A PRACTICAL APPROACH TO TRANSISTOR AND VACUUM TUBE AMPLIFIERS

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Two articles published in past issues of Service Scope contained information that, in our experience, is of particular benefit in analyzing circuits. The first article was "Simplifying Transistor Linear-Amplifier Analysis" (issue #29, December, 1964). It describes a method for doing an adequate circuit analysis for trouble-shooting or evaluation purposes on transistor circuits. It employs the "Transresistance" concept rather than the complicated characteristic-family parameters. The second article was "Understanding and Using Thevenin's Theorem" (issue #40, October, 1966). It offers a step-by-step explanation on how to apply the principles of Thevenin's Theorem to analyze and understand how a circuit operates.

Now, in this issue of Service Scope, we present the first of three articles that will offer a practical approach to transistor and vacuum-tube amplifiers based on a simple DC analysis. These articles will, by virtue of additional information and the tying together of some loose ends, combine and bring into better focus the concepts of "transresistance" and the principles of Thevenin's Theorem. We suggest that a "refresher" reading of the two previous articles will enable our readers to more readily follow the information in this and the two following issues of Service Scope.

The Editor

Part I
THE TRANSISTOR AMPLIFIER
INTRODUCTION

Tubes and transistors are often together to achieve a particular result. Vacuum tubes still serve an important role in electronics and will do so for many years to come despite a determined move towards solid state circuits.

Whether a circuit is designed around vacuum tubes or transistors or both, it is important to recognize the fact that the two are in many ways complementary. It is wrong to divorce vacuum tubes and transistors as separate identities each peculiar to their own mode of operation. Indeed, as this series of articles will show

there is an analogy between the two. It is true of course, that the two are entirely different in concept; but, so often we come across a situation where one can be explained in terms of the other that it is very desirable to recognize this fact.

Transistor and vacuum tube data give us very little help in the practical sense. Parameter Curves and electrical data show the behavior of these devices under very defined conditions. In short, they are more useful to the designer than the technician. We are often reduced to explaining most circuits in terms of an ohms law approach;

so, it seems pointless not to pursue this approach to its logical conclusion.

In this first article we will look at a transistor amplifier as a simple DC model; and then, in the second article, look at a vacuum-tube amplifier in a similar light. We will assume that both devices are operated as linear amplifiers and then use the results in a practical way.

One must bear in mind that this approach cannot be assumed in all cases. It is, as it is meant to be, a simple analysis but the results will prove to be a valuable tool in trouble-shooting and understanding circuits.

Let us consider the general equation for current through a P.N. diode junction.

$$I = I_o \left[\exp \frac{V}{\rho V_e} - 1 \right] \qquad (1)$$

where V = applied volts

I_o = reverse bias current

ρ = constant between 1 & 2

and $V_e = \dfrac{kT}{q}$ where k = Boltzmans

Const., 1.38×10^{-23} Joule/°Kelvin

T = absolute temperature in degree Kelvin at room temperature, i.e., $T = 300°K$

q = electronic charge 1.602×10^{-19} Coulomb.

$$V_e = \frac{300}{11600} = 0.026 \text{ volts}$$

OBJECTIVE

The objective of this paper is to present a practical approach to Transistor and Vacuum-tube amplifiers based on a simple DC analysis.

The articles will be published in the following sequence.

1. The Transistor Amplifier.
2. The Vacuum-tube Amplifier.
3. An analysis of a typical Tektronix hybrid circuit (Type 545B vertical) based on conclusions reached in (1) and (2).

As a corollary they will bring forward some important relationships between vacuum tubes and transistors.

One is quite justified in looking at a transistor in terms of the two-diode concept, refer to Figure 3. Therefore, assuming diode A to be forward biased and diode B to be reverse biased, as would be the case if we were to operate the transistor as a linear amplifier, the current through diode A will conform to equation (1). Let us take a closer look at Figure 2.

