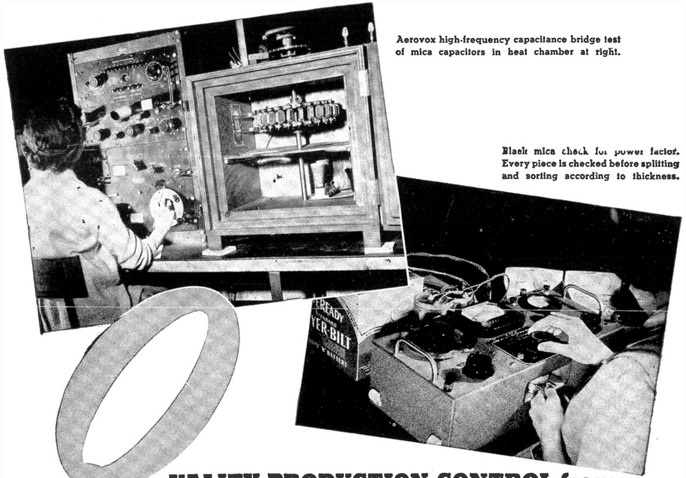

Aerovox high-frequency capacitance bridge test of mica capacitors in heat chamber at right.

Black mica check for power factor. Every piece is checked before splitting and sorting according to thickness.

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Service Tube Tests

By the Engineering Department, Aerovox Corporation

PART 1. Principles

SINCE the electron tube is the essential part of all radio equipment and very nearly all electronic control apparatus, field tests which purpose to show the condition of tubes have great practical value. Tube tests made as a part of service or maintenance routine, while based upon the same principles as laboratory checks, usually are made in a somewhat different manner, and the data interpreted by simplified methods. This article will describe the methods and circuits employed for service tube testing.

FIELD AND LABORATORY TESTS COMPARED

Vacuum-tube bridges are employed in the laboratory for measurement of three important parameters of grid-controlled vacuum tubes, namely: amplification factor (μ), plate resistance (r_p), and transconductance (G_m). The latter characteristic may be taken with reference to various pairs of electrodes, but generally is assumed to mean *control grid-plate transconductance*. Diode and rectifier characteristics are checked by measuring the plate current (I_p) resulting from application of plate voltage of some specified value.

Quick appraisals of tube characteristics in the field do not permit time-consuming bridge measurements nor the calculations which must follow bridge readings. Commercially available service tube testers check either emission or transconductance of grid-type tubes, plate current of rectifier and diode types, and inter-electrode short circuits in all types. In some testers, transconductance is checked on all grid-type tubes except class-B amplifiers which are tested for power output. For quick appraisal of tube condition, the indicating meters in *all* service tube testers have "English" scales. That is, they are graduated BAD-FAIR-GOOD or REPLACE-?-GOOD.

TYPES OF TESTS

Some controversy has arisen among the designers and users of service tube testers as to which *single* test serves best to indicate the condition of a tube. There seems to be little or no disagreement as regards rectifier, diode, and class-B tubes. Tests made on regular grid-type tubes are the ones raising the question. And those in present widest use include (1) emission, (2) static transconductance, and (3) dynamic transconductance. Of these, the emission test is the simplest and requires the least complicated circuit. It accordingly is frequently found in service tube testers. The following comparison of the three prevailing types of test will serve to establish their differences and relative merits.

Emission Test. As its name implies, this test attempts to appraise tube condition in terms of the cathode to emit electrons. The test is made by measuring the rectified current flow when a potential of 40 to 50 volts RMS is applied between the tube cathode and all of the other electrodes. The tube filament or heater is operated at its rated voltage. In this way (See Figure 1), the tube being tested is operated as a diode rectifier, all of its elements except the cathode being connected in parallel to form a multiple plate.

