Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 43 PRINTED IN U.S.A. APRIL 1967

PRACTICAL APPROACH TO TRANSISTOR AND VACUUM TUBE AMPLIFIERS

BY F. J. BECKETT

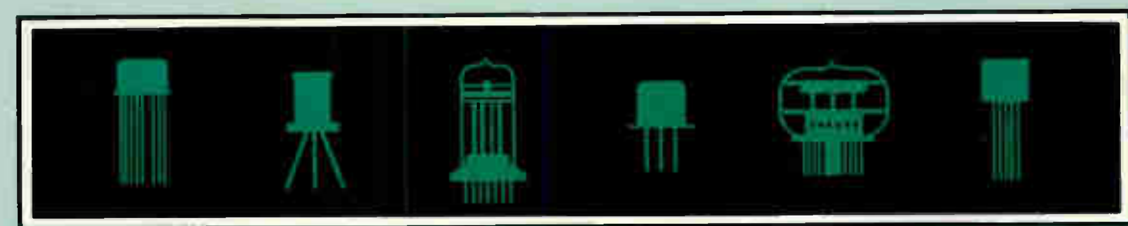
TEKTRONIX, INC.

ELECTRONIC INSTRUMENTATION GROUP

DISPLAY DEVICES DEVELOPMENT

PART 2

THE VACUUM TUBE AMPLIFIER



This is the second in a series of three articles offering a new approach to transistor and vacuum-tube amplifiers. This new approach is based on a simple DC analysis that incorporates the concepts of "transresistance" and the principles of Thévenin's Theorem.

Part 1, "The Transistor Amplifier", which appeared in the February, 1967 issue of SERVICE SCOPE considered the transistor amplifier as a simple DC model. This second article looks at the vacuum-tube amplifier in a similar light and sees some striking similarities in the two devices.

In the previous article (Part I, "The Transistor Amplifier) of this series, it was shown that the gain of a linear transistor amplifier is set by external conditions. The same reasoning can also be applied to vacuum tubes. The equivalent circuit of a vacuum-tube amplifier is shown in Figure 9. The current that is produced in the plate circuit by the signal (E_g) acting on the grid is taken into account by postulating that the plate circuit can be replaced by a generator, $-\mu E_g$ having an internal resistance (rp). We may also consider a vacuum-tube amplifier in terms of the constant-current form by replacing the voltage generator in the constant-voltage form with a current generator (gm E_g) shunting the internal resistance (rp).

These two approaches are valid in every respect but they do not convey much to us in the practical sense. Let us now consider a vacuum-tube amplifier from another approach.

In an amplifier which has its grid referenced to ground all plate-circuit impedances, R_L and rp, when viewed from the cathode are multiplied by the term $\frac{1}{\mu + 1}$. Also, by the same reasoning, the cathode impedances when viewed from the plate circuit are multiplied by the term ($\mu + 1$). Therefore, the impedance we see looking into the cathode must be $\frac{rp + R_L}{\mu + 1}$, where μ equals the amplification factor of the tube.

Hence it is reasonable to suppose that the voltage E_c, reference Figure 10, appears across this impedance we see looking into the cathode.

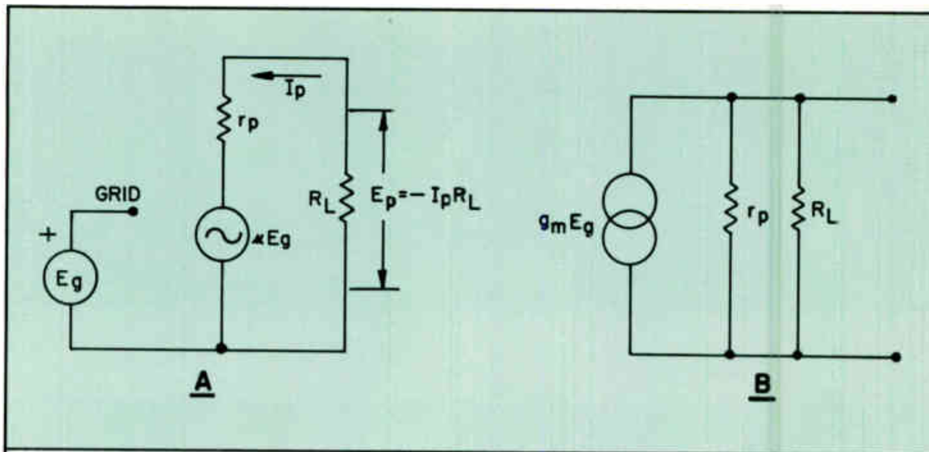


Figure 9. Illustrating the more familiar equivalent circuit of a vacuum tube amplifier.
(a) The constant voltage generator form or the Thévenin equivalent.
(b) The constant current generator form or the Norton equivalent.

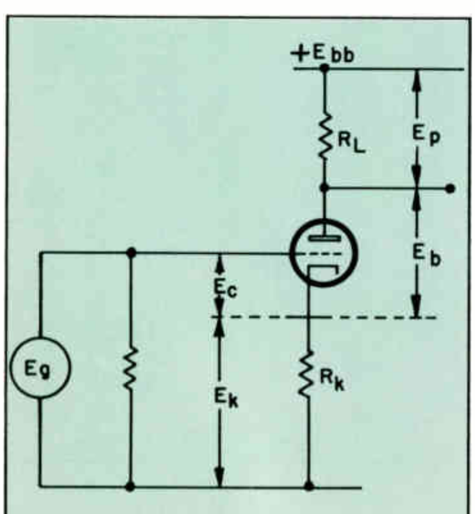


Figure 10. A vacuum tube amplifier in the grounded cathode configuration showing the various voltage measurements around the circuit.