We define conductance in the general case as

$$g = \frac{I}{V}$$

and therefore at our operating point "A" the dynamic conductance

$$g' = \frac{\Delta I}{\Delta V} \qquad (2)$$

hence

$$g' = \frac{I_o \exp \dfrac{V}{\rho V_e}}{\rho V_e}$$

$$= \frac{I + I_o}{\rho V_e} \qquad (3)$$

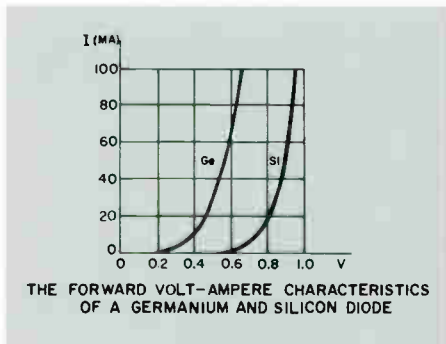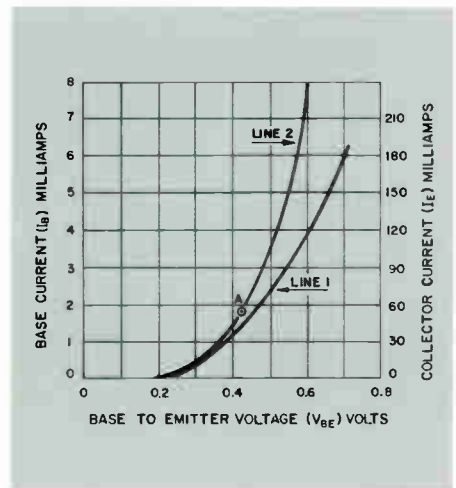THE FORWARD VOLT–AMPERE CHARACTERISTICS OF A GERMANIUM AND SILICON DIODE

Figure 1.

Figure 1 shows a typical forward volt/amp characteristic for germanium and silicon diodes. Figure 2 is a plot of the collector current or the base current versus the base-to-emitter voltage of a transistor; point A on this curve is a typical operating point.

Figure 2. Line (1) is a plot of the base current versus the base-to-emitter voltage (V_{BE}). Line (2) is a plot of the collector current versus the base-to-emitter voltage (V_{BE}). Point "A" is a typical operating point.
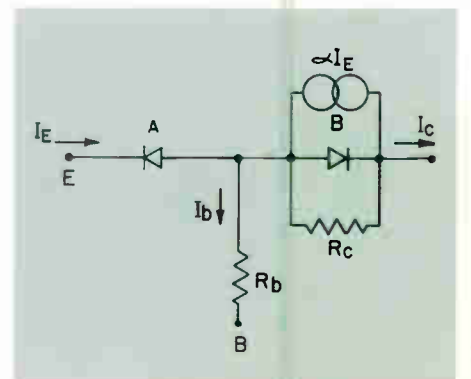

Figure 3. Illustration of the two-diode concept of a transistor.

but $I >> I_o$ then $g' = \dfrac{I}{\rho V_e}$

or $g' = \dfrac{I}{0.026\rho}$ mhos (4)

The term "ρ" takes into account the recombination of carriers in the junction region. It is approximately unity for germanium and approximately 2 for silicon. At a typical operating point this term can usually be neglected. Therefore, we may say that

$g' = \dfrac{I}{26}$ if I is in milliamps. (5)

Now resistance is the reciprocal of conductance and therefore the value of conductance at point "A" can be given in terms of resistance

$r_e = \dfrac{26}{I}$ Ω's (6)

This resistance (r_e) is commonly known as the dynamic emitter resistance.

At this point we will depart from our simple model and look at the transistor in another form; but, bear in mind our first thoughts. Transistor parameters are derived from various equivalent circuits depending upon the configuration i.e., common emitter, common base, or common collector. We will not consider any detailed analysis in this approach; but, to understand the approach it is necessary to know how these parameters are derived. It will be simple enough to derive another set of parameters once we have our basic model constructed.

The simplest and easiest equivalent circuit of a transistor is the "Tee" equivalent. It is a very good approximation about the behavior of a transistor, especially at DC and low frequencies. We can also represent either the common emitter or the common base simply by interchanging R_b and R_e. Figure 4 is a "Tee" equivalent circuit of
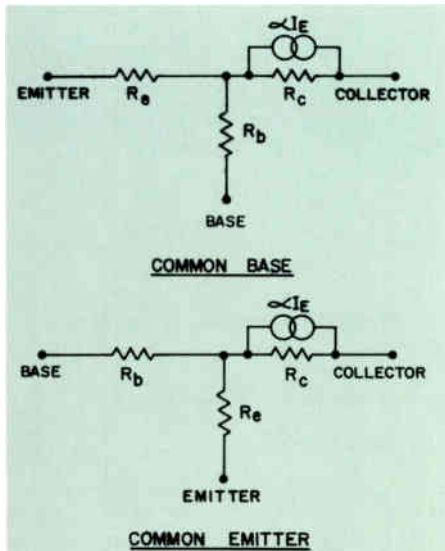

Figure 4. "Tee" equivalent circuits for the common-base and common-emitter configurations of transistors.

the common emitter and the common base configurations.

Firstly, let us define the term β (the small-signal current gain) as

$\beta = \dfrac{\Delta I_c}{\Delta I_b}$ (7)

and since $I_E = I_c + I_b$

then $I_E = I_c \left(1 + \dfrac{1}{\beta}\right)$ (8)

usually $\beta >> 1$ then $I_E \approx I_c$

Equation (8) shows us that only $\dfrac{1}{\beta}$ of the emitter current flows into the base. Hence, it is reasonable to suppose that any impedance in the emitter, when viewed from the base, will be β times as great; and, any impedance in the base, when viewed from the emitter, will be β times as small. That is to say, the dynamic resistance multiplied by β must equal R_e in our equivalent "Tee" circuit.