To enable the d. c. milliammeter to cover the wide range of current values encountered with the numerous receiving tubes (0.1 to 100 ma.), a shunt rheostat is connected in parallel with this meter. The rheostat must be set to a specific resistance for each type of tube tested. After the power is switched on, readings may be taken by depressing the push-button switch. The latter serves to protect the milliammeter from overload while the shunt rheostat is being set.

The emission test cannot be altogether conclusive, since, as tube manufacturers point out, there is no definite 100% emission point which may be used for reference. Also high emission does not necessarily indicate a good tube, since this condition might be present, for instance, in a tube with a faulty grid structure or with a highly emissive spot on its cathode. Very high emission has been observed just before complete tube failure. Nor does fairly low emission necessarily indicate in all cases that the tube is near its end-of-life point.

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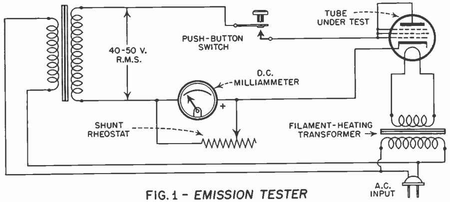


FIG. 1 - *EMISSION TESTER*

A further disadvantage of the emission test is the liberation of gas within the tube by application of the a. c. test voltage unless the test is made quickly. Because the tube is not operated with its recommended d. c. electrode voltages in the emission test, it is not tested under actual operating conditions.

Calibration of privately-built emission testers presents a problem. There is no simple way to calibrate the shunt rheostat in an emission tester. This is because there are no data available on emission values to be expected for the various types of tubes. The most satisfactory method of obtaining a calibration for a specific type of tube consists of adjusting the shunt rheostat with a bad tube of that type in the tester. This tube must have *just* reached the poor performance stage, as indicated by a transconductance type of tester, but must not be burned out. The pushbutton is depressed and the rheostat adjusted for exact center-scale deflection of the milliammeter (this point on the meter scale should be the top of the BAD or REPLACE region). The rheostat setting then is recorded for that particular tube type.

The emission tester accepts or rejects tubes on the basis of readings obtained along this English scale. In all service testers, the entire left-hand half of the scale is marked BAD or REPLACE, and the entire right-hand half GOOD. The question mark (?), indicating questionable tubes, marks a *line* at center scale.

The laboriousness of the "calibration" process and the necessity that a large stock of bad tubes be available for the operation tend to discourage the private construction of emission testers, although the simplicity of the circuit offers a strong initial appeal. The emission tester has the advantage that the same simple circuit is used, without alterations, for checking every type of tube —diodes, triodes, tetrodes, pentodes, converters, dual-purpose types, etc. It is necessary merely to supply a sufficient number of sockets to accommodate the various tube bases.

Static Transconductance Test. This is commonly called the "grid-shift test." In this test, the grid-type tube is supplied with all of its recommended d. c. electrode voltages, and its filament or heater is operated at rated voltage. A d. c. milliammeter indicates the plate current resulting from application of the d. c. plate voltage. To make the test, the d. c. grid voltage (bias) is increased by exactly 1 volt in the positive direction, and this causes the plate current to rise to a new value. The transconductance of the tube then may be determined simply by multiplying by 1000 the difference between the two plate current readings. Voltage amplifier and power amplifier tubes are considered defective when their transconductances, as indicated by a test of this sort, fall to 70% of the values stated in standard tube tables. Oscillator sections of converter tubes are defective when their transconductances fall to 60% of table values.

When making a static transconductance test, the plate, screen, and suppressor voltages must be checked both before and after shifting the grid voltage. Any voltage change then must be corrected before taking the final plate current reading.

A practical circuit arrangement for static transconductance testing is shown in Figure 2. E_B is a source of high d. c. voltage, to which is connected the voltage divider resistor, R_2 Sliders along this resistor tap off recommended grid-cathode, screen-cathode, and plate-cathode voltages. The grid-cathode voltage is measured by means of a high-resistance d. c. voltmeter connected between taps 1 and 2, the screen-cathode voltage between 1 and 3, and the plate-cathode voltage between 1 and 4. A single voltmeter may be switched between cathode and the other electrodes, or three separate potentiometers might be provided with calibrated dials. In some laboratory-type transconductance, where manufacturing cost has not been an important consideration, separate voltmeters are employed for the continuous monitoring of d. c. voltages.