The Triode Amplifier (*Ground Cathode*)

We will now look at a triode amplifier in terms related to our equivalent circuit. The common component is of course, the plate current. The change in this current due to the action of a control grid will determine the output voltage across the load impedance (R_L).

Now $E_g = E_c + E_k$ (19)

That is to say

$$E_g = I_p\left[\frac{rp + R_L}{\mu + 1}\right] + I_pR_k$$

Or, $E_g = I_p\left[\left(\frac{rp + R_L}{\mu + 1}\right) + R_k\right]$ (20)

Also, $E_{bb} = E_b + E_p + E_k$ (21)

or $E_b = E_{bb} - E_p - E_k$ (22)

and $E_p = -I_pR_L$ (23)

We define the voltage gain $A_{(v)}$ as

$$A_{(v)} = \frac{E_p}{E_g} \quad (24)$$

$$\text{Then } A_{(v)} = -\frac{I_pR_L}{I_p\left[\left(\frac{rp + R_L}{\mu + 1}\right) + R_k\right]}$$

$$= -\frac{R_L}{\left(\frac{rp + R_L}{\mu + 1}\right) + R_k} \quad (25)$$

We now have arrived at an equation for gain which is a ratio of impedances. The same approach may be applied to the grounded-grid configuration and we arrive at a similar result, except the sign is positive.

The Pentode Amplifier

In the triode amplifier all the cathode current will flow through the output load impedance (R_L). However, in the case of the pentode and other multigrid tubes, some of this current is diverted into the screen. Equation (23) defines the output voltage in terms of the plate current. Therefore, to derive the actual gain figure we must determine the actual amount of cathode current which will finally reach the plate and become signal current. This figure can be arrived at from a graphical analysis of the mutual-conductance curves. In most cases, about 72% of the cathode current reaches the plate to become signal current. A typical example is a type 12BY7 pentode. However, this figure can be as high as 90% for some types—for example a 7788 pentode. The ratio of the plate current (I_p) to the cathode current (I_k) is the plate efficiency factor, i.e., $\eta = \frac{I_p}{I_k}$.

Now let is reexamine what effect this fact must have on the gain of a pentode amplifier as compared to a triode amplifier. The impedance we see looking into the cathode of a pentode is the same as for a triode.

That is $\frac{rp + R_L}{\mu + 1}$

however rp >> R_L and therefore R_L can usually be neglected in this equation.

That is to say $\frac{rp}{\mu + 1} \approx \frac{1}{gm}$

and since conductance is the reciprocal of resistance we will call this impedance r_k.

i.e. $r_k = \frac{1}{gm}$ (26)

We have seen that the gain equation of the triode amplifier is defined in terms of the parameters μ and rp. We should not lose sight of the fact that μ and rp are related to the plate current and therefore when these parameters are transferred to cathode dimensions these terms must be multiplied by the plate efficiency factor (η). That is to say the impedance we see looking into the cathode r_k must be multiplied by (η). With these facts in mind let us now derive the gain equation for a pentode amplifier.

We recall that:

$$E_b = E_{bb} - E_p - E_k \qquad (22)$$

$$\text{and } E_p = -I_p R_L \qquad (23)$$

$$\text{also } E_g = E_c + E_k \qquad (19)$$

$$= \eta r_k I_k + I_k R_k \qquad (27)$$

$$\text{but } I_k = \frac{I_p}{\eta} \qquad (28)$$

Therefore substituting equation (28) in equation (27)

$$E_g = \frac{\eta r_k I_p}{\eta} + \frac{I_p R_k}{\eta}$$

$$= I_p \left(r_k + \frac{R_k}{\eta}\right) \qquad (29)$$

and since the voltage gain

$$A_{(v)} = \frac{E_p}{E_g}$$

$$= -\frac{I_p R_L}{I_p \left(r_k + \frac{R_k}{\eta}\right)}$$

$$= -\frac{R_L}{r_k + \frac{R_k}{\eta}} \qquad (30)$$

The same remarks we made about the external emitter resistor R_E (refer to Part No. 1, The Transistor Amplifier) apply equally as well to the cathode resistor, R_k; *namely, R_k will be that impedance in which the signal current will flow to the AC ground.*

In the case of the grounded plate (the cathode follower) we do not need to consider the plate efficiency factor if the amplifier is triode connected, therefore, the "gain" can be considered in terms of a simple divider network which can never be greater than unity.

$$A_{(v)} = \frac{R_k}{R_k + r_k} \qquad (31)$$

The Push-Pull Amplifier

We can view a push-pull amplifier in a similar light by recognizing the existence of a virtual AC ground point between the cathodes of $V_{(1)}$ and $V_{(2)}$ as shown in Figure 11. Therefore, the gain of a push-pull triode amplifier will be:

$$A_{(v)} = \frac{R_{L(1)} + R_{L(2)}}{r_{k(1)} + r_{k(2)} + R_{k(1)} + R_{k(2)}} \qquad (32)$$

where subscripts (1) and (2) are associated with $V_{(1)}$ and $V_{(2)}$.

