SERVICE SCOPE

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A NEW
PHYSIOLOGICAL
MONITOR

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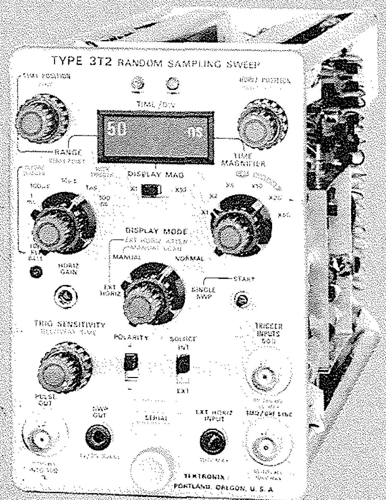

A NEW
MEASUREMENT CONCEPT—
RANDOM SAMPLING

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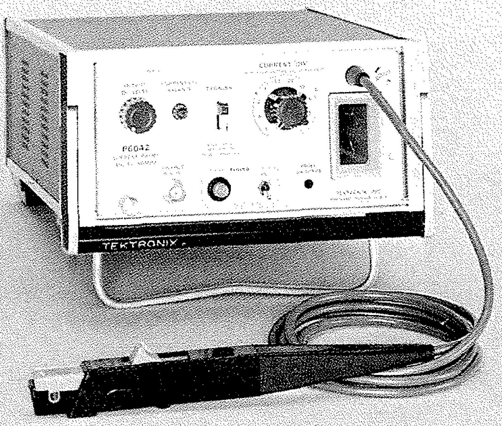

A NEW
DC-TO-50 MHz
CURRENT PROBE

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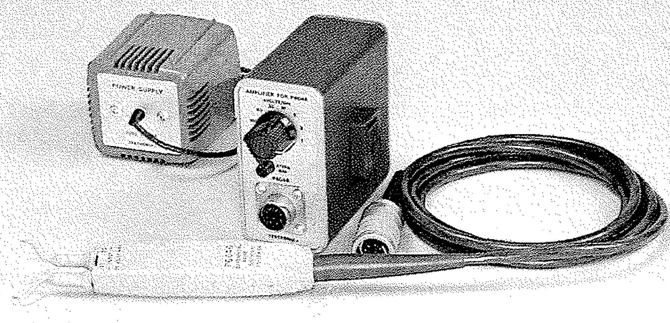

