



# TEKSCOPE

APRIL 1969



Measuring Conventional Oscilloscope Noise . . . page 8    Service Scope . . . page 12

# A NEW INSIGHT INTO RECIPROCATING MACHINERY

By Bill Verhoef

***The Tektronix Engine Analyzer System is designed to provide information for effectively evaluating engine, pump, and compressor performance. By using this oscilloscope information, potential problems and trends can be detected and corrective action taken before extensive damage occurs. Preventive-maintenance overhauls may be eliminated or delayed, since the analyzer detects trouble spots without unnecessary downtime. The Engine Analyzer System is also useful as a standard general-purpose laboratory oscilloscope.***

## COVER

*The rotating film disc shown is the heart of the Rotational Function Generator (RFG). When coupled to an engine or compressor, the RFG generates three wave-shapes: outer ring — 10°, 60°, and 360° (TDC) markers; second ring — sawtooth ramp; third ring — sinewave with harmonic content (equivalent to piston volume).*

## 4 CHANNELS OF INFORMATION

Tektronix Engine Analyzers offer simultaneous observation of pressure, ignition, vibration, and crankshaft rotation. These quantities may all be observed as a function of time, crankangle, or piston displacement (i.e., P-V diagram). Tektronix Engine Analyzer Systems consist of a Type 561B or 564B oscilloscope, two plug-in units, and a rotational function generator (RFG) with appropriate transducers and cables.

By using the 4-trace electronic switching capability of the Type 3A74 Engine Analyzer Amplifier, one charge

amplifier and 3-voltage channels (DC-2 MHz) are available. The operator is provided with new ease in interpreting displays, since all transducer outputs may be monitored simultaneously.

The 564B Split-Screen Storage Oscilloscope is ideal for use with Engine Analyzer plug-ins. Either half of the CRT screen may be independently controlled and used for conventional non-stored displays, or information may be stored on the CRT phosphor up to 1 hour. Storage is particularly convenient when making pressure measurements, since 10 or more engine cycles may be stored on the display and changes detected in pressure. Pre-ignition problems are also readily observed.

## PREDICTABLE MAINTENANCE

Vibration pickups, normally piezoelectric crystals mounted on a magnetic base, may be placed anywhere on an engine or compressor to analyze the various vibrations. Operators can thus detect leaking valves, piston blow-by, destructive detonation, excessive cylinder ring wear, and other signs of wear and deterioration.

Ignition measurements are useful for proper engine timing and assist in detection of a wide range of ignition problems. Faulty spark plugs, point arcing and bounce problems, faulty condensers, ignition coils and proper engine timing may all be observed with an ignition probe.

Pressure monitoring allows detecting peak-firing pressures, compression pressures, early or late cylinder fir-

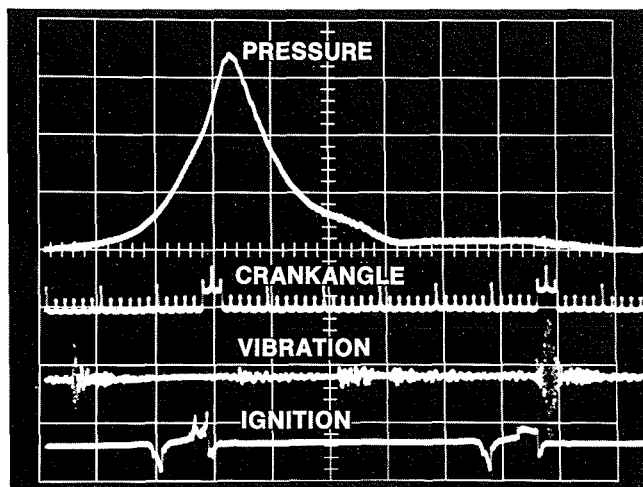


Fig 1. The Tektronix Engine Analyzer System allows simultaneous monitoring of pressure, crankangle, ignition, and vibration.

ing, and pre-ignition of the engine under test. P-V diagrams determine indicated engine horsepower and overall performance in engines, pumps, and compressors.

## ROTATIONAL FUNCTION GENERATOR

The Tektronix Engine Analyzer includes a rotational function generator (RFG) that is mechanically coupled to the engine under test and generates 10°, 60°, and 360° crankangle markers. The RFG operates to a maximum of 20,000 r/min\* and generates three separate outputs as shown below.

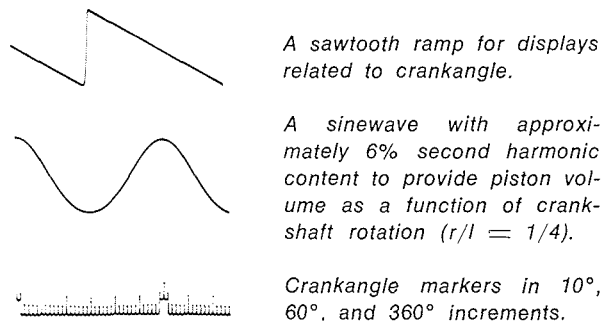


Fig 2. Rotational function generator waveshapes.

The various markers (10°, 60°, 360°) have different amplitudes and are displayed in ruler form on one trace. These markers are coupled internally into channel 2 of the Type 3A74 Engine Analyzer Amplifier Unit. A top dead center (TDC) mark is obtained from a magnetic pickup sensing a marker on the flywheel. This magnetic pickup signal is then easily superimposed on channel 2 to coincide with the RFG 360° marker. The RFG volume signal is then aligned with the particular cylinder of interest.

The RFG generates the wave shape necessary for determining piston displacement at any point in the combustion cycle. To accomplish this, the RFG generates a waveform containing 6.35% second harmonic to approximate an  $r/l$  ratio of 1/4 (the ratio relates the length of the connecting rod ( $l$ ) to the radius of the circle described by the rotation of the crankshaft ( $r$ ), see fig 3). This waveform is then used to generate the V axis for a P-V diagram curve.

\*(RPM) Ref IEEE Standard Symbols for Units IEEE No 260 Jan 1965

Most engines have r/l ratios ranging between 1/3.5 to 1/6. The chart below shows the displacement for various values of crankshaft rotation for r/l ratios of 1/6, 1/4, and 1/3.5. Based on a 100-mm displacement, the 1/4 maximum displacement error of the RFG (at 90° of crankshaft rotation) is only -2.15 mm and +0.95 mm respectively. Thus, a variable r/l control is not required.

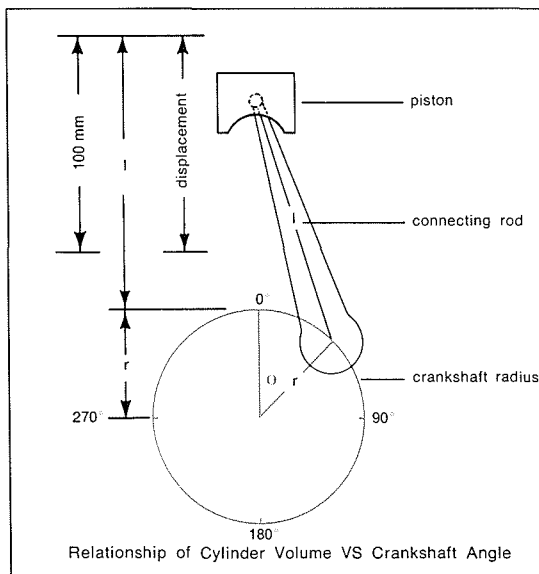
Once a P-V display is obtained, mean effective pressure can be found as it is proportional to the area within the loop. The mean effective pressure is then used to determine the indicated horsepower of the engine by the formula  $HP = \frac{PLAN}{33,000}$ . In the case of a 4-cycle engine it is necessary to determine the difference between the two loops since one is negative work and the other is positive work.

