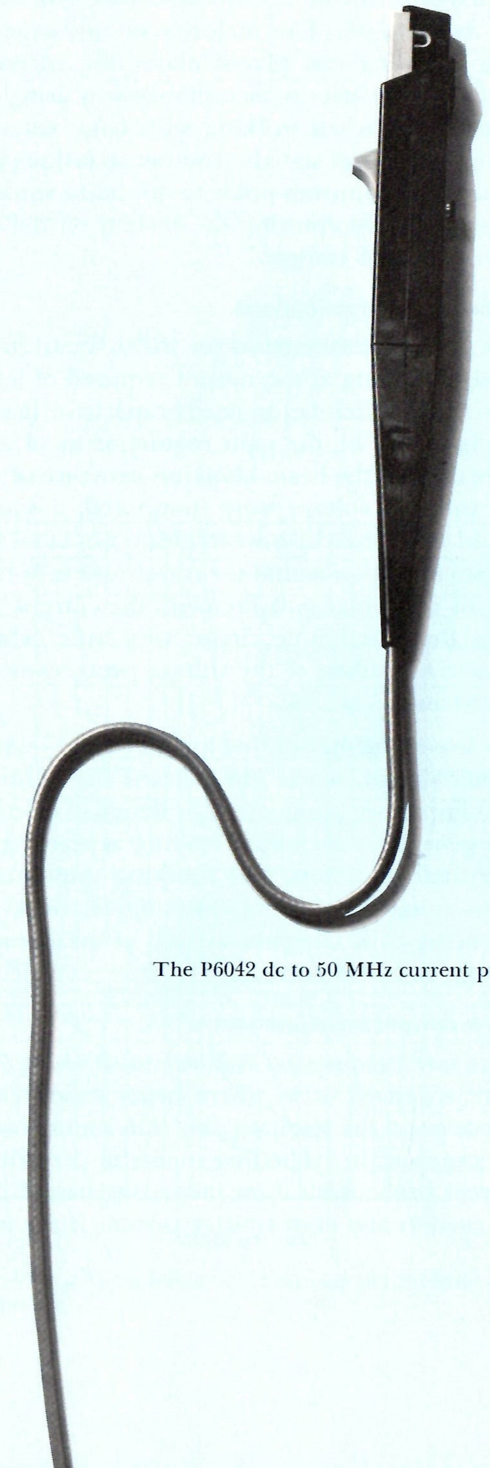
Here are some general considerations leading to current probe use.

1. The current probe can be considered complementary to the voltage probe in the respect that where the voltage probe desires low impedance points for accurate measurements, higher impedance points are desired for the current probe.
2. The current probe exhibits lower loading than any voltage probe. This generally implies minimum signal amplitude attenuation and minimum risetime inaccuracies.
3. Where information on current supply requirements is needed, primarily into capacitive elements, the current probe is almost a necessity.

The P6201 dc to 900 MHz active probe.

Conclusion

Both the active probe and current probe extend the measurement capability of your oscilloscope. They can yield more accurate measurements than passive voltage probes in many instances, and often provide the only means of making some measurements. They could prove to be ready-made solutions to some of your more difficult measurement problems.



The P6042 dc to 50 MHz current probe.

Tektronix, Inc. offers a wide variety of probes to help accomplish a wide variety of measurements. The charts below detail the specifications of some of the most widely used probes.

Voltage Probes for 1 MΩ Inputs

TYPE	ATTEN	LENGTH IN FEET	PACKAGE NUMBER	LOADING		USEFUL BW MHz	DC MAX	SCOPE C IN pF	READ OUT
P6009	100X	9	010-0264-01 Std	10 MΩ	2.5 pF	100	1.5 kV	12 to 47	YES
P6015	1000X	10	010-0172-00 Std	100 MΩ	3 pF	75	20 kV	12 to 47	NO
P6028	1X	6	010-0075-00 Std	1 MΩ	67	10	600 V	ANY	NO
P6048	10X	6	010-0215-00	1 kΩ	1 pF	100	20 V	15 to 20	NO
P6053B	10X	6	010-6053-13 Opt 1	10 MΩ	12.5	250	500 V	15 to 24	YES
P6055[3]	10X	3.5	010-6055-01 Std	1 MΩ	10 pF[2]	60	500 V	20 to 47	YES
P6062A	10X or 1X	6	010-6062-03 Std	10 MΩ	14 pF	100			
				1 MΩ	105 pF	6.7	500 V	15 to 47	YES
P6063A	10X or 1X	6	010-6063-03 Std	10 MΩ	14 pF	200	500 V	15 to 24	YES
				1 MΩ	105 pF	6			
P6065A	10X	6	010-6065-13 Std	10 MΩ	12.5	100[5]	500 V	20 to 24	YES

[5] 100 MHz with 465, 75 MHz.