A NEW
DC-TO-100 MHz
DIFFERENTIAL PROBE
AND AMPLIFIER

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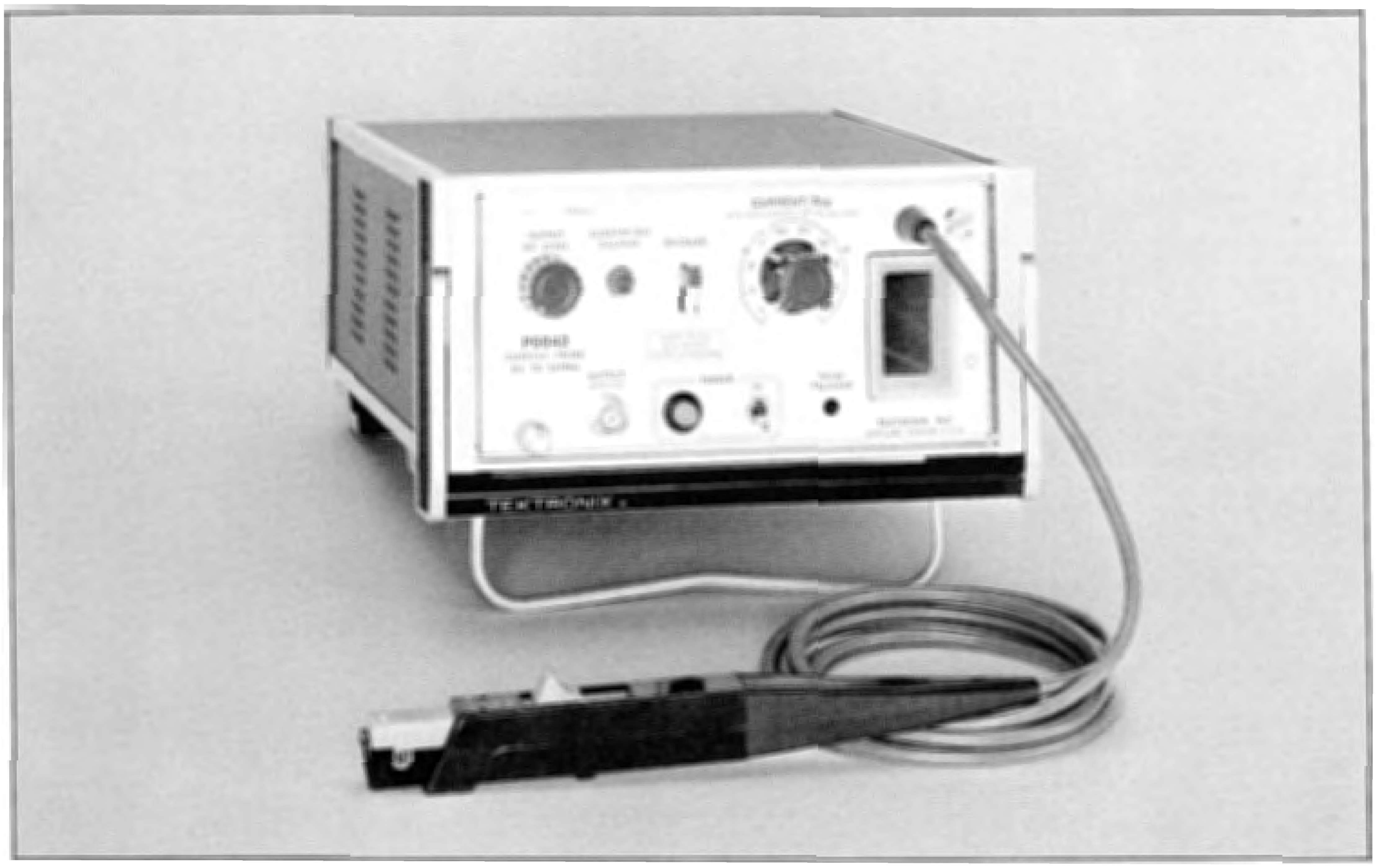
P6042 DC-to-50 MHz CURRENT PROBE

by Cal Hongel



INTRODUCTION

Current probes have become increasingly useful and popular with the expanding use of semiconductor devices which are current sensing devices (current amplifiers). A new current probe has just been developed at Tektronix that provides unique measurement capabilities.

Utilizing the Hall-effect plus AC current probe technology (P6019/P6020), the P6042 DC-to-50 MHz current probe can be used simultaneously for both high-frequency and direct-current measurements. AC signals with DC components can be displayed on an oscilloscope with true waveform presentation. The probe is particularly useful for evaluating the performance of semi-conductor circuits where a wide range of parameters exist. Fast switching transients, low-frequency response, and DC level can all be displayed simultaneously (Figure 1). The P6042 can also be used to measure the sums or differences of currents in separate wires. When the probe is clipped around two wires carrying current in the same direction, the sum is displayed; around two wires carrying current in the opposite direction, the difference is displayed. For increased sensitivity the wire can be looped through the probe several times increasing the sensitivity by the number of loops.

The probe is easy to use. The conductor is simply placed into the slot of the probe and the spring loaded slide closed . . . no need to break the circuit under test. Measurements can be made only when the probe is in the locked position (push slide forward to lock). A warning light on the front panel indicates when the slide is in the unlocked position. A compartment is provided in the front panel for convenient storage of the probe when the system is not in use and an inter-lock is provided in this compartment for degaussing the probe. The probe can be degaussed only when in the compartment to prevent possible damage to the circuit under test.