And if:

$$R_{k(1)} = R_{k(2)}$$

$$\text{and } r_{k(1)} = r_{k(2)}$$

which is usually the case; then,

$$A_{(v)} = \frac{R_{L(1)} + R_{L(2)}}{2r_k + 2R_k} \qquad (33)$$

$$\text{Where } r_k = \frac{r_p + R_L}{\mu + 1} \text{ (either } V_{(1)} \text{ or } V_{(2)})$$

$$\text{and } R_k = R_{k(1)} \text{ or } R_{k(2)}$$

With a push-pull pentode amplifier we must consider the plate-efficiency factor (η). Therefore,

$$A_{(v)} \text{ pentode} = \frac{R_{L(1)} + R_{L(2)}}{2r_k + \frac{2R_k}{\eta}} \qquad (34)$$

$$\text{where } r_k = \frac{1}{gm} \text{ either } V_{(1)} \text{ or } V_{(2)}$$

$$R_k = R_{k(1)} \text{ or } R_{k(2)}$$

η = plate-efficiency factor of either $V_{(1)}$ or $V_{(2)}$.

The Cascode Amplifier

The cascode amplifier fundamentally consists of two tubes connected in series, see Figure 12. Normally we usually fix the grid of $V_{(1)}$ at some positive voltage.

The key to understanding this type of circuit is to consider $V_{(2)}$ as a voltage-activated current generator. All the current delivered by $V_{(2)}$ passes through the output load impedance R_L. Any change in voltage appearing at the grid of $V_{(2)}$ appears as a change in current across R_L. We can derive the gain equation in the same way as we did for a pentode amplifier. There is no need to consider (η) if both tubes are triodes.

$$A_{(v)} \text{ (stage)} = \frac{R_{L(1)}}{R_{k(2)} + r_{k(2)}} \qquad (35)$$

$$\text{where } r_{k(2)} = \frac{r_{p(2)}}{\mu_{(2)} + 1}$$

$$= \frac{1}{gm_{(2)}}$$

where the subscripts (1) and (2) are associated with $V_{(1)}$ and $V_{(2)}$.

One of the advantages of this type of circuit is that the internal impedance which shunts R_L is extremely high.

In this respect the triode cascode amplifier closely approximates a pentode amplifier. If we compare the plate-current versus plate-voltage curves of both devices we see a close resemblance.

The Hybrid Cascode Amplifier

Figure 13 is a typical configuration consisting of a vacuum tube V_1 and a transistor, Q_1, connected in series. We can apply much the same approach as we did for the cascode vacuum-tube amplifier. Let us assume the base to emitter junction of Q_1 to be forward biased. The collector current of Q_1 becomes the plate current of V_1. Therefore, any change occurring at the base of Q_1 is reflected as a change in plate current in V_1.

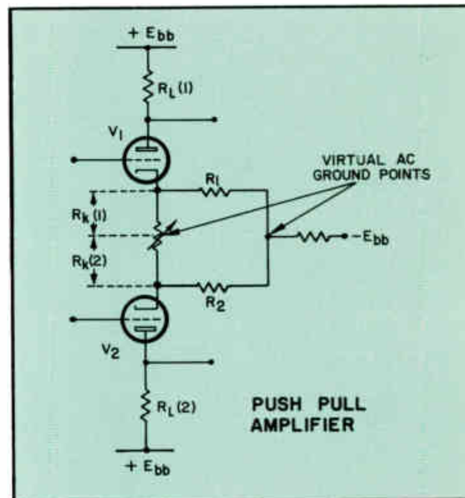


Figure 11. A typical push-pull triode amplifier. We normally encounter two virtual AC ground points between the cathodes V_1 and V_2. It may be necessary to consider the effect of the virtual AC ground point at the junction of R_1 and R_2. If R_1 or R_2 is large in value compared respectively to $R_{k(1)}$ or $R_{k(2)}$ then we can neglect this virtual AC ground and consider R_k in terms of $R_{k(1)}$ or $R_{k(2)}$. However, if this is not so, R_k will be the parallel combination of $R_{k(1)}$ and R_1 or $R_{k(2)}$ and R_2.

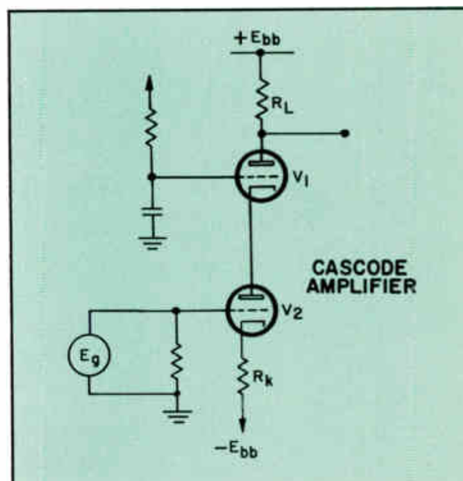


Figure 12. Illustrating a cascode amplifier using two triodes.