Hence $R_e = \beta r_e$

Our equivalent circuit shows a resistance R_b. This resistance is known as the base-spreading resistance. It is a physical quantity and can be expressed in terms of resistivity associated with the base-emitter junction. It can vary between a few ohms to hundreds of ohms, depending upon the type of transistor; and therefore, must be taken into consideration. Looking into the emitter we see it as an impedance whose value is divided by β and appears in series with the dynamic emitter resistance (r_e). Hence the emitter current encounters an impedance in the base/emitter junction which is equal to the sum of the dynamic resistance plus $\dfrac{R_b}{\beta}$, the latter term we will designate R_r and the sum of these two resistances we will designate R_t.

Hence $R_t = r_e + R_r$ (9)

The value of R_r can vary anywhere between $2\,\Omega$ to $24\,\Omega$ depending on the value of R_b. R_b is difficult to measure and rarely given in electrical data on transistors. A figure of $250\,\Omega$'s is a typical value at low frequencies. Therefore, if β were 50 then R_r would be $5\,\Omega$'s.

Now if we look into the base in the common emitter or the common collector configuration it is reasonable to suppose we will see the resistance (R_t)—plus any other impedance which may be wired to the emitter terminal—multiplied by β, then

$R_{in} = \beta(R_t + R_E)$ (10)

where R_E = the external emitter resistance.
If $R_E >> R_t$ then $R_{in} = \beta R_E$

So far we have had very little to say about R_e shunted by the current generator $\propto I_E$. If our equivalent "Tee" circuit consisted of resistances alone, it would be passive; i.e., it could supply no energy of its own. But a transistor can amplify energy to the signal. To represent this we have shown a current generator shunting R_e. The value of R_e will depend on the circuit configuration; i.e., tens of kilohms for a common emitter configuration, to many megohms for a common base configuration. In our approach it is not necessary to pursue this matter any further since we will not be considering a transistor in any extreme condition.

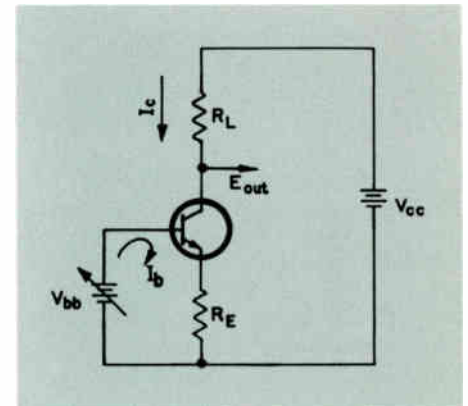Now in a more practical sense, let us look at Figure 5, a typical common-emitter configuration.

Figure 5. A typical common-emitter circuit.

Now we will assume $R_e >> R_L$.

Now by inspection

$E_{out} = V_{cc} - \Delta I_c R_L$ (11)

hence $\Delta E_{out} = -\Delta I_c R_L$ (12)

The input impedance we see looking into the base of a transistor in the common emitter configuration is

$R_{in} = \beta(R_E + R_t)$ (10)

also $\Delta I_b = \dfrac{\Delta V_{bb}}{R_{in}}$

$= \dfrac{\Delta V_{bb}}{\beta(R_E + R_t)}$ (13)

we also recall that

$\beta = \dfrac{\Delta I_c}{\Delta I_b}$ (7)

hence $\Delta I_c = \beta \Delta I_b$ (14)

Therefore substituting equation (13) in equation (14)

$\Delta I_c = \beta \dfrac{\Delta V_{bb}}{\beta(R_E + R_t)}$ (15)

and from equation (15)

$\Delta V_{bb} = \Delta I_c (R_E + R_t)$ (16)

we define the voltage gain as

$$A_{(v)} = \frac{\Delta E_{out}}{\Delta V_{bb}}$$

Then from equation (12) and equation (16)

$$A_{(v)} = - \frac{\Delta I_c \, R_L}{\Delta I_e \, (R_E + R_t)} \qquad (17)$$

$$= - \frac{R_L}{R_E + R_t}$$

and if $R_E >> R_t$ then

$$A_{(v)} = - \frac{R_L}{R_E} \qquad (18)$$

If we analyze the common-base configuration in a similar manner we arrive at the same result with the one exception that the sign is positive.

The conclusion we can draw from this analysis is that the gain of a transistor stage is set by external conditions provided that the emitter resistance is sufficiently great enough to "swamp" our internal resistance (R_t). In the absence of an emitter resistance

$$A_{(v)} = \frac{R_L}{R_t}$$

There is one very important fact we must remember about R_E. R_E will be that impedance in which the signal current will flow to the AC ground. We define an AC ground point as that point in a circuit at which the power level of the signal has been reduced to zero.