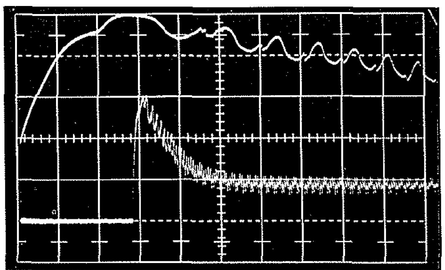


Fig 1. Double exposure photograph using the P6042 and a Type 547/1A5 Oscilloscope to display the current characteristics of a small DC motor. Lower display shows the zero current level, starting current, and running current. Current/div setting is 0.2 *A/div with a sweep rate of 50 ms/cm. In* the upper display, the sweep rate is increased to 5 ms/cm to show the current change as the commutator bars pass the brushes.

DESIGN CONCEPTS

The P6042 Current Probe includes a sliding-core type probe and associated amplifier as shown in Figure 2. The probe contains a stationary core around which is wound a 50-turn secondary, a moveable core which slides over the end of the stationary core and the current-carrying conductor, and a Hall voltage device. The amplifier houses the power supplies, low-frequency amplifiers, attenuators and the output amplifier.

High Frequency

High-frequency measurements are made in the same manner as in an AC current probe. The AC current probe is basically a transformer. The current-carrying conductor forms a one-turn primary winding for the transformer; the windings in the probe around the core form the 50-turn secondary winding. The relationship between the current, voltage and turns is shown below:

$$N_p I_p = N_s I_s$$

For a one-turn primary,

$$I_p = N_s I_s$$

Then for a 50-turn secondary,

$$I_s = \frac{I_p}{50}$$

The secondary voltage is

$$E_s = I_s R_s$$

R_s is 50 Ω, so $E_s = \frac{I_p}{50} \quad (50\,\Omega)$

or $\quad E_s = I_p \; (\Omega)$

For AC signals the voltage output of the current probe into the secondary load (R_s) is 1 mV per mA of input current.

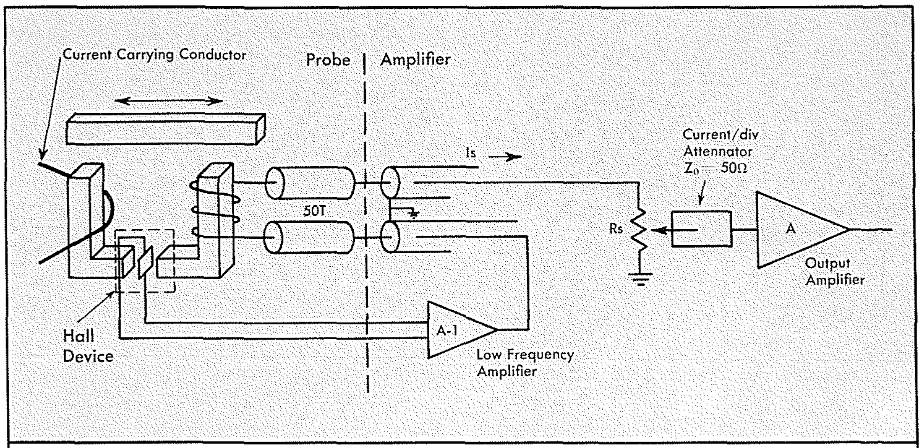


Fig 2. Block Diagram of P6042 Probe.

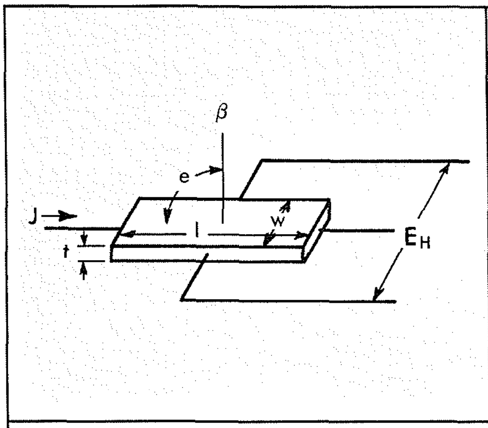


Fig 3. Hall device.

The Hall device is a thin rectangular sheet of semiconductor material sandwiched in the stationary portion of the transformer core. The Hall effect is a voltage generated across opposite edges of a current carrying conductor placed in the magnetic field.