- P = mean effective pressure (lbf/in<sup>2</sup>) \*
- L = length of piston stroke (ft)
- A = cross-sectional area of cylinder (in<sup>2</sup>)
- N = speed of rotation (r/min) [N/2 (4 cycle)]

## PRESSURE MEASUREMENTS

Pressure measurements are made with the Tektronix Engine Analyzer by using a piezoelectric pressure transducer and a charge amplifier (channel 1 of the Type 3A74 Engine Analyzer Amplifier). 50 feet of special Tektronix designed low-noise cable is used to connect the pressure transducer to the amplifier input. Cable noise is not apparent with the special low-noise cable supplied.

\*(psi) Ref IEEE Standard Symbols for Units IEEE No 260 Jan 1965



$\theta$	$\frac{r}{l} = \frac{1}{6}$	$\frac{r}{l} = \frac{1}{4}$	$\frac{r}{l} = \frac{1}{3.5}$
0°	0	0	0
30	7.74	8.3	8.5
60	28.1	29.76	30.4
90	54.2	56.35	57.3
120	78.1	79.76	80.4
150	94.34	94.9	95.1
180	100.0	100.0	100.0

Fig 3. The table above shows the amount of deviation from an r/l of 1/4 as the crankshaft moves the piston from minimum to maximum displacement. Note that the maximum displacement error (90°) at 1/3.5 is +0.95 mm and at 1/6 is -2.15 mm.

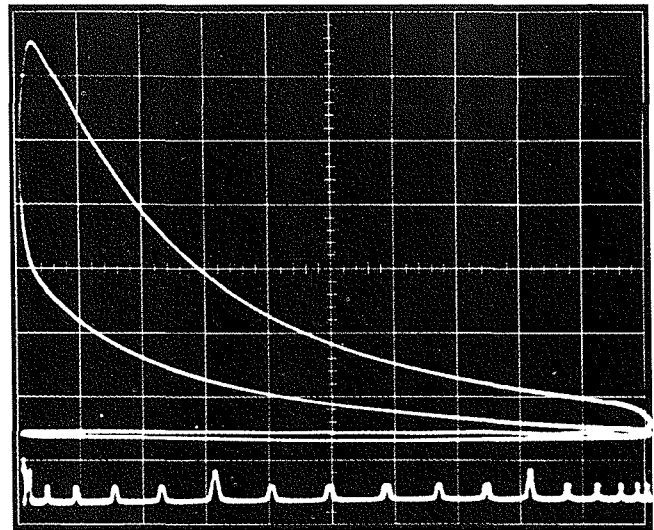
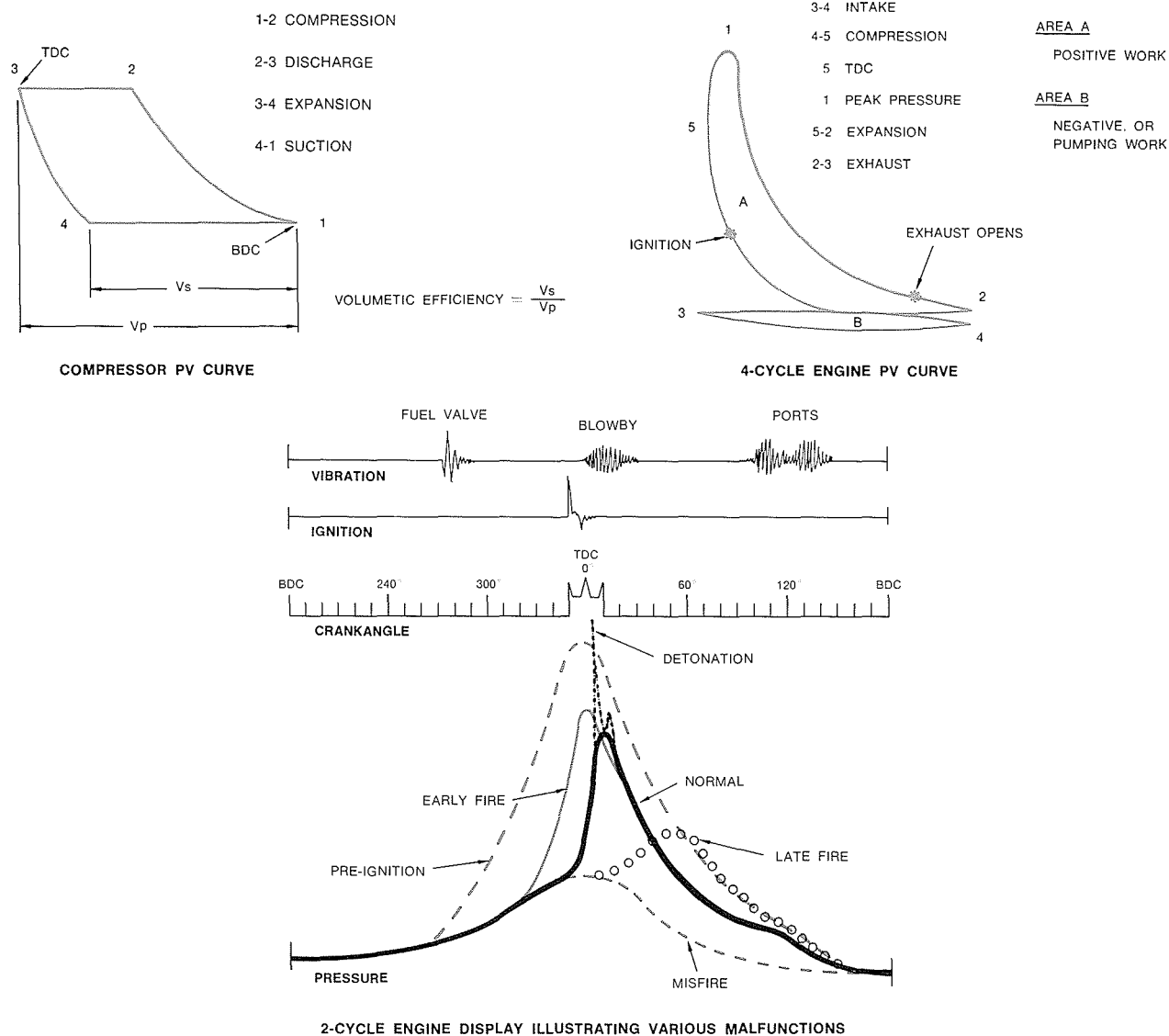


Fig 4. Pressure vs cylinder volume. The area within the loop is the mean effective pressure and may be determined accurately with a planimeter.

The low-noise cable, the pressure transducer, and the channel 1 amplifier allow three displays of cylinder pressure to be quickly and easily obtained: (1) Pressure versus crankangle; (2) Pressure versus cylinder volume; (3) Pressure versus time.

The Tektronix Engine Analyzer System measures the charge of the pressure transducer instead of a voltage. As a result, the system is insensitive to variations in transducer or cable capacitance. This feature enables the Engine Analyzer System to use cables as long as 2000 feet, even in the most sensitive position.

## ENGINE AND COMPRESSOR BASICS



The pressure transducer operates over a range of  $-40^{\circ}$  to  $+150^{\circ}$  C and speeds up to 6000 r/min. The transducer should always be used with a cooling adapter where environmental conditions exceed  $+150^{\circ}$  C. Engine speed must be derated to 1500 r/min when using the cooling adapter, and to 1000 r/min when using the cooling adapter and coupling pipes of 5 to 10 inches.

Special low-noise coaxial cables have been designed by Tektronix with a conductive plastic jacket underneath the braiding. This reduces the cable movement noise by a factor of at least 100 over standard RG58

cable. All coaxial cables are provided with the same BNC connectors as the transducers. As a result there are no problems in interchanging connectors or replacing and repairing cables.

The high-charge sensitivity of the transducer makes the system impervious to cable and connector noise and eliminates resistivity problems caused by dirty connectors. The pressure transducer has a range from 0 to 3000 lbf/in<sup>2</sup> and when used with channel 1 of the Type 3A74 Engine Analyzer Amplifier deflection factors from 1 lbf/in<sup>2</sup>/div to 500 lbf/in<sup>2</sup>/div are pro-

vided in a 1-2-5 sequence. The transducer can stand overload of 9000 lbf/in<sup>2</sup> which enables it to withstand knocks in the transducer access pipes.