We normally encounter three types of an AC ground:

1. An Actual AC Ground.

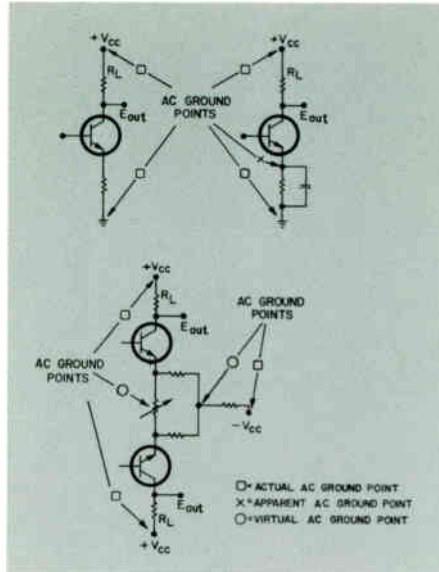This is the chassis point or the DC ground point. It is as well to remember the

Figure 6. Illustrating the three types of AC ground normally encountered in electronic circuits.

power supply can be placed in this category so far as the signal is concerned.

2. An Apparent AC Ground.

The apparent AC ground may be represented by any point in a circuit which acts as to represent a low impedance between that point and the actual AC ground thereby bypassing the signal to an actual AC ground. A large value capacitor is a typical example should one side be returned to an actual AC ground.

3. The Virtual AC Ground.

The virtual A.C. groun point is perhaps the most difficult to recognize. It may best be explained as that point in a circuit where we have two signals of equal amplitude and frequency but exactly opposite in phase. Figure 6 will help clarify these points.

Figure 8 summarizes the results of our DC analysis of the common emitter, common base and common collector.
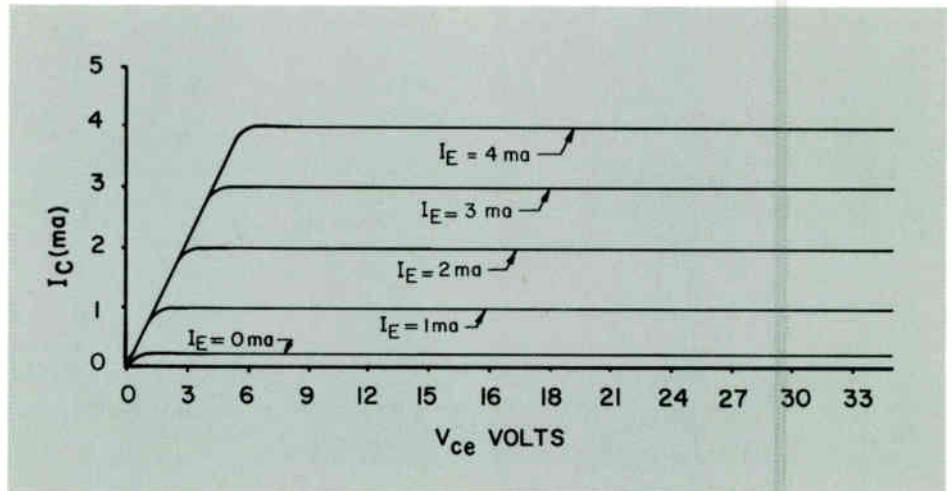

Figure 7. We define the parameter $\bar{R}_c$ in the common-base "Tee" configuration as;

$$R_c = \frac{\Delta V_{ce}}{\Delta I_c} \bigg|_{I_E} \text{ ohms}$$

Where ΔV_{ce} is the change in the collector voltage because of the change in collector current ΔI_c, when we hold the emitter current I_E constant.

Once the collector becomes saturated, the change in I_c is very small for a large change in V_{ce}. Hence, R_c is a very large resistance and does not modify the DC equivalent circuit to any extent. For this reason it was omitted from Figure 7. Therefore; $R_{out} = R_L$ (Common Base).

LIST OF SYMBOLS

$A_{(v)}$ Voltage gain defined as $\frac{\Delta E_{out}}{\Delta E_{in}}$

I_b Base current

I_c Collector current

I_E Emitter current

R_c Collector resistance (Tee Equivalent)

R_b Base spreading resistance (Tee Equivalent)

R_e Emitter resistance (Tee Equivalent)

R_E External Emitter resistance (refer to text)

$R_{E(s)}$ The equivalent resistance between the signal source and the emitter terminal of the transistor in the common base configuration.