The potentiometer R_1 is adjusted so that exactly 1 volt is obtained from the low-voltage d. c. source, E_C. When the pushbutton, S, is depressed. the control grid voltage is shifted in value.

For the test, slider 2 is set on the voltage divider resistor for a grid voltage ½ volt lower than recommended bias for the tube under test. When pushbutton S is depressed, the grid voltage accordingly will be shifted from ½ volt lower than recommended bias to ½ volt higher than this bias. A net shift of 1 volt thus is obtained in the region of re-

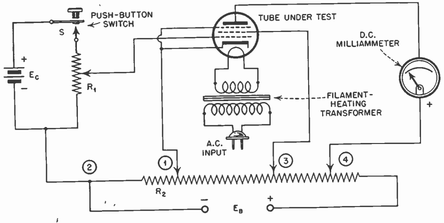


FIG. 2 - *STATIC TRANSCONDUCTANCE TESTER*

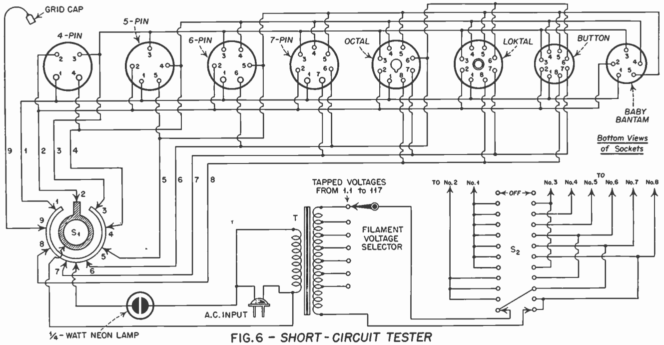


FIG. 6 - *SHORT-CIRCUIT TESTER*

TESTS FOR SHORT CIRCUITS

Several schemes have been devised for locating interelectrode short circuits in a tube. One of the simpler circuits, often incorporated in complete tube testers, is shown in Figure 6. In this arrangement, a 115-volt potential is applied in series with a ¼-watt neon lamp between any one electrode of the tube and all of the others in parallel. As the switch is rotated, different parallel combinations of electrodes are checked against other single electrodes. The tube is operated at its rated filament or heater voltage. A continuous glow of the neon lamp indicates a short circuit.

The electrode combination to be checked for short circuit is selected by means of a rotary switch, S_1. The points of this switch have been numbered in Figure 6 to correspond to numbering of the tube socket terminals. Thus, when pole A of switch S_1 is in position 2, as shown, the short-circuit test is made between socket terminal 2 and the parallel connection of terminals 1, 3, 4, 5, 6, 7, 8, and 9. Terminal 9 is the top-cap grid connection.

If the lamp should glow with switch S_1 in the position shown, a short circuit would be indicated between either 1 & 2, 2 & 3, 2 & 4, 2 & 5, 2 & 6, 2 & 7, 2 & 8, or 2 & 9. In order to locate exactly the second electrode contributing to the short circuit, the switch is rotated, noting that the lamp glows for a second time when the pole is set to the second electrode. Thus, a 2-9 short circuit will be indicated by glowing of the lamp when S_1 is at settings 2 and 9. If more than one interelectrode short circuit is present at any switch setting, the individual ones may be located, as just explained, by successive settings.

Sockets are included to accommodate all tube bases. Filament voltage is supplied by the tapped transformer, T, to all tubes, and is applied to the proper socket terminals by means of the 11-position switch, S_2. Socket filament terminal combinations selected by this switch are 1-3, 1-4, 1-5, 1-6, 1-7, 1-8, 2-3, 2-6, 2-7, 2-8, and 7-8.