The charge amplifier of channel 1 can be set for either LONG ( $\approx 4$  s) or SHORT ( $\approx 0.4$  s) recovery time, and is constant in all PSI/DIV positions. The low-frequency response is 0.05 Hz (LONG) and 0.5 Hz (SHORT). Long recovery times are normally selected below 600 r/min, and where critical pressure measurement is required.

## VIBRATION MEASUREMENTS

The piezoelectric vibration transducer is capable of 1000 g's maximum acceleration over a range of  $-40^{\circ}$  C to  $+150^{\circ}$  C. 50 feet of the Tektronix designed low-noise cable is provided to connect the vibration transducer to one of the channels of the 4-channel amplifier. The vibration transducer normally provided with a Tektronix Engine Analyzer has a sensitivity of nominally 6 mV/g ( $4\frac{1}{2}$  mV/g with the 50-foot included cable). Vibration transducers are provided with a calibration chart for the individual transducer. The vibration transducer has a bandwidth of 40 Hz to 15 kHz into the 1 M $\Omega$  impedance of the 4-trace amplifier, with a resonant frequency (+25 dB) at approximately 10 kHz.

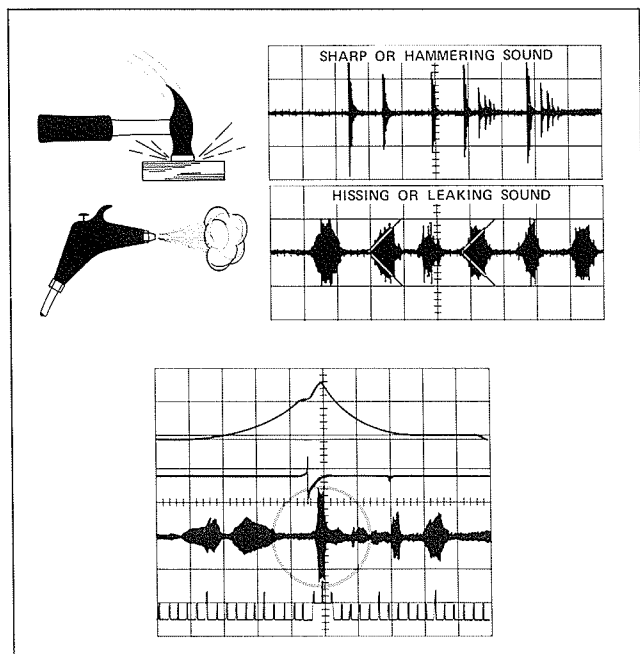


Fig 5. Two basic sounds of interest in engine analysis. The hammering sound has a steep wavefront while that of the leaking sound is much more sloping. The circled area in the bottom photograph indicates a piston slap condition.

The 10-kHz resonant frequency enhances the indication of mechanical shocks (valve closings, loose piston rings), and leaking gases (blow-by). This transducer also aids the operator by filtering out the low-frequency vibrations of lesser interest (below 40 Hz).

## IGNITION MEASUREMENTS

The 50-foot low-noise ignition probe consists of a 1000X capacitive attenuator that clamps onto the secondary coil and spark plug wire and presents a signal to the oscilloscope. The exact attenuation of the ignition pickoff is determined by the capacitance between the pickoff and the secondary lead ( $\approx 10$  pF) and the built-in capacitance of the probe. The probe may easily be calibrated by using a piece of similar cable and the oscilloscope calibrator.

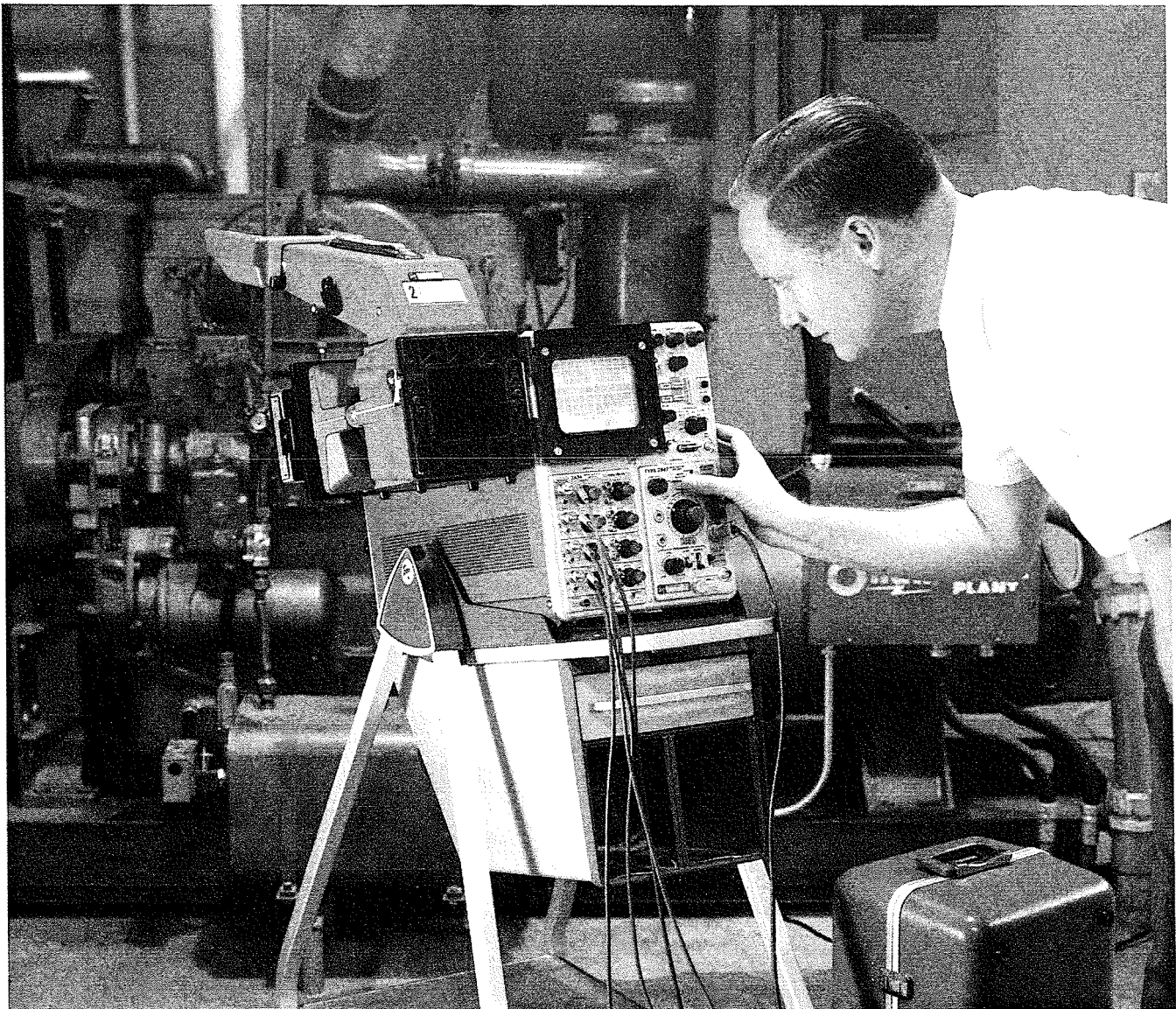
Magnetic pickups are used to indicate the TDC of a piston by detecting a hole or steel stud on the flywheel. The use of magnetic pickups eliminates the inconvenience of timing lights. It is no longer necessary to connect to the high voltage of a spark plug buried somewhere inside the head of a large engine. In addition, there is no large cable capacitance loading the secondary of the ignition system and affecting the timing.