The basis for the effect is the Lorentz force which is the deflection of charged particles moving in a magnetic field. The force is both perpendicular to the direction of the particle (current) flow and the direction of the magnetic field. Equation follows:

$E_{Hall} = wR_H \, J \, \beta \sin \phi$
E_{Hall} = voltage from Hall device
w = width of Hall element
R_H = Hall coefficient
J = current density
β = field strength

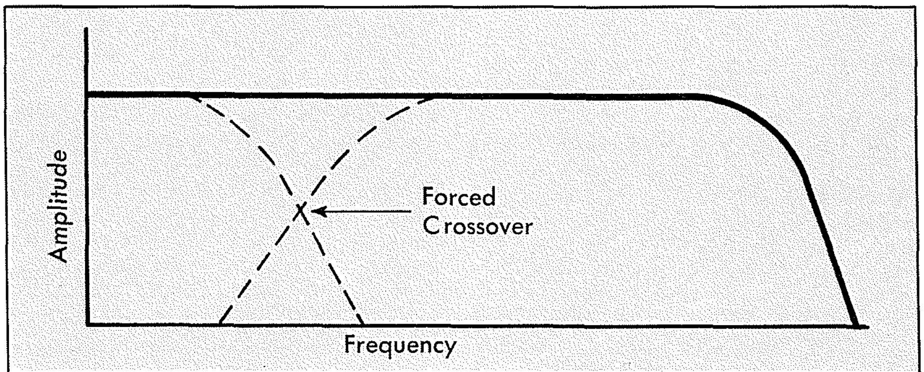


Fig 4. Forced crossover.

DC and Low Frequency

The heart of the DC measurement capability is a highly-sensitive Hall device developed by the Tektronix Integrated Circuit Department. The Hall device is located in a cross section of the ferrite core contained in the probe head. At the point where the AC response of the core becomes ineffective due to the low-frequency L/R time constant of the core, the back EMF of the secondary no longer cancels the flux generated in the core by the primary current. The flux remaining in the core (primarily flux due to DC and low-frequency current) passes through the Hall device generating a small voltage directly related to the applied field. Figure 3 shows the current, voltage, and flux relationship of a Hall device.

The Hall device voltage (about 50 μV per mA of applied current) is amplified by the operational amplifier (A-1) and applied to the 50-turn secondary, to cancel the remaining flux in the core. Most of the flux in the core is cancelled either by the back EMF of the secondary or by feedback from the operational amplifier. As a result, the non-linearity of the core does not affect accuracy, nor does it directly limit maximum current handling ability. At DC and low frequencies, the operational amplifier supplies an output across the secondary load (R_s) of 1 mV per mA of primary current.

The maximum input current is related to the current handling ability of the operational amplifier. To handle ± 10 A in the primary, the amplifier (A-1) must supply $10\,A \times \frac{1}{50}$ to the 50-turn secondary to cancel the flux at DC and to supply ± 200 mA across R_s.

Attenuator and Output Amplifier

The current induced in the secondary by the primary (at high frequency) and the current applied to the secondary at low frequency by amplifier (A-1), produces a voltage across the secondary load that is directly related to the input current. The adding of the low-frequency signal to the high-frequency signal is done in such a way as to force one to take over where the other leaves off (see Figure 4). This is commonly known as a forced complement system.

The sensitivity at this point is 1 mV output for a 1 mA of primary current (input current). The 50-Ω secondary load is in the form of a 50-Ω attenuator that provides attenuation of up to 1000X (1 A/div) in 10 steps with a 1-2-5 sequence. The signal from the 50-Ω attenuator is applied to a 50X DC-to-50 MHz output amplifier. The output amplifier supplies an output of 50 mV per mA of primary current or 1 mA/div with the oscilloscope deflection set at 50 mV/div.

The P6042 output amplifier has an output impedance of 50 Ω. A 50-Ω termination is supplied with the P6042 probe for use with oscilloscopes having 1-MΩ inputs.

CIRCUIT LOADING

All probes load the circuit under test in one form or another. Voltage probes have input capacitance and DC resistance. Current probes load in a different manner. They have an insertion impedance due to the secondary load being reflected into the primary and very low-capacitive loading.