In order to prevent switch S_1 from short circuiting and extinguishing the tube heater during operation, an auxiliary set of contacts is provided on S_2 which open one leg of the leads between S_1 and the filament or heater terminals of the sockets. One leg of the heater line is still left accessible to S_1 for short circuit test against all other electrodes. These auxiliary contacts have been omitted from the schematic in Figure 6, in order to minimize confusion in reading the drawing. The lines opened by the contacts are No. 1 when S_2 is in one of the seven topmost positions, No. 2 when S_2 is in the next three positions, and No. 8 when S_2 is in the lowermost position. By setting S_2 to its OFF position, heater voltage is removed from the tube and the short-circuit test may be applied (for continuity indication) between the heater terminals.

When making a complete short-circuit test, the operator must be familiar with the tube base connections in order best to interpret the flashlamp indications. Some tubes, for example, have two base connections to a single electrode. An example is the 45Z3 whose plate is connected to pins 2 and 6. Such base connections will yield a continuity test which might be taken erroneously as a short circuit between terminals 2 and 6. From standard tube data, it will be easy to identify all terminals (such as filament or heater connections, and cases such as the one just cited) between which continuity should be expected, and to determine corresponding switch positions.

COMPLETE TUBE TESTS

This article has dealt with the principles underlying service tube testers. The separate test circuits shown may be combined into a single complete, field-type instrument, such as carried by radio servicemen, by means of ingenious switching systems. And this instrument may be used for complete tube tests including transconductance or emission of regular triodes, tetrodes, pentodes, and converters; power output of class-B tubes; rectified current of diodes and rectifiers; and short circuits in all types.

The next article will describe the complete circuits employed in field tube testers.

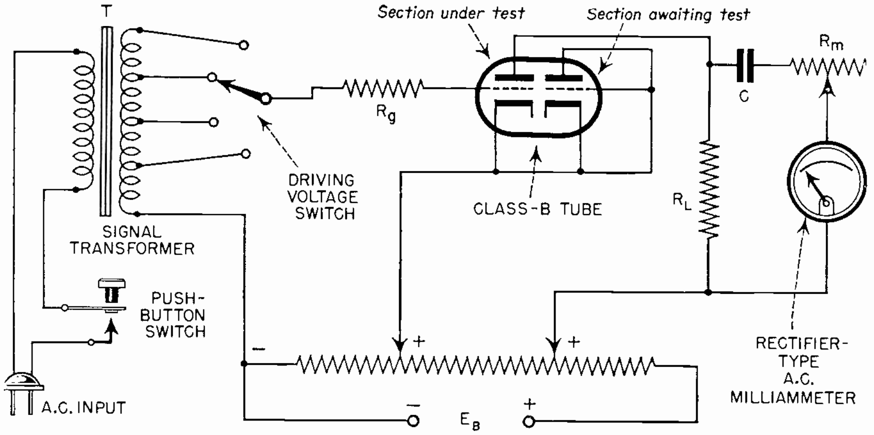


FIG. 4 — *TESTER FOR CLASS-B TUBES*

In the equations, E_g is the required grid signal (a. c. volts), I_p the desired plate current (a. c. milliamperes), and G_m the rated transconductance (micromhos).

If the oscillator section of a converter tube is being tested, all of the other conditions stated above being taken to be the same, the denominator in Equations (1) and (2) becomes 0.6 G_m.

No elaborate calibration is needed for the dynamic transconductance tester employing an accurate a. c. milliammeter and 1-volt grid-signal, since G_m values are obtained directly from meter readings multiplied mentally by 1000. Calibration procedure for the English scale is simple, it being necessary merely to determine beforehand, by means of Equations (1) or (2), the signal voltage required by each type of tube, and to record that value with the d. c. electrode voltages for the particular type of tube.