## HORIZONTAL DISPLAY

The horizontal display capabilities of the Engine Analyzer are time, crankangle rotation, and piston displacement. The single-sweep mode of the Type 2B67 Engine Analyzer is available for time displays as well as for 2 or 4-cycle engine volume and crankangle displays.

A triangular horizontal modulation signal is provided when no horizontal output is present. This safety precaution prevents accidental CRT phosphor burns. When using the time base the sweep may be triggered externally by the RFG (this connection is built-in), making the triggering insensitive to ignition RFI.

The rotational function generator operates on a photoelectric principle and is a compact lightweight unit with very low rotating torque and a 1:1 ratio. The housing unit is easily rotated for alignment with individual cylinders and has an adjustable dial marked



*Bill Verhoef, Engine Analyzer Project Engineer, monitors an Engine Analyzer display.*

in degrees to measure the amount of this rotation. A polarity switch is provided, so regardless of crankshaft rotation, the desired crankangle sweep direction is obtained.

### **SUMMARY**

The Tektronix Engine Analyzer System provides valuable information on engine, pump, and compressor performance. The ability to simultaneously monitor pressure, ignition, vibration, and crankshaft rotation provides sufficient information to analyze most problems before extensive damage occurs.

Tektronix manufactures a line of oscilloscope cameras. These cameras all use Polaroid® backs and are ideal for maintaining a history of an engine's performance.

A convenient carrying case is provided which contains all cables, transducers, and accessories required. In addition, space is provided for a planimeter, Polaroid film, timing light, and small tools.

Further information on Tektronix Engine Analyzer Systems is available on pages 178-182 of the Tektronix 1969 Catalog 28, or from your local field engineer. A demonstration is available by contacting any of the 52 field offices serving the United States.

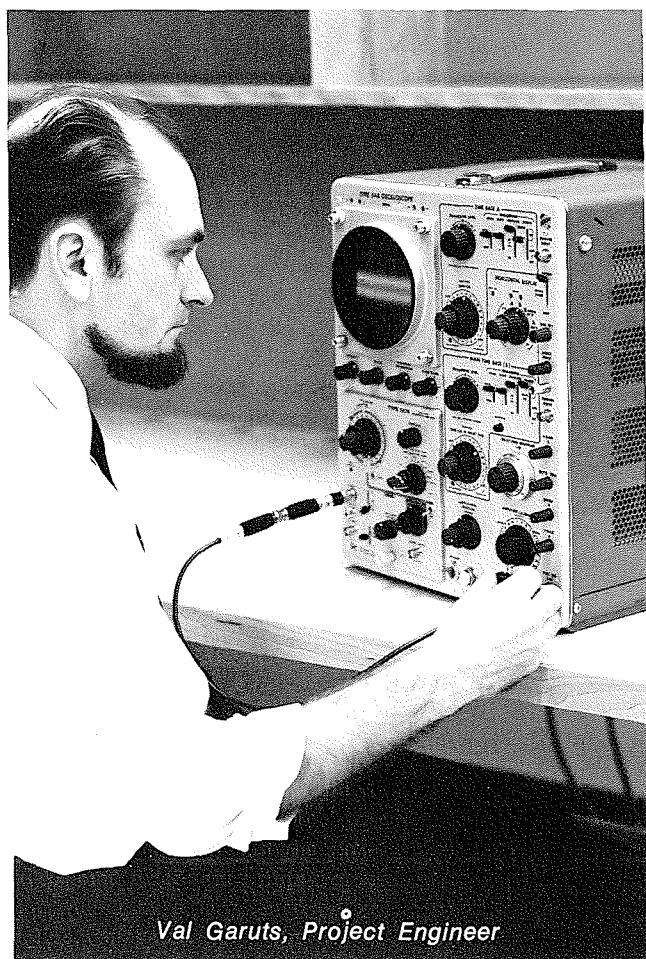
\*Registered Trademark Polaroid Corporation



# measuring conventional oscilloscope noise

By Val Garuts and Charles Samuel

**Noise—random and specific unwanted variations of the trace on a cathode-ray tube (CRT)—is a limiting factor in high-sensitivity measurements with an oscilloscope. The amount of noise visible on a CRT display depends on the oscilloscope's bandwidth, deflection factor setting, the ambient temperature, power line waveform characteristics, and other factors.**



Val Garuts, Project Engineer

Small amounts of noise usually have little effect on oscilloscope display interpretations. As a result, instruments with less than about 0.2 divisions of noise deflection do not generally have noise performance specified. Instruments with more than 0.2 divisions of noise deflection may have performance areas which are noise limited and thus, a performance specification is required. If the visible noise is much larger than this it may affect measurements made with the oscilloscope.

Three methods to measure and specify noise are presently used on conventional Tektronix instruments:

1. Determine the noise on the display by measuring it at some output point with an RMS voltmeter.
2. Observe the apparent trace width on the CRT.
3. Display a known signal and determine the amount of noise present by tangential measurement (displayed noise).

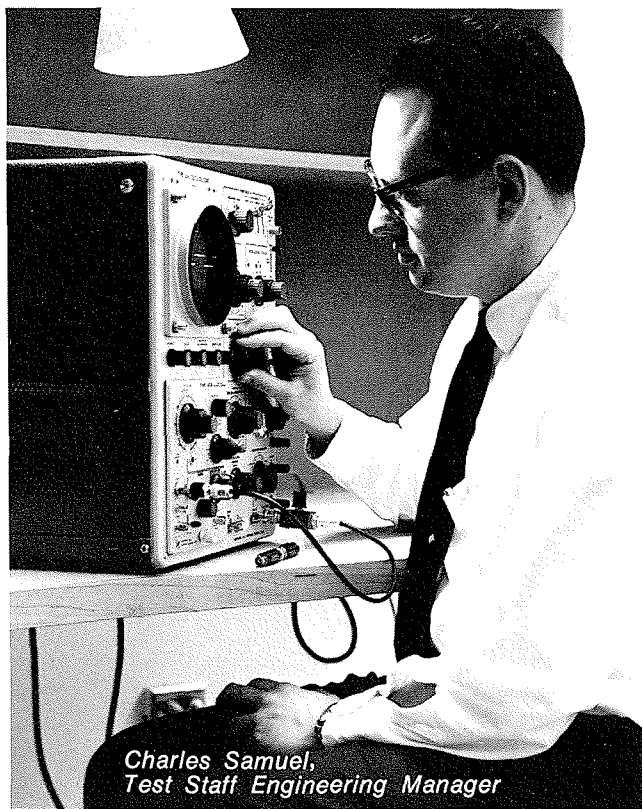
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## NOISE MEASURED WITH METER (RMS)

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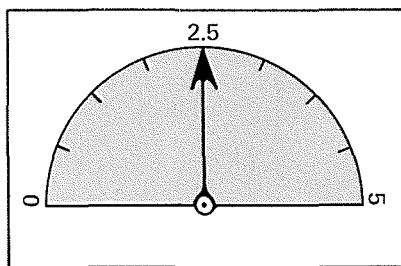
The most repeatable means of measuring noise is with a RMS voltmeter. This method requires access to the signal before it is displayed on the CRT. A calculation is necessary to convert RMS noise to a value corresponding to the CRT observation. The meter *must be* connected to the proper impedance point in the circuit



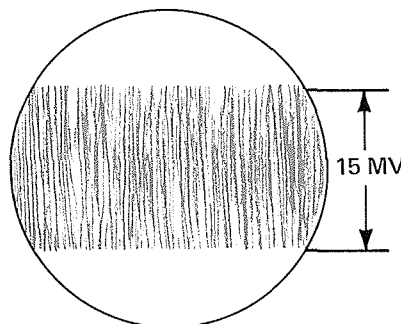


or the measured noise amplitude will be incorrect. RMS voltmeters are seldom used to describe noise for oscilloscope displays because:

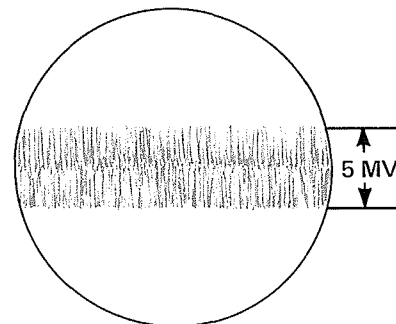
1. Oscilloscope users generally are interested in a specification which can be measured directly from a CRT observation.
2. The complexity of the various sources of noise make it impractical to completely specify noise and difficult to determine where in the circuit to make the measurement.
3. The meter bandwidth will affect the result.
4. Expensive instrumentation is required to verify the specification.