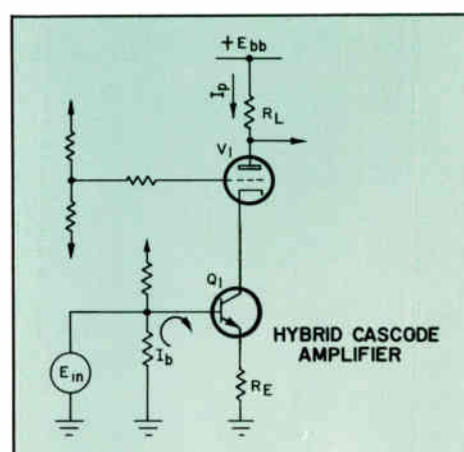
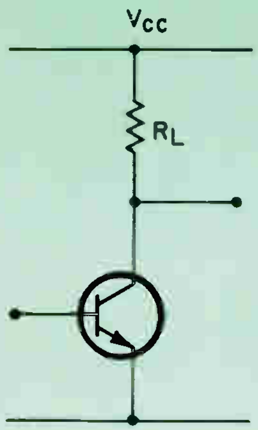


Figure 13. A typical hybrid cascode amplifier using a transistor and a vacuum tube.

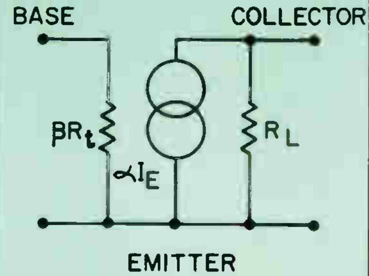
BASIC CIRCUIT	EQUIVALENT CIRCUIT	EQUATIONS	REMARKS

COMMON EMITTER

Basic circuit



Equivalent circuit



Equations

$$\text{GAIN} = A(v) = -\frac{R_L}{R_t}$$

$$R_{IN} = \beta R_t$$

Remarks

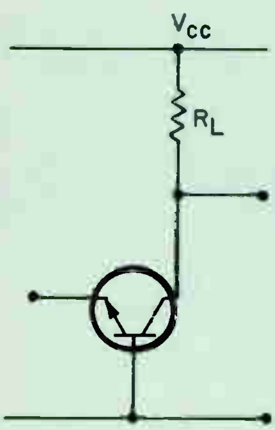
A resistance (R_E) between the emitter terminal of the transistor to the AC ground will modify the gain equation and the input impedance; then,

$$A(v) = -\frac{R_L}{R_t + R_E} \text{ and}$$

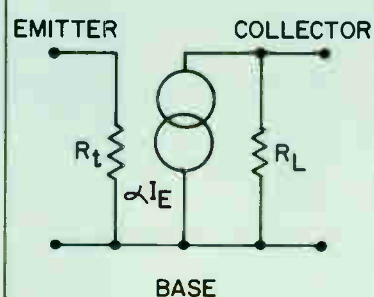
$$R_{in} = \beta\,(R_E + R_t).$$

COMMON BASE

Basic circuit



Equivalent circuit



Equations

$$\text{GAIN} = A(v) = +\frac{R_L}{R_t}$$

$$R_{IN} = R_t$$

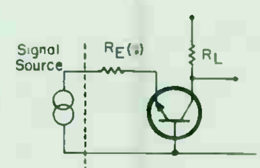
$$R_{OUT} = R_L$$

Remarks

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,

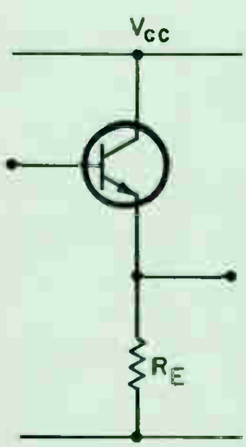
$$A(v) = +\frac{R_L}{R_t + R_{E(s)}} \text{ and}$$

$$R_{in} = R_t + R_{E(s)}.$$

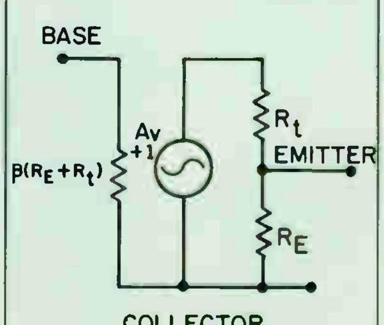


COMMON COLLECTOR

Basic circuit



Equivalent circuit



Equations

$$\text{GAIN} = A(v) = \frac{R_E}{R_E + R_t}$$

$$R_{IN} = \beta\,(R_E + R_t)$$

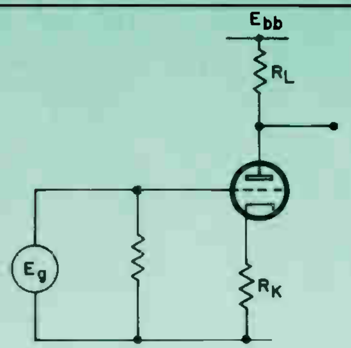
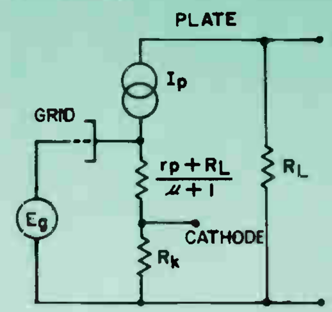
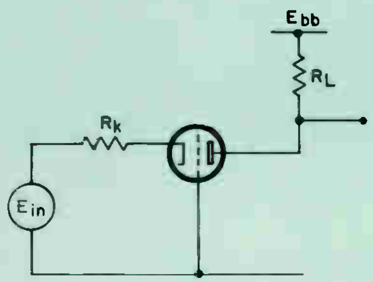
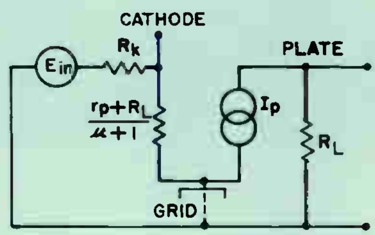
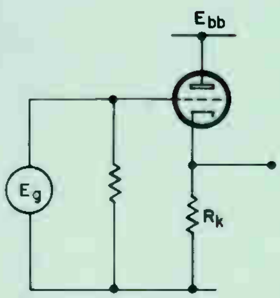
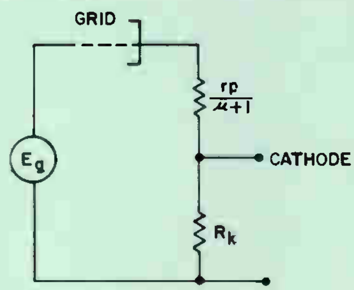
$$R_{OUT} = \left(R_t + \frac{1}{\beta}\right) \text{ in parallel with } R_E$$