R_L Load resistance

R_r $\frac{R_b}{\beta}$

R_t The "Transresistance" resistance ($r_e + R_r$)

r_e dynamic emitter resistance

V_{bb} Base voltage

V_{cc} Supply voltage

V_{ce} Collector to emitter voltage

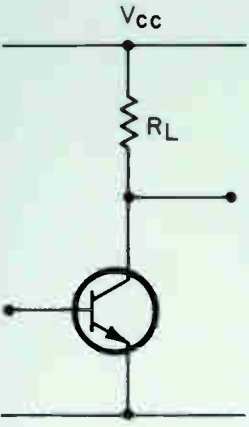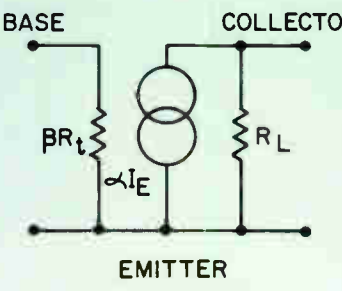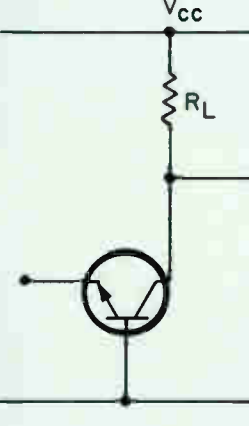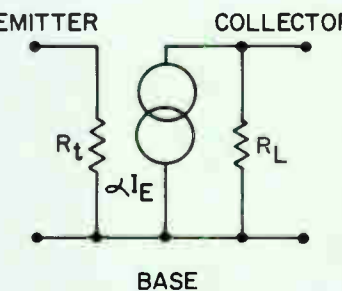Δ (Delta) the change in the variable with which it is associated.

BASIC CIRCUIT	EQUIVALENT CIRCUIT	EQUATIONS	REMARKS
		$\text{GAIN} = A(v) = -\dfrac{R_L}{R_t}$ $R_{IN} = \beta R_t$	A resistance (R_E) between the emitter terminal of the transistor to the AC ground will modify the gain equation and the input impedance; then, $A(v) = -\dfrac{R_L}{R_t + R_E}$ and $R = \beta (R_E + R_t)$.
	COMMON EMITTER		
		$\text{GAIN} = A(v) = +\dfrac{R_L}{R_t}$ $R_{IN} = R_t$ $R_{OUT} = R_L$	The equivalent resistance $R_E(s)$ between the input signal source and the emitter terminal of the transistor will modify the gain equation and the input impedance as seen from the signal source; then, $A(v) = +\dfrac{R_L}{R_t + R(s)}$ and $R = R_t + R(s)$.
	COMMON BASE		
		$\text{GAIN} = A(v) = \dfrac{R_E}{R_E + R_t}$ $R_{IN} = \beta (R_E + R_t)$ $R_{OUT} = \left(R_t + \dfrac{1}{\beta}\right)$ in parallel with R_E	The actual value of R_{out} will depend on what resistance is connected to the base. Let us assume the base is directly coupled to the preceding stage. The equivalent output impedance of the preceding stage becomes the numerator over beta in the second term in the parenthesis and the output impedance of the stage under consideration R_{out} is modified accordingly; eg., if the output impedance of the previous stage is 100 Ω, then $R = \left(R_t + \dfrac{100}{\beta}\right)$ in parallel with R_E.
	COMMON COLLECTOR		

Figure 8.

SERVICE NOTES

SILVER-BEARING SOLDER AND SILVER SOLDER: TWO DIFFERENT THINGS

Many components in Tektronix instruments are mounted on ceramic strips. The notches in these strips are lined with a silver alloy and repeated use of ordinary tin-lead solder will breakdown the silver-to-ceramic bond. For this reason, we recommend the use of a silver-*bearing* solder containing 3% silver when performing service or maintenance work that requires soldering on these ceramic strips. This type of solder is used frequently in printed circuits and should be readily available from radio-supply houses.*

Silver-*bearing* solder should not be confused with silver solder. They are two different things!

The use of silver-*bearing* solder in the construction and maintenance and repair of electronic circuits is a safe and accepted practice. The silver-*bearing* solder used and recommended by Tektronix for ceramic strip soldering, melts at about 365 degrees Fahrenheit, and is applied with an ordinary soldering iron. It is composed of 60% tin, 37% lead, and 3% silver. It contains absolutely no cadmium! It produces no toxic or lethal fumes!

Silver solder, on the other hand, is a brazing alloy and is most commonly used by welders. It is composed essentially of silver, copper, zinc, and sometimes cadmium. When the alloy is composed of 45% silver, 30% copper and 25% zinc it requires approximately 1340 degrees Fahrenheit and it is usually applied with an acetylene torch. Should either the silver solder or the metals to which it is being applied contain cadmium, this high temperature will cause the cadmium to vaporize and release fumes. These fumes will be toxic and they can be lethal.