RMS noise  
2.5 mV  $\pm 2-5\%$



Apparent trace width  
15 mV  $\pm 50-300\%$



Displayed noise  
5 mV  $\pm 10-20\%$

Fig 1. Example illustrating relative amplitudes and accuracies of the three methods used to measure conventional oscilloscope noise at Tektronix.

## APPARENT TRACE WIDTH

The most convenient method of noise measurement is to determine the peak-to-peak vertical trace width due to noise. Measuring the noise directly at the CRT graticule is also the simplest way to determine the amount of noise present. This requires no extra equipment but is useful only on small amounts of noise deflection where accuracies of  $\pm 50\%$  or so are adequate.

Repeatable measurements are difficult to obtain with deflections larger than 0.2 divisions. Different amounts of noise are read at different times and the apparent noise value is changed by ambient lighting and trace intensity. Thus, this method is not adequate for verifying noise performance unless the specification is 0.2 divisions or less. With the apparent trace width method, it is only possible to state that the noise voltage is within a certain value for the time it is observed.

## DISPLAYED NOISE

Traditionally, the amplitude of random noise in an amplifier has been stated by an equivalent RMS value of the noise referred to the input. As previously discussed, describing the noise amplitude by stating its RMS value is somewhat unsatisfactory for CRT displays.

Noise interferes with an oscilloscope's usefulness and appears as a visible widening of the trace. This reduces the oscilloscope's ability to display and measure small vertical deflections. A measure of noise-limited resolution may be obtained by noting the vertical signal am-

plitude which will merge two noise traces into one. Noise measured in this manner is defined as displayed noise and is measured by the tangential noise measurement method. This method of stating the noise is more meaningful than the RMS value, since it more closely approximates the actual effect of noise interfering with measurements. It is also much more repeatable than just observing the trace width.

## TANGENTIAL NOISE MEASUREMENT

This method is useful with all noise-limited instruments (apparent trace width of 0.2 division or greater). The equipment required is listed below:

1. A squarewave generator, with an internal or external variable attenuator, to produce a frequency 1/10 or less the bandwidth of the oscilloscope.
2. A precision (e.g.,  $\pm 1\%$ ) 100X attenuator.
3. Necessary terminations, cables, etc.

By following the steps below, the displayed noise is easily measured.

1. Set up equipment as in fig 2.
2. Adjust the oscilloscope sweep controls for a free running sweep at about 0.2 ms/div. Adjust the oscilloscope intensity control for comfortable viewing; also adjust the focus and astigmatism controls if necessary. The setting of the CRT controls is not particularly critical. Any intensity which produces comfortable viewing may be used and sweep time can have any value that does not produce flicker.

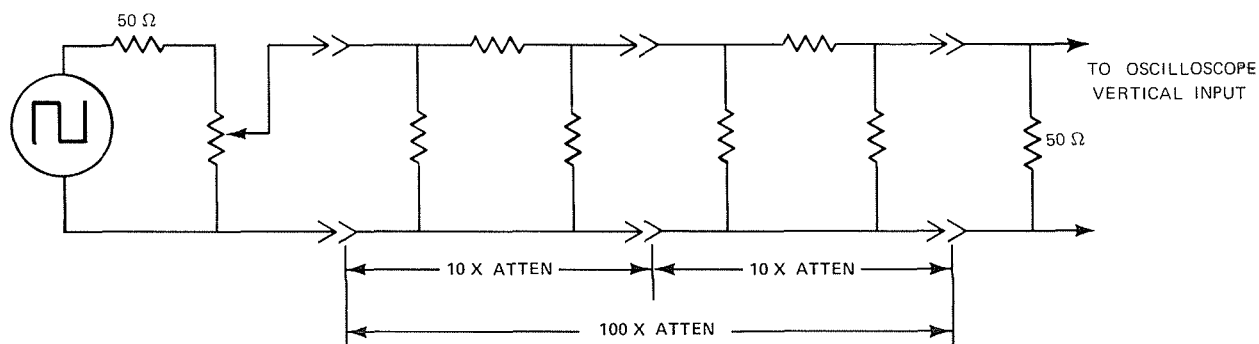


Fig 2. Equipment setup for measuring displayed noise.

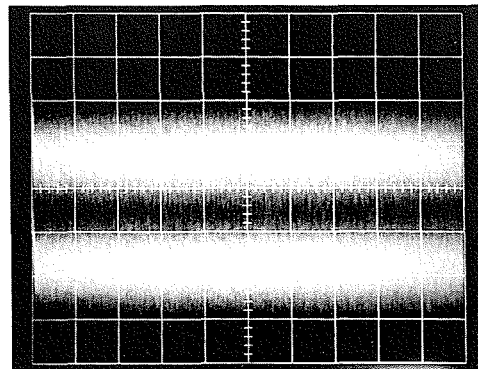


Fig 3. Initial setup for tangential noise measurement.

3. Set the oscilloscope vertical volts/division to the deflection factor where the noise is to be measured, and apply the signal from the test setup shown in fig 2. Adjust the squarewave amplitude so two bands of noise can be observed on the CRT, see fig 3.
4. Reduce the squarewave amplitude till the two noise bands merge (the point where the darker band between the noise bands just vanishes), see fig 4. The final amplitude adjustment should be made slowly, since the observer may adapt to the pattern and tend to observe a residual dark band where none is observable a few seconds later. A total adjustment time of 1 minute is typical.
5. Remove the 100X attenuator from the square-wave path, change the oscilloscope deflection to

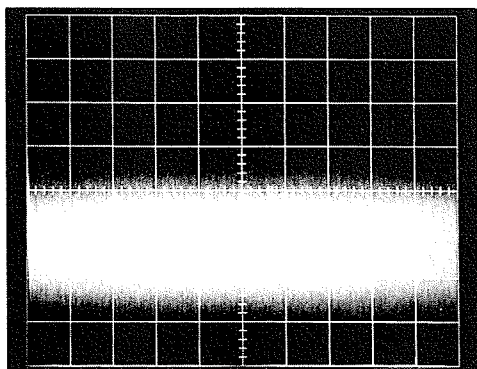


Fig 4. Final Adjustment. Dark band between the noise bands has just vanished.

a suitable value, and measure the squarewave amplitude. Divide this amplitude by 100 to obtain the amplitude of the displayed noise.

### RELATIONSHIP TO RMS VALUE

For the very common case of a Gaussian noise amplitude distribution (e.g., thermal resistance noise), tangentially measured displayed noise has a simple relationship to RMS noise: displayed noise  $\approx 2X$  RMS noise. A common situation where these relationships do not hold is for essentially Gaussian noise mixed with a comparable amount of single-frequency signal (i.e., hum).

### ACCURACY AND REPEATABILITY

The repeatability of the tangential method is relatively unchanged by changes in trace intensity or ambient lighting. The measurement accuracy depends primarily on the user's ability to detect small differences in the brightness of two adjacent regions. This difference threshold depends upon the absolute brightness of the regions, the brightness relative to background, the closeness of the regions (rate of change of brightness with dimension), the absolute angular size, and other factors. Under optimal conditions, brightness differences as small as 2% can be seen; a 50% brightness difference is always easily perceived. Experiments indicate

a 20% brightness difference may be perceived by most operators since conditions such as size, absolute brightness, and relative brightness are under the operator's control. Statistical analysis of independent measurements indicate that 99% of all observations should lie within 20% of the mean of all observations.