[2] Rating varies with scopes having other than 20 pF inputs.

[3] Designed for use with scopes having differential inputs.

VOLTAGE PROBES for 50 Ω inputs, or 1 MΩ inputs

TYPE	ATTEN	LENGTH IN FEET	PACKAGE NUMBER	LOADING		RISETIME IN NS	INPUT LIMITS			READ-OUT
							MAX. DC + PK. AC	LINEAR DYNAMIC RANGE	DC OFFSET RANGE	
P6045 FET	1X	6.0	010-0204-00 Std	10 M	5.5 pF	1.5	±12 V	±.5 V	±1 V	NO
	10X				2.5 pF		±100 V	±5 V	±10 V	
	100X				1.8 pF		±100 V	±50 V	±100 V	
P6046 DIFF/AMP	1X	6.0	010-0213-00 Std	1 M	10 pF	3.5	±25 V	±5 V		NO
	10X			10 M	3 pF		±250 V	±5 V		
P6056[1]	10X	6.0	010-6056-03 Std	500 Ω	1 pF	0.1	±16 V	±16 V		YES
		9.0	010-6056-05 Opt 2							
P6057[1]	100X	6.0	010-6057-03 Std	5 KΩ	1 pF	0.25	±50 V	±50 V		YES
		9.0	010-6057-05 Opt 2							
P6201 FET	1X	6.0	010-6201-01 Std	100 K	3.0 pF	0.4	±100 V	±.6 V	±5.6 V	YES
	10X				1.5 pF		±200 V	±6 V	±56 V	
	100X			1 M	1.5 pF		±200 V	±60 V	±200 V	

[1] Must be shunted by 50 Ω (011-0049-01) on a 1-MΩ system.

CURRENT PROBES

TYPE	USEFUL BANDWIDTH Hz to MHz		CURRENT/DIV SCOPE AT 50 mV/DIV	SATURATION		MAXIMUM CURRENT			
				DC	AMP ms PRODUCT	MAX RMS	PEAK PULSE	DERATE BELOW	ABOVE
P6021 with Term	120	50	.1 A to .5 A	.5 A	.5	5.3 A	250 A	300 Hz	5 MHz
with 134 and PS	12	35	1 mA to 1 A	.5 A	.5	5.3 A	15 A	230 Hz	5 MHz
P6022 with Term	8.5 k	100	50 mA or .5 A	.2 A	.009	2.1 A	100 A	3 kHz	10 MHz
with 134 and PS	100	60	1 mA to 1 A	.2 A	.009	2.1 A	15 A	1.3 kHz	10 MHz
P6042	Dc	50	1 mA to 1 A	10 A	—	10 A	10 A	—	1 MHz
CT-1	30 k	1000	10 mA	.2 A	.001	.5 A	100 A		
CT-2	1.2 k	85	50 mA	.2 A	.05	2.5 A	100 A		
CT-3	30 k	1000	10 mA	.2 A	.001	.5 A	100 A		
CT-5 with P6021/134	12 k	20	20 mA to 1 kA	20 A	500	700 A	15 kA	230 Hz	1.2 kHz
with P6042	.5 k	20	20 mA to 10 kA	20 A	8000	700 A	10 kA	20 Hz	1.2 kHz
CT-5 with P6021 Passive Termination	120	20	100 A to 500 A	20 A	500	700 A	50 kA	300 Hz	1.2 kHz

Tektronix, Inc.

P. O. Box 500, Beaverton, Oregon 97077
Telephone: (503) 644-0161 TWX: 910-467-8708 TEKTRONIX BEAV. Cable: TEKTRONIX

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Portland
8845 S.W. Center Court
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†Factory Service Center
Tektronix Industrial Park
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