ADVANTAGES OF TRANSCONDUCTANCE TESTS

All transconductance tests have the advantage that the tube is checked under conditions which approximate actual operation in electronic equipment. That is, the tube is operated at its rated filament voltage, recommended d. c. electrode voltages are applied, and an examination is made of the extent to which grid voltage will control plate current flow.

If the tube has defective electrodes, its transconductance will be affected. The effectiveness of the tube to function as a grid-controlled amplifier is revealed by the correlation of plate current and grid voltage increments by this test.

The dynamic transconductance test has the advantage that it is rapid, gives direct indications, and more closely approximates actual operating conditions than does the static transconductance test.

TESTING CLASS-B TUBES

Class-B amplifier tubes, such as types 6A6, 6N7, 53, etc., are checked for power output, since it is not convenient to check these types for transconductance. The circuit shown in Figure 4 is satisfactory.

A 60-cycle signal voltage is applied to the control grid of the tube under test by means of transformer T. Taps on the secondary winding of this transformer enable the operator to obtain the recommended driving voltage for each tube type. The series grid resistor, R_g, simulates the reflected impedance of the driver stage found in class-B amplifiers. When a dual tube is being tested, electrodes of the "floating" section are connected to the cathode of the section under test, as shown in Figure 4.

A. c. output voltage (E_O) is developed across the load resistor, R_L, which is selected to have the proper ohmic value for the tube under test. This voltage, which is proportional to power output, actuates a voltmeter consisting of the a. c. milliammeter, variable multiplier (R_m), and 1-mfd. coupling capacitor (**C**).

Class-B tubes are rejected when their power output (E_O^2/R_L) falls to about 55% of its rated value. When the tube under test is operated at its recommended grid driving voltage and rated load resistance, the English scale of the tester may be standardized for a specific class-B tube in the following manner: Rheostat R_m is set to bring that deflection of the meter corresponding to 55% of rated power output to the top of the BAD or REPLACE section of the scale.

TESTING RECTIFIER AND DIODE TUBES

Diode and rectifier tubes and the diode sections of multi-section tubes are checked in a manner similar to the emission test described earlier in this article. The tube filament or heater is operated at rated value, and a 60-cycle voltage is applied to the series circuit embracing the diode (or rectifier section), a d. c. milliammeter of appropriate range, and a load resistor. A satisfactory circuit is shown in Figure 5. The load resistor is shunted by a capacitor. Each type of tube is rejected when its rectified current, as indicated by the milliammeter, falls to 80% of the rated value for the RMS voltage applied. Current and voltage data for this test are obtained from the graphs and tables supplied by tube manufacturers.

A meter shunt rheostat (R_m) is set to bring the meter deflection corresponding to 80% of rated current for a specific type of tube to the top of the BAD or REPLACE section of the English scale.