In summary, let us repeat; Silver-*bearing* solder and silver solder are two different things:

Silver-*bearing* solder is used primarily in the soldering of electronic circuits. Silver solder is an alloy used in the brazing and welding of metals.

Silver-*bearing* solder is applied with a soldering iron and requires only relatively low temperature to melt it. Silver solder is applied with an acetylene torch and requires a high temperature to melt it.

Silver-*bearing* solder absolutely does not produce toxic fumes. Silver solder, if it contains cadmium or is used on metal containing cadmium, does produce fumes that are toxic and can be lethal.

Positively no silver solder is used in any instrument produced by Tektronix, Inc.

> *If you prefer you can order this solder directly through your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor. Order Tektronix part number 251-0515-00.

OOPS! WRONG PART NUMBER

In the December 1966 issue of Service Scope, we transposed two figures in the Tektronix part numbers for the probe identification tags. The part number for the identification tags for use on the smaller (0.125" diameter) cables is 334-0798-00, and the number for the larger (0.178 to 0.185" diameter) cables is 334-0798-01.

COMPONENT LUBRICATION KIT FOR TEKTRONIX INSTRUMENTS

We have available a component lubrication kit for Tektronix instruments. The kit contains: a detent lubricant in a container-applicator; a switch-contact lubricant in a container-applicator; a pot lubricant in a container-applicator; 12 each detent-ball replacements (for lost or worn detent balls) in the following sizes—5/32", 3/16", and 7/32"; a #3 brush, and an instruction book.

The instruction book contains information on the cleaning and washing of Tektronix instruments and when an instrument needs lubrication. It also contains illustrations showing the different types of switches used in Tektronix instruments and tells how to lubricate them and replace worn or lost detent balls. The lubrication of potentiometers and fan motors and the care of air filters are also covered. Suggestions for the lubrication of rackmount tracks are given.

You may order the kit through your local Tektronix Field Office, Field Engineer, Field Representative, or Distributor. Specify Tektronix part number 003-0342-00.

TYPE 1L5, TYPE 1L10, TYPE 1L20, AND TYPE 1L30 PLUG-IN SPECTRUM ANALYZERS WITH A TYPE 132 POWER SUPPLY

These spectrum analyzers can be used in conjunction with a Type 132 Plug-In Unit Power Supply and the output displayed on any Tektronix oscilloscope that has a Sawtooth-Out sweep voltage available on the front panel.

Positive output-polarity voltage from the Type 132 can be applied to the DC-coupled input of the oscilloscope. Centering of the oscilloscope sweep is performed with the oscilloscope vertical-position control prior to RF signal application to the analyzer. The analyzer vertical-position control can then be used for trace positioning.

The Sawtooth-Out sweep voltage from the oscilloscope is applied to the Sweep-Input connector.

TYPE 1L10, TYPE 1L20, AND TYPE 1L30 PLUG-IN SPECTRUM ANALYZERS—VERTICAL TRACE SHIFT

If a vertical trace shift is encountered when a Type 1L10, Type 1L20, or Type 1L30 Plug-In Spectrum Analyzer is switched between linear and log mode, suspect a gassy input tube in the indicator (oscilloscope) vertical amplifier. The output impedance of the analyzer unit is much higher in the log mode than it is in the linear mode. If grid current is present in the input tube, this current will give a different voltage drop across the input resistance (analyzer output impedance); consequently, a DC shift of the trace will result.

1—Type 110 Pulse Generator, sn 663. Price: $400.00. Please contact: Wheeler Electronics, 3558 West Lawrence Street, Chicago, Illinois 60625. Attn: Mr. A. C. Tripoli. Telephone: 312—588-1443.

4—Type K Fast-Rise DC Units; 4—Type S Diode Recovery Units; 4—Type 105 Square-Wave Generators. All equipment is new, unused and in original shipping cartons. Please contact: Jerry Kreutz, P. O. Box 1018, Hawthorne, California. Telephone: 213—SP2-4551.

1—Type 516 Oscilloscope, sn 003086. Approximately one year old. Excellent condition. Contact: Lee Gibbons, Dia-Log Company, Houston, Texas. Telephone: 713—R17-2100.

1—Type 545B Oscilloscope (with dual sweep delay), sn 1838; 1—Type 1A2 Dual-Trace plug-in unit, sn 0642. Factory specification for dual-channel bandwidth and risetime of this oscilloscope-plug-in combination is DC to 33 MHz— 10.5 ns at 50 mV/cm. Instruments new in March 1965. Contact: John H. Cone, 775 South Madison, Pasadena, California 91106. Telephone: 213 —792-5271.