Remarks

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

$$R_{out} = \left(R_t + \frac{100}{\beta}\right) \text{ in parallel with } R_E.$$

Figure 8.

BASIC CIRCUIT (TRIODE)	EQUIVALENT CIRCUIT	EQUATIONS
	 GROUNDED CATHODE	$\text{GAIN} = A_{(v)} = -\dfrac{R_L}{\dfrac{r_p + R_L}{\mu + 1} + R_k}$
	 GROUNDED GRID	$\text{GAIN} = A_{(v)} = +\dfrac{R_L}{\dfrac{r_p + R_L}{\mu + 1} + R_k}$ $R_{IN} = R_k + \dfrac{r_p + R_L}{\mu + 1}$
	 GROUNDED PLATE	$\text{GAIN} = A_{(v)} = +\dfrac{R_k}{R_k + r_k}$ ROUT $= r_k$ in parallel with R_k WHERE: $r_k = \dfrac{r_p}{\mu + 1}$

PENTODE AMPLIFIER

$$\text{GAIN} = A_{(v)} = \frac{R_L}{r_k + \dfrac{R_k}{\eta}}$$

WHERE:

R_L = LOAD RESISTANCE

$r_k = \dfrac{1}{gm}$

R_k = CATHODE RESISTOR (Refer Text)

η = PLATE EFFICIENCY FACTOR

PUSH PULL AMPLIFIER

TRIODE PAIR

$$\text{GAIN} = A_{(v)} = \frac{R_{L(1)} + R_{L(2)}}{2r_k + 2R_k}$$

WHERE:

$$r_k = \frac{r_p + R_L}{\mu + 1}$$

PENTODE PAIR

$$\text{GAIN} = A_{(v)} = \frac{R_{L(1)} + R_{L(2)}}{2r_k + \dfrac{2R_k}{\eta}}$$

WHERE: $r_k = \dfrac{1}{gm}$

SUBSCRIPTS (1) AND (2) ARE ASSOCIATED WITH V_1 AND V_2

CASCODE AMPLIFIER

$$\text{GAIN} = A_{(v)} = \frac{R_{L(1)}}{r_{k(2)} + R_{k(2)}}$$

WHERE:

$$r_k = \frac{1}{gm(2)}$$

HYBRID CASCODE AMPLIFIER

$$\text{GAIN} = A_{(v)} = \frac{R_L}{R_E + R_t}$$

WHERE:

R_L = LOAD RESISTANCE

* $R_t = r_e + R_r$

* R_E = EXTERNAL EMITTER RESISTANCE

* REFER PART I "THE TRANSISTOR AMPLIFIER"

Figure 16

We recall (Part 1, The Transistor Amplifier, Eq. 10) that the input impedance we see looking into the base of a transistor in the common-emitter configuration is:

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

Now $E_{in} = I_b R_{in}$

$$= I_b \beta (R_E + R_t) \quad (36)$$

also $\beta = \frac{I_c}{I_b}$

or $I_c = \beta I_b \quad (37)$

therefore substituting equation (37) in equation (36)

$$E_{in} = I_c (R_E + R_t) \quad (38)$$

now the collector current Q_1 becomes the plate current of V_1. Then,

$$E_{in} = I_p (R_E + R_t) \text{ since } I_p = I_c \quad (39)$$

also $E_p = -I_p R_L \quad (23)$

and since

$$A_{(v)} \text{ (stage)} = \frac{E_p}{E_{in}}$$

then from equations (23) and (39)

$$A_{(v)} \text{ (stage)} = -\frac{I_p R_L}{I_p (R_E + R_t)}$$

$$= -\frac{R_L}{R_E + R_t} \quad (40)$$

If the vacuum tube is not a triode but some other multigrid tube such as a pentode, the gain equation will have to be multiplied by the plate efficiency factor (η).

The same remarks concerning the output impedance of the vacuum-tube cascode amplifier can be applied to the hybrid counterpart.