Reflected Load

The secondary inductance and load resistance is reflected through the turns ratio squared and appears as a series load in the primary (current-carrying conductor). Calculations of the typical reflected loading of P6042 current probe is shown below:

$$R_p = \frac{R_s}{T^2} = \frac{50\,\Omega}{(50)^2} = 0.02\,\Omega$$

$$L_p = \frac{L_s}{T^2} = \frac{0.5\,mH}{(50)^2} = 0.2\,\mu H$$

Shield Inductance

Another factor affecting circuit loading is the reflection of the current probe shield into the current carrying conductor. The shield appears as a shorted turn around the conductor. Leakage inductance also appears in series with the primary.

Stray Capacitance

The only other factor involved with circuit loading is the stray capacitance between the probe and the conductor. This capacitance depends on the size of the current carrying conductor and its position in the hole. It is typically 1 pF and can be measured using a Type 130 LC Meter. As with voltage probes, stray capacitance can limit the risetime of the measurement ($T_{rise} = 2.2\ R_{source}\ C_{strays}$). By inserting the current probe on the ground or B+ side of the load resistor the stray capacitance loading can be reduced.

The total insertion impedance can best be represented by the graph in figure 5.

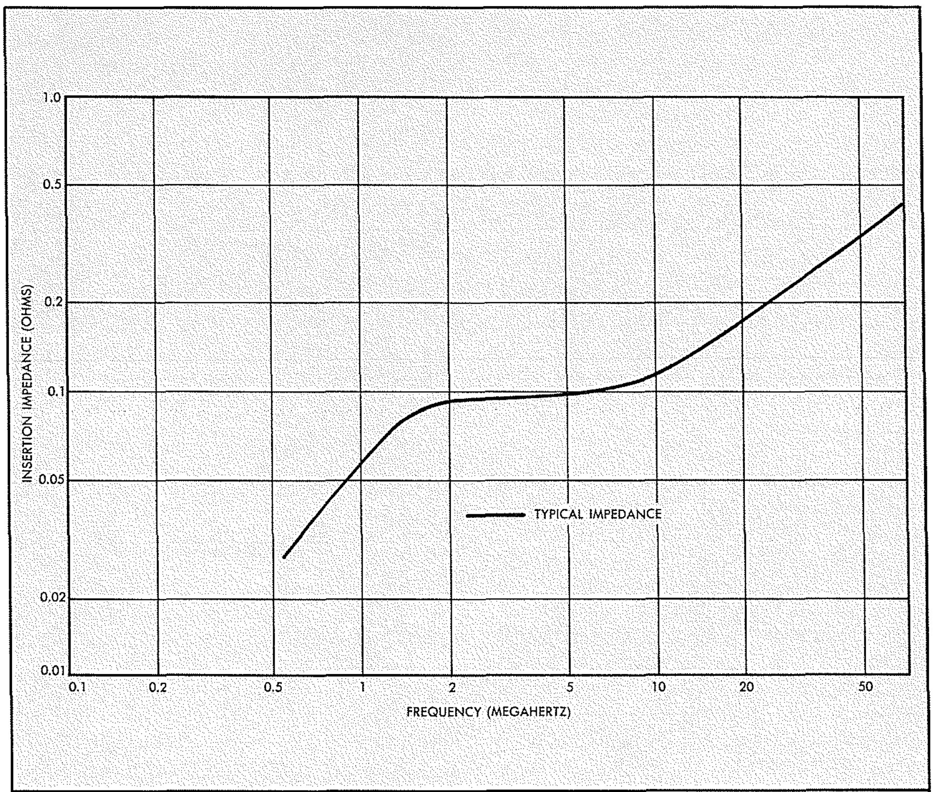


Fig 5. Insertion impedance.