The relationship of the three measurement methods described was determined by experiment. Values were determined for the conversion factors described in the following 2 equations:

Noise measured with a RMS meter  $\times$  conversion factor 1 = displayed noise.

Displayed noise  $\times$  conversion factor 2 = apparent peak-to-peak trace width of noise band.

Five observers made measurements on each of 13 Tektronix Type 545B/1A7A Oscilloscopes. They made judgments of the amplitude of the noise band observed, measured the RMS noise with a meter at the signal output connector of the Type 1A7A, and measured the displayed noise by the method just described. These observations were tabulated and the conversion factors were determined. These conversion factors indicated that the following relationships are valid for conventional oscilloscopes:

Displayed noise  $\approx 2$  RMS equivalent noise

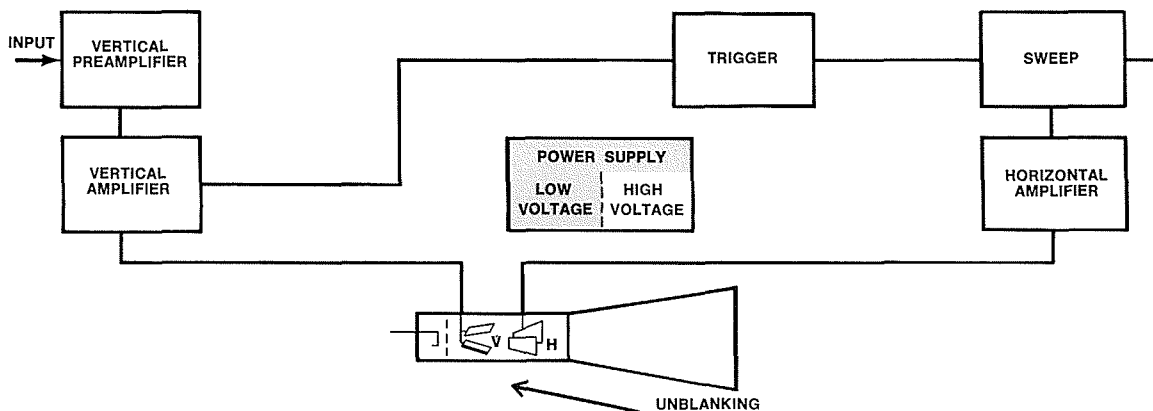
Displayed noise  $\approx \frac{\text{apparent trace width}}{3}$

Note that the visible effects of random noise on a CRT display (apparent trace width) is approximately 6 times the RMS noise value.

### CONCLUSION

A tangential noise measurement requires a minimum amount of equipment and offers an accuracy of approximately  $\pm 20\%$ . The mean of 5 observations should be accurate to  $\pm 10\%$ , provided a particular observer has no fixed bias. In comparison, the accuracy of the apparent trace width measurements may vary several hundred percent. The RMS meter is slightly more accurate than the displayed noise technique but requires more care and additional equipment to make an accurate measurement. As a result of these conclusions, all new Tektronix conventional oscilloscopes specify displayed noise performance by the tangential method of measurement discussed.

# SERVICE SCOPE



## TROUBLESHOOTING THE POWER SUPPLY

By Charles Phillips  
Product Service Technician  
Factory Service Center

*This second article in a series discusses troubleshooting techniques for Tektronix power supplies. The February TEKSCOPE discusses localizing problems to a major block of an oscilloscope.*

The power supply is the most fundamental block of an oscilloscope. The performance of the instrument is only as good as the condition of the power supply. The following information will assist in checking and obtaining the optimum performance from Tektronix power supplies.

For effective troubleshooting, examine the simple possibilities before proceeding with extensive troubleshooting. The following list provides a logical sequence to follow while troubleshooting:

1. Check control settings.
2. Check associated equipment.
3. Thorough visual check.
4. Check instrument calibration.
5. Isolate trouble to block.
6. Check voltages and waveforms.
7. Check individual components.

Incorrect operation of all circuits usually indicates trouble in the power supply. Check first for correct voltage of the

individual supplies. However, a defective component elsewhere in the instrument can appear as a power-supply trouble and may also affect the operation of other circuits. A short circuit in any regulated supply may cause the output level of all supplies in the instrument to drop to zero until the short is removed. If the output level of all the supplies is incorrect, check that the Line Voltage Selector Assembly is set for the correct line voltage and regulating range.

Most Tektronix manuals list the tolerances of the power supplies. If a power-supply voltage is within the listed tolerance, the supply can be assumed to be working correctly. If outside the tolerance, the supply may be misadjusted or operating incorrectly. When testing for shorts or overloads, remove the loads from the output filter. Check the resistance of each to segregate which load is causing the short or overload. Next, look in the defective circuit for connections from the power supply directly to ground. Diodes and potentiometers are a good place to start.

## CHECKING POWER SUPPLY REGULATION

Connect the oscilloscope under test to a variable auto-transformer. Turn off the sweep and calibrator, and monitor the individual supplies with a 1X probe, AC-coupled to the test oscilloscope. Begin with the reference supply since other supplies are related to this reference. Adjust the variable auto-transformer to the point where the supply goes completely out of regulation, noted by a large increase in ripple. Next, increase the line voltage to the point where the supply pulls into complete regulation, and note the

voltage. This point is the low-line regulation voltage (low-line regulation is checked in this manner because of the regulator tube characteristic of holding gain when heated). Next, increase the line voltage to the point where the supply starts to go out of regulation. This point is the high-line regulation voltage. Fig 1 illustrates the various line conditions normally encountered.

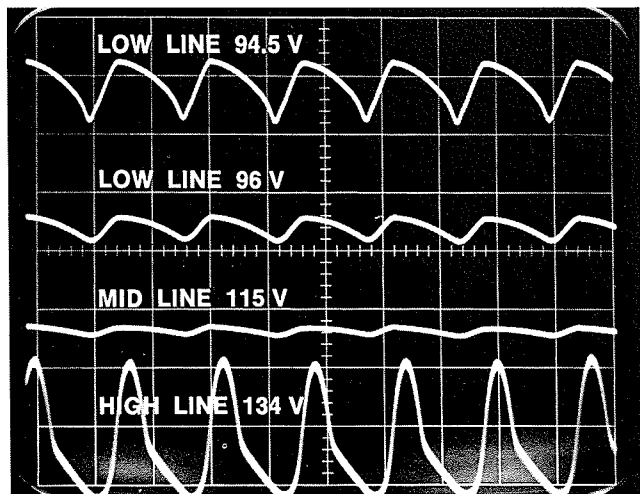


Fig 1. Regulation indications of a typical tube-type power supply.

### POWER SUPPLY NOISE

A power supply voltage with noise or microphonics can often be located by rapping softly with a finger. The finger acts as a convenient, reasonably uniform reference when checking for noise. It is often helpful to turn the oscilloscope upside down or on its side and then recheck. This will usually show up loose connections.

### RESISTANCE MEASUREMENTS

In tube type instruments (where stacking of supplies is common) the supply resistance will start at  $\approx 2\text{--}3\text{ k}\Omega$  in the reference supply and increase with each supply. Note—if a supply reads low ( $500\ \Omega$  or so) reverse your meter leads. Some voltage supplies employ a diode at the output and the low reading may be the resistance of the diode. If there is any doubt, consult the instrument manual and check the circuit schematic.

The same technique works with solid-state supplies, although the resistance values are lower. Solid-state power supplies, because of their lower impedance qualities, have supply resistances as low as  $25\text{--}50\ \Omega$ .

Silicon diodes can usually be checked in the circuit and typically read  $\approx 2\text{ k}\Omega$  in one direction. When a power supply diode fails it usually will be either a dead short or open. If an in-circuit check leaves doubt as to the condition of a supply, lift one end of the diode to be sure of the reading. Most silicon power supply diodes read  $\approx 2\text{ k}\Omega$  or  $\approx 2\text{ M}\Omega$ , depending on direction of current flow.