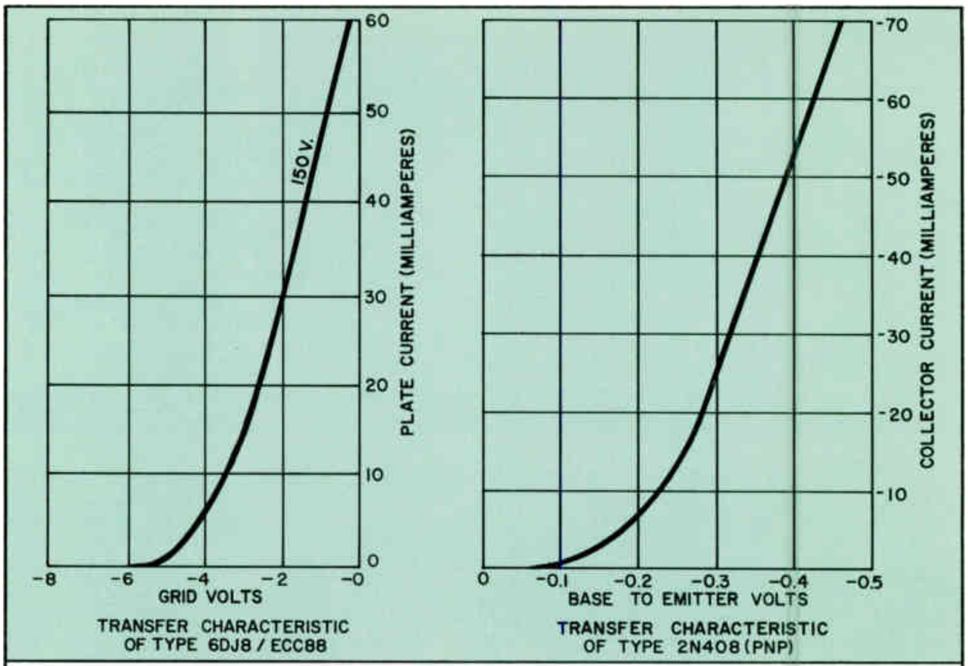


Figure 14. The transfer characteristic curves of a vacuum tube (6DJ8) and a PNP transistor (2N408), illustrating the basic similarity between vacuum tubes and transistors.

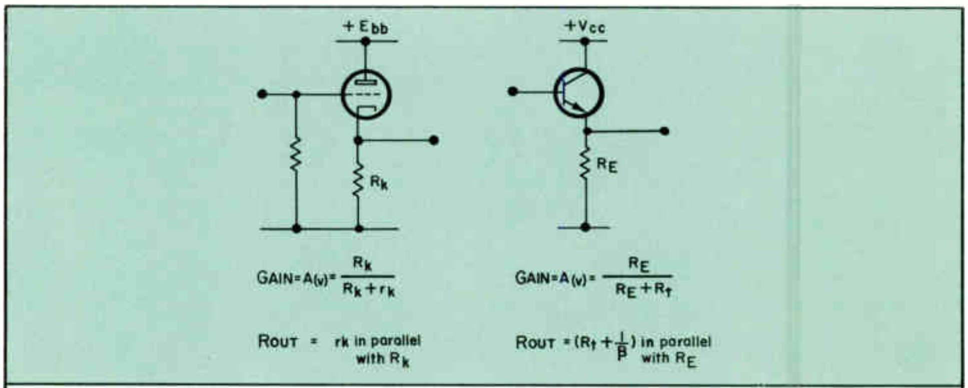


Figure 15. The analogy between the cathode follower (grounded plate) and the emitter follower (the common collector) in terms of "gain" and output impedances of both devices.

Summary

We have shown that the gain of a linear amplifier, transistor or vacuum tube, is a ratio of impedances. We can, of course, derive the gain equations for both devices in terms of mutual conductance. In fact, if we compare the transfer curves of both devices, Figure 14, we see a striking similarity. V_{BE} and E_g can be thought of in the same terms and in like manner I_p and I_c perform identical functions. Our analysis of both devices has shown that this fact is not coincidence.

It is not unreasonable to say that when we compare the cathode-follower (grounded-plate) against the common-collector configuration, Figure 15, we can think of both devices as being identical in operation—differing only in concept. The same argument can be put forward about the common-base amplifier and the grounded-grid amplifier. So too, the common-emitter amplifier and the grounded-cathode amplifier if we chose to ignore the input impedances of both devices.

Figure 16 (see page 5) summarizes the results of our analysis of the grounded cathode, grounded grid, and grounded plate amplifiers. Opposite this Figure we have reprinted Figure No. 8 from the previous article (Part I, The Transistor Amplifier) which summarized the results of the analysis on the three types of transistor amplifiers. These two charts will assist you to follow more closely our analysis of the 545B vertical amplifier (appearing in the next issue of SERVICE SCOPE) and to make a comparison between transistor and vacuum tube amplifiers.

It is not surprising we sometime find ourselves explaining one device in terms of another. Nature has a charming way of making most things interdependent upon one another. Recognize this fact and most tasks become a little easier.

The third and concluding article in this series will appear in the June, 1967 issue of SERVICE SCOPE. That article will present an analysis of a typical Tektronix hybrid circuit—a Type 545B Oscilloscope's vertical amplifier.

The analysis will be based on conclusions reached in Part 1 (February, 1967 issue) and Part 2 (this issue) of the series of articles.

ERRATA

We call your attention to a typographical error in the caption under Figure 7 in the February issue of SERVICE SCOPE. The Figure referred to in the last line of this caption should be Figure 8—not Figure 7.

USED INSTRUMENTS FOR SALE

1—Type 132 Power Supply; 1—Type O Operational Amplifier. Contact: Dr. Neil Moore, Comparative Cardio Vascular Studies Unit, Philadelphia, Pennsylvania 19104. Telephone: 594-8897.

1—Type 310A Portable Oscilloscope. Instrument is about 2 years old. Contact: Richard Cosgrove, 717 Brent Road, Rockville, Maryland.