1—Type 516 Oscilloscope, sn 3668. Price: $900.00. In excellent condition. Please contact Mr. Oniki, Sony Corporation, 47-47 Van Dam Street, Long Island City, New York. Telephone: 212— 361-8600.

1—Type 514 Oscilloscope, sn 5370. In good condition. Please contact: Frank Butler, 10 Clive Place, E. Northport, New York 11731.

The Superior Electric Company offers the following Tektronix instruments for sale:
1—Type 104 Square-Wave Generator, sn 450. Price: $50.00.

2—Type 122 Low-Level Preamplifiers, sn's 524 and 529. Price: $50.00 each.
1—Type 53/54E Low-Level AC Differential Plug-In Unit, sn 230. Price: $100.00.
1—Type 502 Oscilloscope, sn 1003. Price: $625.00.
1—Type 502 Oscilloscope, sn 2139. Price: $650.00.
Please contact: Eric W. Vaughan, The Superior Electric Company, 383 Middle Street, Bristol, Connecticut 06012. Telephone: 203—582-9561.

3—Type 517A Oscilloscopes. Please contact: Bill Hart, Vicon, Inc., P. O. Box 1676, Colorado Springs, Colorado.

We have the following Tektronix equipment for sale:
1—Type 547 Oscilloscope
1—Type 1A1 Dual-Trace Plug-In Unit
1—Type 128 Probe Power Supply
1—C-12 Camera
1—TU5 Pulser
1—P6008 Probe
1—P6028 Probe
1—P500CF (Cathode-Follower) Probe
1—Scope-Mobile® Cart
1—Viewing Hood
Plus assorted tool alignment kits. standardizers, and connectors.
Best offer on the lot. Contact Mrs. Al Browdy, 1962 S. Stearns Drive, Los Angeles, California 90034.

1—Type 315D Oscilloscope, sn 1155. This instrument is in excellent condition. Please contact Joe Buffington, 114 Ladera Street, Monterey Park, California. Telephone: 213—289-8157.

2—Type 502 Oscilloscopes. Pick from the 5 following serial numbers: 2847, 2848, 4033, 4034,

and 4268. $550.00 each. Contact Mr. Harry Halton or Mr. Robert Nelson, Benson-Lehner Corporation, 14761 Califa Street, Van Nuys, California 91401. Telephone: 781-7100.

1—Type RM527 Television Waveform Monitor, sn 000590. Contact: Ed Tink, Chief Engineer, KWWL-TV, Waterloo, Iowa. Telephone: 319— 234-4401.

1—Type 533A Oscilloscope; 1—Type 1A1 Dual-Trace Plug-In Unit. These are new instruments. Contact Robertson Photo-Mechanix, Inc., 250 West Willie Road, Des Plaines, Illinois 60018. Telephone: 312—827-7711. Ask for Dave Krzak or Bayne Gibson.

1—Type 524AD Television Oscilloscope sn 7077. Instrument is 3 years old and in very good condition. Price: $780.00. Please contact: Mr. Talbot, Loyola University, TV Department, 7101 W. 80th Street, Los Angeles, California. Telephone: 213—776-0400, Ext. 352.

1—Type P Fast-Rise Test Plug-In Unit, sn 2530. About 4 years old, in new condition. Price: $50.00. 1—Type Q Transducer and Strain Gage Plug-In Unit, sn 1742. About 2 years old, new condition. Price: $275.00. All instruments FOB West Palm Beach, Florida. Contact: Jerry Strasser, Solitron Devices, Inc., 1177 Blue Heron Boulevard, Riviera Beach, Florida. Telephone: 305—848-4311.

1—Type 544 Oscilloscope; 1—Type 1A2 Dual-Trace Plug-In Unit; 1—P6016 AC Current Probe; 1—Type 131 Amplifier. Approximate age 14 months. Contact Tom Thompson, Bemis Bag Company, 325-27th Avenue, N.E., Minneapolis, Minnesota.

1—Type 3A3 Dual-Trace Differential Amplifier (Plug-In Unit). Please contact American Optical Company, Medical Division, Crosby Drive, Bedford, Massachusetts 01730, Attn: Mr. Carlo D'Agostino.

1—Type 310A Oscilloscope in good condition. Contact W. Shibler, 5899 Barnes Avenue, Bethel Park, Pennsylvania 15102. Telephone: 412—835-7015.

1—Type 504 Oscilloscope. Please contact Mr. Al Margolin, Certified Test Equipment Service, 8136 Orion Avenue, Van Nuys, California 91406. Telephone: 213—781-4123.

1—Type 513 Oscilloscope to cannibalize for parts. Especially need a Type 210B high voltage supply. Contact Ron Silver, 2576 Wren Road, Salt Lake City, Utah. Telephone 277-1697.