### DIFFERENCES IN TRANSISTOR SUPPLIES

Solid-state supplies are more and more common in present day electronic equipment. The following points summarize the major differences between vacuum tube and solid-state supplies:

1. Lower output impedance. As a result, solid-state supplies have lower output ripple—usually on the order of  $2\text{ mV}$ .
2. Resistance of supplies is typically lower but checking is the same due to stacking of supplies.
3. Supplies may be checked for shorts immediately after power is applied (no time delay relays).

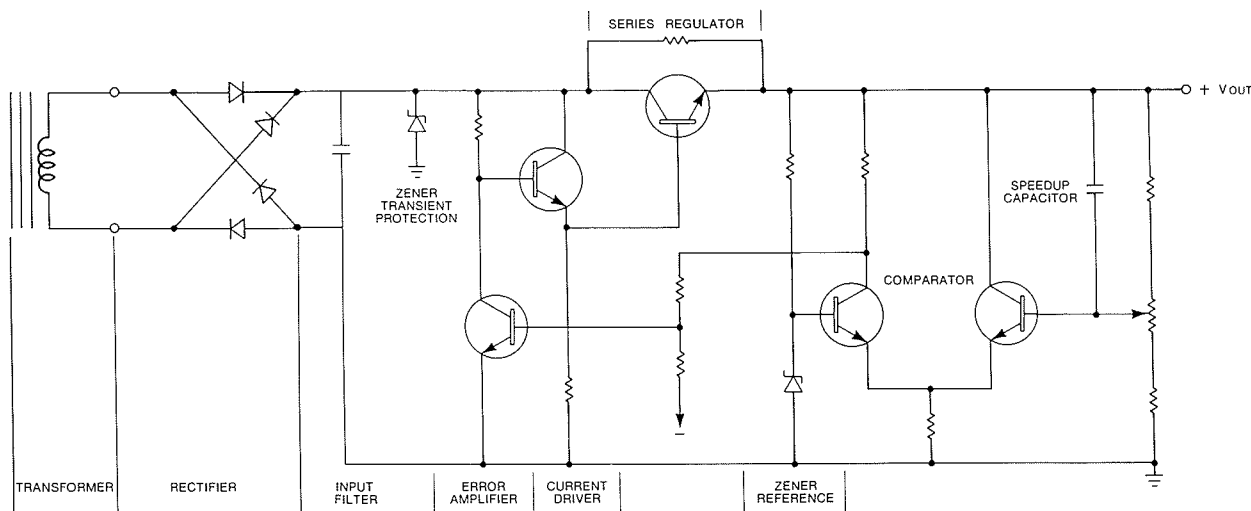


Fig 2. Simplified schematic of solid-state power supply.

4. Less problems with regulators because of less heat dissipation.
5. Varying line voltage does not provide as much information on regulation in a solid-state supply. Use a hair dryer to heat the power supplies, then cool with an aerosol circuit coolant to determine if a supply is faulty. This technique simulates the ambient conditions the supplies encounter over a longer period (2 or 3 hours) than the auto-transformer test. Often this check will indicate a heat sensitive device early and eliminate the need to recalibrate portions of the instrument twice.

### COMMON POWER SUPPLY PROBLEMS

1. Fuse blows when power is applied—shorted diode in bridge.
2. Fuse blows when time delay relay closes—overloaded output.
3. Excessive ripple—divide by 10 for approximate solidstate values.
  - (a) 50 mV to 1.5 V—comparator, speedup capacitor
  - (b) 1.5 V to 8 V—output filter
  - (c) 8 V or more—input filter
4. Off tolerance—leakage speedup capacitor (lift one end, change both output voltage setting resistors).
5. Poor regulation:
  - at 117 V line—weak compartor
  - at 105 V line—weak regulator
6. Noisy output—noisy comparator or regulator, noisy output voltage setting divider, noisy tube or poor connection.

### NOTE

Power transformers, manufactured in our plant, are warranted for the life of the instrument. If the power transformer is defective, contact your local Tektronix field engineer for a warranty replacement. Be certain to replace only with a direct replacement Tektronix transformer.

### IMPROVED BNC ATTENUATORS

A significant improvement in performance has been incorporated into a new series of BNC attenuators and terminations available from Tektronix. The new design features improved VSWR, greater bandwidth, increased reliability, and extended power ratings (see chart below).

SPECIFICATIONS OLD		NEW
Power Rating	1 watt	2 watts
VSWR — 250 MHz	(1.1 - 100 MHz)	1.1
VSWR — 500 MHz		1.2
Attenuation Ratio	+ 2% - DC + 3% - 100 MHz	+ 2% - DC + 3% - 500 MHz

These new accessories are shorter in length and lower in cost and are available in the following configurations: 50- $\Omega$  feedthrough terminations (white); 50- $\Omega$  2X attenuator (red); 50- $\Omega$  2.5X attenuator (white); 50- $\Omega$  5X attenuator (green); and 50- $\Omega$  10X attenuator (brown). In addition, a 5 watt 50- $\Omega$  feedthrough termination (black) is available.

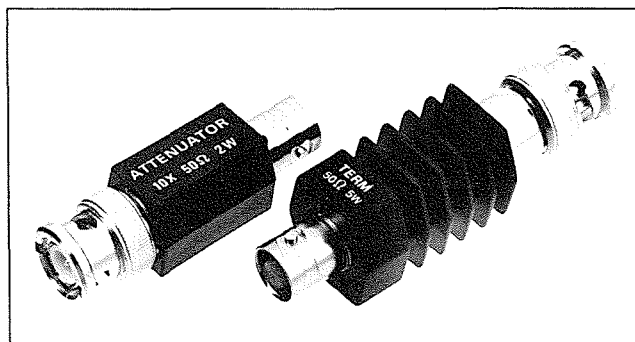


Fig 3. New two-watt attenuator and five-watt termination.

### TEKTRONIX WIRING COLOR CODE

All insulated wire and cable used in the Tektronix instruments is color-coded to facilitate circuit tracing. Signal carrying leads are identified with one or two colored stripes. Voltage supply leads are identified with three stripes to indicate the approximate voltage using the EIA resistor color code. (See fig 4). A white background color indicates a positive voltage and a tan background indicates a negative voltage. Note—older Tektronix instruments may use a black background to indicate a negative voltage. The widest color stripe identifies the first color of the code.

Black	0	
Brown	1	
Red	2	
Orange	3	
Yellow	4	
Green	5	
Blue	6	
Violet	7	
Gray	8	
White	9	

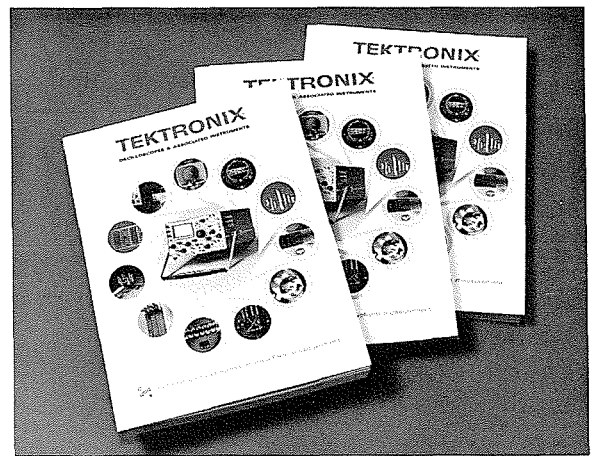
Fig 4. Tektronix color-coded insulated wire.

## 1969 TEKTRONIX CATALOG

The new 1969 Tektronix Instrument Catalog 28 has been distributed to the mail list and your copy should now have reached you.

Over 40 new Tektronix products have been added since mailing of Catalog 27. The catalog includes a new functional index in the rear and an expanded reference section in the front.

If you have not yet received your 1969 Tektronix Catalog, contact your local field engineer.



## INSTRUMENTS FOR SALE

1—Type 122 Low Level Preamplifier. Good condition. Contact: Mr. Ed McKenna, Mechanical Engineering Department, University of Colorado, Boulder, Colorado 80302.