1—Type 561A Oscilloscope. Almost new. Contact: Dr. S. Diamond, Clin-Neurophysiology Department, Mt. Sinai Hospital, Madison Avenue & 100 Street, New York, New York.

1—Type 567 Oscilloscope, sn 000440; 1—Type 6R1 Plug-In, sn 000103; 1—Type 3S3 Sampling Plug-In Unit, sn 000122; 1—Type 3T77 Sampling Time-Base Plug-In Unit, sn 000420. These units have been continuously serviced at the Tektronix, Inc. Repair Center. Will consider sale of the Type 567/6R1 separately. Contact: Walt Farnum, Borg-Warner Controls, 3300 South Halladay Avenue, Santa Ana, California 92702. Telephone: 714—545-5581.

1—Type CA Dual-Trace Plug-In Unit, sn 8596; 1—Type L Fast-Rise High-Gain Plug-In Unit, sn 4902 (just reconditioned); 2—Type 310 Portable Oscilloscopes. For details contact: Wilbur Allmeyer or Walter Wesley, KMOX-TV, 1215 Cole Street, St. Louis, Missouri 63106.

1—Type 535A Oscilloscope, sn 020361 (no plug-ins); 1—Type 515A Oscilloscope, sn 3796. Contact: Richard Lobley, Aero Service Corporation. Telephone: 215—JE 3-3900, Ext. 307.

1—Type 113 Delay Cable, sn 1119; 1—Type N Sampling Plug-In Unit, sn 1754. Contact: Jim Ricksner, American Optical Company, 4709 Baum Boulevard, Pittsburgh, Pennsylvania 15213.

1—Type 514 Oscilloscope, sn 1842. New 5APB1 crt installed. Instrument has less than 20 hours since overhaul. Price: $350.00 (I will prepay shipping charges.) Contact: T. W. Cooper, 1213 W. 8th Street, McGregor, Texas 76657.

1—Type 80/P80 Vertical Plug-In & Cathode-Anode Follower Probe. Price: $150.00. 1—Type N Pulse Sampling Plug-In Unit. Price: $375.00. Instruments are in excellent condition. Contact: Lectronic Research Labs, 715 Arch Street, Philadelphia, Pennsylvania, 19106. Telephone: 215—MA7-6771.

1—Type 545A Oscilloscope; 1—Type CA Dual-Trace Plug-In Unit. Contact: Woodrow Moe, Memistor Corporation, 295 Polaris Avenue, Mt. View, California. Telephone: 415—948-9450.

1—Type 514AD Oscilloscope in good condition. Contact: Jim Emmett, Emmett Research Laboratories, 1309 East McDowell Road, Phoenix, Arizona 85006. Telephone: AL 3-4783.

1—Type 555 Dual-Beam Oscilloscope, sn 001548. Excellent condition. Contact: Dr. Adnan Sokollu, Western Reserve University, University Circle, Room 639 Wearn Building, Cleveland, Ohio 44106. Telephone: 216-791-7300, Ext. 2381.

1—Type 514D Oscilloscope, sn 225. Contact: Lenn Chatis, Electronics Model Shop, 512 N. Citrus Avenue, Los Angeles, California 90036. Telephone: 213—934-5762.

1—Type 533A Oscilloscope; 1—Type CA Dual-Trace Plug-In Unit; 2-10X Probes. Contact: Stanley Schorum, 1312 S. Crescent, Park Ridge, Illinois. Telephone: Days, 312—745-4871; Evenings, 312—825-4198.

1—Type 581 Oscilloscope; 1—Type 86 Single-Trace Plug-In Unit. Units are approximately one year old and in like-new condition. Contact: Dick Landgraf, 24805 - 128th Place, S.E., Kent, Washington. Telephone: UL 2-8274.

1—Type 519 DC-to-1 GHz Oscilloscope. Will sell or trade for another Tektronix, Inc. oscilloscope. Contact: William S. Ward, 6110 Otis Street, Landover Hills, Maryland 20785. Telephone: 301—772-0443.

1—Type 514AD Oscilloscope in good condition. All functions working. Best offer. Contact: Engineering Associates, 434 Patterson Road, Dayton, Ohio 45419.

1—Type Q Transducer & Strain Gage Unit, sn 000653. Excellent condition. Contact: Richard Price, 10461 Halcyon Drive, Cleveland, Ohio 44130. Telephone: 216—885-3486.

1—Type RM181 Time-Mark Generator. Price: $140.00. Contact: Dan Enriques, Lear Siegler, 3171 S. Bundy Drive, Santa Monica, California 90405. Telephone: 391-7211, Ext. 328.

1—Type 585 Oscilloscope, sn 001374; 1—Type 82 Dual-Trace Plug-In Unit, sn 000346. Has CW triggering mod. and front end mod. Good condition. Price: $1,000.00 (firm) FOB Auburn, New York. Contact: Mr. Springer, Creative Electric, Inc., 18 Hulbert Street, Auburn, New York. Telephone: 314—253-9759.

1—Beckman DVM Model 910-VR-P, sn 135, modified to 4910-P specifications. Will sell or trade for a Type 561A Oscilloscope with Type 2B67 Time-Base and Type 3A1 Dual-Trace Plug-In Units; or, any Tektronix, Inc., combination that will give a dual-trace 10-MHz presentation. Contact: Wes Olson, 8556 East Sage Drive, Scottsdale, Arizona 85251. Telephone: 945-0281.