PROBE DEGAUSSING

Whenever a magnetic field is applied to the transformer core in the probe with the system turned off, or if a current beyond the maximum specified level is applied, the core may become magnetized. A portion of this magnetic flux is likely to remain in the current probe core causing measurement errors. To remove this flux the probe is placed in the storage compartment and the degaussing switch is depressed. The degaussing switch connects the 50-turn secondary winding to an oscillator as shown in Figure 6. The oscillator produces a 10-kHz exponentially decreasing sinewave which initially saturates the core. The decaying current eliminates stored flux due to core hysteresis.

An interlock switch for the degaussing oscillator is provided in the probe storage compartment. The switch eliminates any possibility of introducing transformed current from the oscillator into the test circuit. The compartment, accessible from the front panel, provides convenient storage for the probe when not in use.

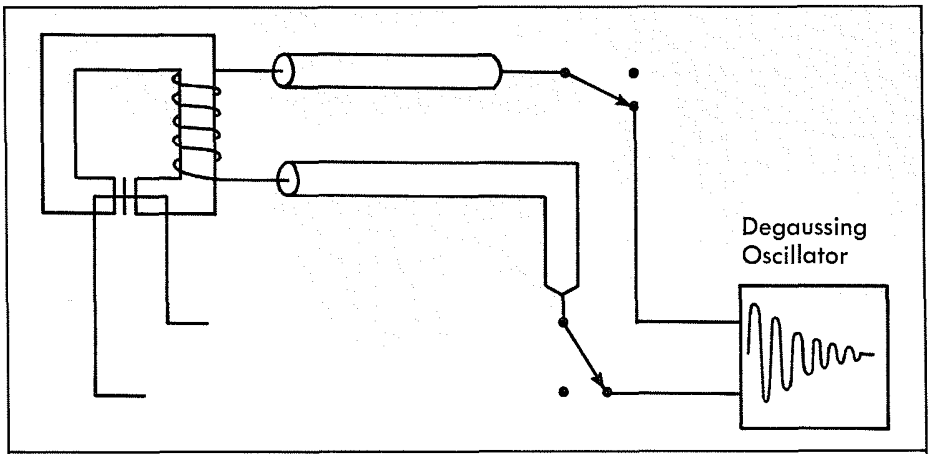


Fig 6. Probe degaussing.

CHARACTERISTICS

Probe and Amplifier

SENSITIVITY is 1 mA/div to 1 A/div in 10 calibrated steps, 1-2-5 sequence, accurate within 3% (with an oscilloscope deflection factor of 50 mV/div).

BANDWIDTH is DC to 50 MHz at 3-dB down.

RISETIME is 7 ns or less.

DYNAMIC RANGE is + and — 10 divisions of display.

NOISE (periodic and random deviation) is 0.5 mA or less plus 0.2 or less major divisions of display. Random trace shift is 1.5 mA or less.

THERMAL DRIFT is 2 mA/°C or less, plus 0.2 or less major division of display per °C.

MAXIMUM INPUT CURRENT is 10 A (DC plus Peak AC).*

*Peak-to-peak current derating is necessary for CW frequencies higher than 2 MHz. At 50 MHz, the maximum allowable current is 2 A.

MAXIMUM INPUT VOLTAGE is 600 V (DC plus Peak AC).

OUTPUT IMPEDANCE is 50 Ω through a BNC-type connector. A 50-Ω termination is supplied with the probe for use with 1-megohm systems.

AMPLIFIER POWER REQUIREMENT is approximately 10 W, 50 Hz to 400 Hz. Quick-change line-voltage selector permits operation from 90 V to 136 V or 180 V to 272 V.

DIMENSIONS AND WEIGHT of the amplifier are 4½ in. (11.4 cm) high by 7½ in. (19.2 cm) wide by 9¾ in. (24.8 cm) deep; 6½ lbs. (3.1 kg).

PROBE CABLE is 6 feet long, permanently connected between the probe head and amplifier.

P6042 DC CURRENT PROBE PACKAGE (010-0207-00)

Includes: 50-Ω BNC cable (012-0057-01); 50-Ω BNC termination (011-0049-00); 3-inch ground lead (175-0263-00); 5-inch ground lead (175-0124-00); two alligator clips (344-0046-00); 3-wire to 2-wire adapter (103-0013-00); instruction manual (070-0629-00).