1—Type 203, Model A, Scope-Mobile® Cart for 561A, with plug-in carrier. Contact: Mr. Kian Miradadian, 7020 Atwell, Houston, Texas 77036. Telephone: (713) MO7-5067.

1—Type 514AD, SN 139 in excellent condition. Latest mod kits and flat face tube. Price: \$275. Contact: Mr. George L. Garton, 3576 Texas Street, San Diego, California. Telephone: (714) 460-4509.

1—Type 524AD, SN 5715. Contact: Mr. George Groth, Jampiro Antenna Co., 6939 Power Inn Road, Sacramento, California 95828. Telephone: (916) 383-1177.

1—Type 561A, SN 20580; 1—Type 3S1, SN B090795; 1—Type 3T77A, SN 5463; 1—Type P6034; 1—Type P6035. Price: \$2,250. All in excellent condition. Contact: Judy Masters, Sudmier Enterprises, Inc., 1527 W. El Segundo Blvd., Gardena, California 90249. Telephone: (213) 754-2821.

1—Type 545B, SN 236; 1—Type W; 1—Type P6019, with 134 Amplifier. Contact: E. Schwab, 8 Chatham Place, Huntington, Long Island, New York 11743. Telephone: (516) 864-8725.

1—Type 535-S2, SN 5737; 1—Type CA Dual-Trace, SN 017641. Price: \$600 sold as a unit. Contact: James Hooper, Argonaut Insurance Company,

250 Middlefield Road, Menlo Park, California 94025. Telephone: (415) 326-0900 Ext. 44.

1—Type 422, SN 10685 (Mod 125 without battery pack). Price: \$1400. 1—Type 310A, SN 20903. Price: \$500. Contact: A Zandbergen, Northern Radio, 4027 - 21st Avenue West, Seattle, Washington 98199. Telephone: (206) AT 4-0534.

1—Type 512, SN 1016. Price: \$125. Contact: Larry Keyser, Econolite Division, 3644 Albion Place North, Seattle, Washington 98103. Telephone: (206) ME 3-2159.

1—Type 80/P80 Vertical Plug-In Probe with 5 attenuators, SN 003904. Price: \$125. 1—Type 81 Plug-In, SN 3149. Price: \$85. Contact: A. Barron, 1122 Brunswick Way, Santa Ana, California 92705. Telephone: (714) 540-1234.

1—Type 535A Oscilloscope. Two Scope-Mobiles®, Models 500/53A. Used moderately. Price: \$1,200. Contact: Miss Cannon, Biochemical Procedures, 12020 Chandler Blvd., North Hollywood, California 91607. Telephone: (916) 766-3926 Ext. 36.

1—Type 515; 1—Type 516. Good condition. Contact: Robert Galbraith, 11513 Bar Harbor Place, N. E. Albuquerque, New Mexico 87111. Telephone: (505) 264-6468 (work); (505) 298-9590 (home).

1—Type 541A, SN 022675; 1—Type B Plug-In, SN 019056; two probes. Contact: Alvin Walker, Electro of Arizona, 4025 N. 6th Street, Phoenix, Arizona 85012.

1—Type 545A; 1—Type D; 1—Type CA; 1—Type 160A; 1—Type 161; 1—Type 162; 1—Type 163. Contact: In-

telectron, Inc. P. O. Box 584, Waltham, Massachusetts 02154. Telephone: (413) 891-4114.

1—Type 310A, SN 21847. Price: \$450. Very good condition. Contact: Frank A. Hayes, Red Hill Road, Middletown, New Jersey 07748. Telephone: (201) 671-0271.

1—Type 585 Oscilloscope, SN 002799; 1—Type 80, SN 003456; 1—Type P80 Probe; 1—Type L Plug-In Unit, SN 019918; 1—Type 81 Adapter, SN 005-006. Price: \$1000 for entire package. Instruments recently factory calibrated. Contact: Mr. Art Godsen, Maritime Communications, 4210 Lincoln Blvd., Venice, California. Telephone: (213) 397-7705.

1—Type RM561, SN 717; 1—Type 2A63, SN 4463; 1—Type 3B3, SN 131. Will consider separate sales. Contact: Mr. Russ W. Johnson, Ball Brothers Company, P. O. Box 1062, Boulder, Colorado 80302.

## INSTRUMENTS WANTED

1—Type 545/CA or equivalent. Contact: Mr. Jerry Cowan, Sperry Rail Service Division Automation Industries, Shelter Rock Road, Danbury, Connecticut 06810. Telephone: Office (203) 748-9243, Home (203) 868-2252.

1—Type 585 with Type 82 Plug-In. Contact: Donald A. Paris, 48 East Circle Drive, East, Longmeadow, Massachusetts 01028. Telephone: (413) 525-2333.

1—Type S Plug-In. Contact: Dr. T. S. Chu, Electronic Sciences Department, Southern Methodist University, Dallas, Texas. Telephone: (214) 363-5611 Ext. 2221.





# TEKSCOPE

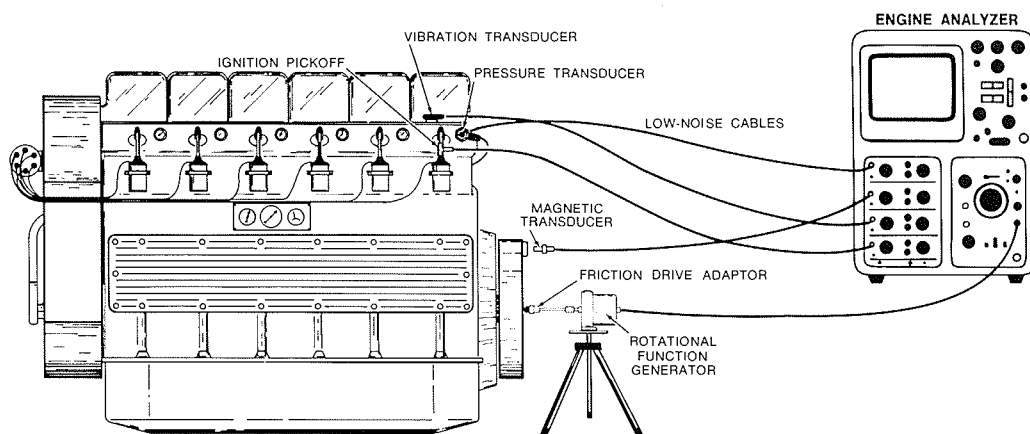
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Customer Information from Tektronix, Inc., P. O. Box 500, Beaverton, Oregon 97005  
Editor: R. Kehrli Artist: N. Sageaser For regular receipt of Tekscope contact your local field engineer.

## ENGINE ANALYSIS



### DISPLAY

### APPLICATION

Pressure-Time	Observe many combustion cycles to measure variations in peak pressures, rate of pressure rise, and r/min.
Pressure-Volume (Compressors, Pumps)	Evaluate performance of suction and discharge valves, compressor capacity, ring action, volumetric efficiency, and overall compressor, and pump operation.
Pressure-Volume (Combustion Engines)	Evaluate engine performance, cause of horsepower variation, measurement of efficiency, compression ratio, capacity, power balancing, and horsepower.
Pressure-Crankangle	Observe engine events (valve openings and closings, ignition or pre-ignition, etc.), against the crankangle at which they occur. Four-trace oscilloscope displays vibration, pressure, ignition, or any desired combination of curves required to evaluate compressor and engine performance.
Vibration Analysis	Detect, locate, and identify defective parts to uncover destructive detonation, improper valve functions, piston slap, improper function of compressor valves, worn valve cams, carbon buildup, blow-by, leaking valves, ring damage, blower bearings, engine cylinder run-in, and other malfunctions.
Ignition Analysis	Proper timing of engine, evaluation of breaker point gapping, point arcing, point bounce, low and high resistance in secondary circuits, spark plug condition, shorted primary, coil condition, etc.