USED INSTRUMENTS WANTED

1—Type 310, Type 315, Type 316, Type 317, Type 321, or Type 515 Oscilloscope. Wanted for home use. Contact: Larry Rucker, 1472 Pacheco Street, Santa Clara, California 95051. Telephone: 408—248-2184.

1—Type 190A Constant-Amplitude Signal Generator. Contact: W. R. McClelland, 120 Washington, Palo Alto, California. Telephone: 321-9349.

1—Type 547 Oscilloscope. Instrument should be in the Southern California area for personal evaluation. Contact: John Nakata, Martin Company, P. O. Box 1681, Mail Stop A-12, Vandenberg AFB, California 93437.

1—Type 516 Oscilloscope, preferably 3-4 years old. Contact: W. R. Miller, Miller & Moody, 1400 E. Lafayette Street, Bloomington, Illinois 61701.

1—Type 63 or Type 2A63 Differential Amplifier Unit and 2—Type 3A72 Dual-Trace Amplifier Units. Contact: Dr. Wendell Caley, Department of Physics, Eastern Nazarene College, 23 East Elm Avenue, Wollaston, Massachusetts 02170.

1—Type 517 Power Supply. Contact: Ward Technical Institute, 315 Hudson Street, Hartford, Connecticut 06105, Attention: Mr. Gehman. Telephone: 203—246-7431.

1—Any Type 3" Tektronix Oscilloscope. No Rack-Mounts. Contact: Lee Noga, 306 Goethals, Richland, Washington 99352.

1—Type 515 or Type 516 Oscilloscope; or, 1—Type 531 Oscilloscope with a Type CA Dual-Trace Plug-In Unit. Contact: Lester Shirkey, 1S150 Luther Street, Lombard, Illinois 60148. Telephone: 312-MA 7-2470.

1—Type 561A Oscilloscope with 1—Type 3A1 Dual-Trace Unit and 1—Type 3B4 Time-Base Unit; and, 1—Type 422 Portable Oscilloscope. Contact: Mr. Philip C. Doolittle, 163 Birch Street, Park Forest, Illinois 60466. Telephone: 312—748-7287.

MISSING INSTRUMENTS

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 575 Transistor-Curve Tracer, sn 003682. This instrument disappeared from the owner's premises on or about February 16, 1967. It is believed to be stolen. Contact: Cal-Power Company, 140 Kansas Street, El Segundo, California 90245. Telephone: SP 2-2171.

1—Type 453 Portable Oscilloscope, sn 2298. This instrument, which is presumed to be stolen, is in need of a new crt. It was taken from the University of Calgary in Calgary, Alberta, Canada. The instrument is owned by: Alan Crawford Associates, 65 Martin Ross Road, Downsview, Ontario, Canada.

1—Type 545B Oscilloscope, sn 198 (Honeywell I.D. #4-255), 1—Type 53/54 C Dual-Trace Plug-In Unit, sn 1344 (Honeywell I.D. #330). Mr. Robert Hough is the man to contact at Honeywell if you have information regarding these instruments. His telephone: 301—587-1712. The address is Honeywell, Inc., Computer Control Division, 8121 Georgia Avenue, Silver Springs, Maryland.

1—Type 564 Oscilloscope, sn 3969; 1—Type 3A74 Four-Trace Amplifier Unit, sn 1032; 1—Type 2B67 Time-Base Unit, sn 13230. These instruments were reported as missing and believed stolen by: Mr. Pete Vanderhelft, Robotron Corporation, 21300 West Eight Mile Road, Detroit, Michigan 48219.

1—Type 321 Portable Oscilloscope, sn 002388, (Hughes Aircraft Company ID #H-103842). This instrument was shipped via Emery Air Freight and is reported as "missing in transit." Information regarding the instrument should be referred to Hughes Aircraft Company, Fullerton, California.

1—Type 310 Portable Oscilloscope, sn 10050. Missing from General Electric X-Ray Company, Denver, Colorado.

1—Type 532 Oscilloscope, sn 560; and 1—Type 53/54 B Plug-In Unit, sn 8876. These instruments were removed from an unmanned radar site near New Preston, Connecticut sometime between July 28, 1966 and August 1, 1966. They are presumed to be stolen since their removal was not sanctioned by any of the authorized personnel of the 656th Radar Group to which the instruments were issued. Information on the whereabouts of these instruments should be reported to the Federal Bureau of Investigation, New Haven, Connecticut.

1—Type 503 Oscilloscope, sn 001094. This instrument was either lost or stolen from the University of California at Los Angeles between September, 1966 and January, 1967. The person to contact if you have information on this instrument is: Myron M. Bell, Supervisor, Inventory Division, University of California at Los Angeles, 405 Hilgard Avenue, Los Angeles, California 90024. Telephone: 213—272-8911, Ext. 3610.

1—Type 2B67 Time-Base Unit, sn 017657; 1—Type 3A3 Dual-Trace Differential Unit, sn 001337. These instruments are missing from the Tektronix Field Office, 1722 East Rose Avenue, Orange, California 92667. Telephone: 714—633-3450.

Service Scope

USEFUL INFORMATION FOR

USERS OF TEKTRONIX INSTRUMENTS

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon, U.S.A. 97005

BULK RATE
U. S. POSTAGE
PAID
Beaverton, Oregon
Permit No. 1

Mr. Ed Harding 4/66
5329 Dupont Ave. S.
Minneapolis, Minn. 55419

RETURN REQUESTED