1—Type 543A Oscilloscope; 1—Type L Fast-Rise High-Gain Plug-In Unit. Contact Jerry W. Keefe, Box 399, R.R. #1, Le Claire, Iowa.

1—Type N Plug-In Unit in at least marginal condition. Under $200.00. State malfunction and condition. 2—Type CA Dual-Trace Plug-In Units in operable condition; 1—Type H Wide-Band High-Gain Plug-In Unit. Contact Robert Baer, 921 Lincoln Avenue, Palo Alto, California 94301.

1—Type 531 or 1—Type 532 Oscilloscope in good condition. Please contact Mr. Ernie Guerri, Translab Inc., 4754 Federal Boulevard, San Diego, California 92102. Telephone: 714—263-1876.

1—Type 503 Oscilloscope. Contact Jim Grichnik, 1107 South Aldine, Park Ridge, Illinois. Telephone: 312—825-3538.

1—DC to 15 MHz Oscilloscope with dual-trace capabilities. Sweep delay not required. Will consider Type 516, Type 422, Type 530 Series and/or Type 540 Series (with plug-ins) Oscilloscopes. Contact Harvey Smith, Rt. 1, Box 323A, Morgantown, West Virginia 26505. Telephone: 304—292-5293.

Following are the instruments reported to us in the past 60 days as lost or presumed stolen. With each instrument (or group of instruments) we list their legal owner. Should you have any information on the present whereabouts of any of these instruments, or if you have information that might lead to their eventual recovery, please contact the individual or firm listed as the owner. If you prefer, you may relay your information to your local Tektronix Field Office, Field Engineer or Field Representative. Or, The Editor, Service Scope, Tektronix, Inc., P. O. Box 500, Beaverton, Oregon 97005. Telephone: 503—292-2611, Ext. 318.

1—Type 453 Portable Oscilloscope, sn 2702. Last seen at the Van Nuys Field Office in California. Contact: Mr. Bill Carter, Tektronix, Inc., 16930 Sherman Way, Van Nuys, California. Telephone 213—987-2600.

1—Type 321 Oscilloscope, sn 4259, has been either lost or stolen from the Miami, Florida UNIVAC Office. Anyone with information regarding this instrument should call collect. Telephone: 305—758-4764.

1—Type 191 Constant-Amplitude Signal Generator, sn 784. Missing from Sprague Electric

Company, 115 Northeast Cutoff, Worcester, Massachusetts 01606. Please contact: Mr. Eugene Baxter. Telephone: 617—791-9211, Ext. 251.

1—Type 321A Portable Oscilloscope, sn 4282, tagged with Air Force Property Tag #06-68864 on front or top of case. Disappeared from Aerospace approximately October 14, 1966. If this is found, Mr. McQuady or Mr. Kingon should be notified at Aerospace, Security Dept., Box 95095, Los Angeles, California 90045. Telephone: 213—648-6124.

1—Type 453 Portable Oscilloscope, sn 4227, has been reported missing from Mr. Gene Brammer, Massachusetts Inst. of Tech., Project MAC, 545 Technology Square, Room 821, Cambridge, Mass. Telephone: 617—864-6900, Ext. 5862.

1—Type 561A Oscilloscope, sn 11563 and 1— Type 3B3 Time Base Unit, sn 2314, are missing and presumed stolen from The Bunker-Ramo Corp., 427 South LaSalle, Chicago, Illinois. Please contact Mr. Lemoine. Telephone: 312— 922-2172.

1—Type 310A Portable Oscilloscope, sn 18962. On November 28, 1966, this instrument disappeared from the premises at Filmotype Corp., 8 West 40th Street, New York, New York 10018. Telephone: 212—LA 4-7371.

1—Type 561A Oscilloscope, sn 14844; 1—Type 2B67 Time Base Unit, sn 13062; 1—Type 3A6 Dual-Trace Plug-In Unit, sn 1100. This oscilloscope and plug-in units were shipped air express from a customer in Wisconsin Rapids to Tektronix Field Office in Chicago and lost in transit. Please refer any information to your local Tektronix Field Office.

1—Type 453 Portable Oscilloscope, sn 3063 and 1—Type 422 Portable Oscilloscope, sn 1957, are missing and presumed stolen from Honeywell, Inc., at 235 Montgomery Street, San Francisco, Calif. Please contact: Ronald Faith, Branch Manager, Field Service Dept. Telephone: YU 1-8010.

1—Type 564 Oscilloscope, sn 3969; 1—Type 2B67 Time Base Unit, sn 13230; 1—Type 3A74 Four-Trace Amplifier Unit, sn 1032. These instruments have been missing since December 26, 1966. Contact: Mr. Pete Vanderhelft, Robotron Corp., 21300 West Eight-Mile Road, Detroit, Michigan 48219.

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Mr. Ed Harding   4/66
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RETURN REQUESTED