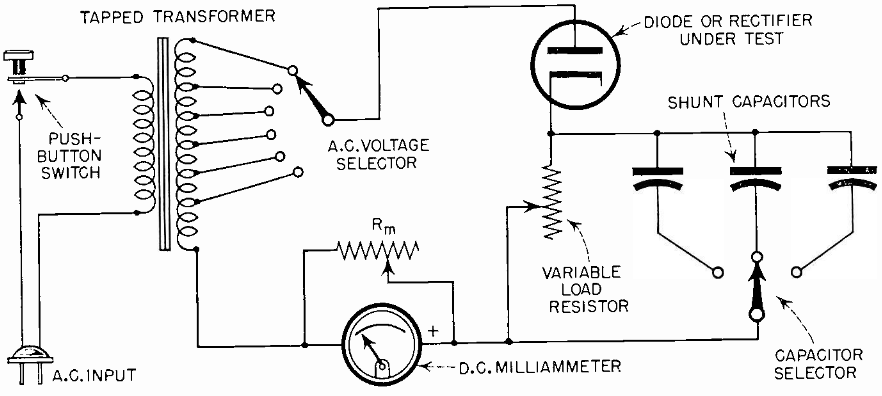
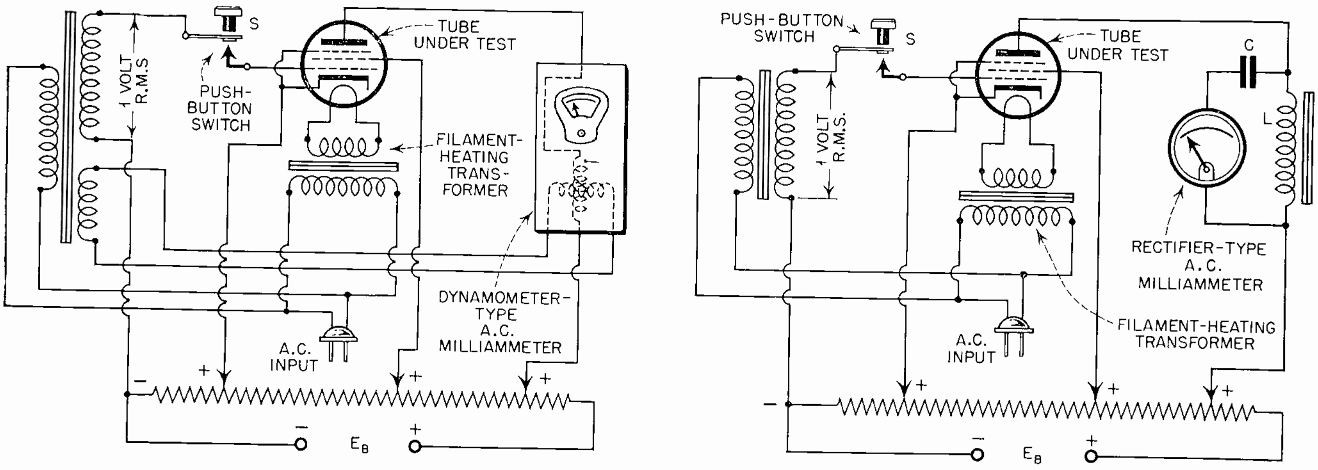


FIG. 5 - *TESTER FOR DIODES and RECTIFIERS*



(A) *DYNAMIC TRANSCONDUCTANCE TESTERS* (B)

FIG. 3

commended bias, without moving too far up the characteristic curve of the tube.

For testing of the wide variety of receiving tubes, the plate milliammeter must have at least three ranges: 0-1, 0-10, and 0-100 ma. d. c.

The static transconductance test has the disadvantage that it often requires that small plate current increments be read on relatively high current scales. This leads to inaccuracy in results. If some means is provided for bucking out the initial plate current through the meter, a lower-range instrument then may be employed to read only plate current change, and may be made to read direct in transconductance (micromhos).

A further, often questioned, disadvantage of the static transconductance test is the fact that the test voltage applied to the control grid is d. c., and in the actual operation of a tube in equipment this is seldom the case, a. c. grid signals being usual. The argument is that here again the tube is not being tested under actual conditions encountered in application.

The static transconductance test is not so widely used at this time. It may be found today perhaps only as the "grid-shift" feature of radio set analyzers. Occasionally, however, an experimenter who has no tube tester and desires to check a single tube will rig up a grid-shift meter for the purpose.

Dynamic Transconductance Test. This test, like the previous one, applies recommended d. c. voltages to each tube electrode. These voltages are obtained and checked in the same manner as before. But, unlike the static test, the dynamic transconductance test requires an a. c. grid signal, which more closely approximates tube operating conditions. A 60-cycle voltage from the secondary winding of a step-down transformer is a satisfactory signal.

Practical circuits for dynamic checking of transconductance are shown in Figure 3. In each case, the plate circuit instrument is an a. c. milliammeter. There accordingly is no deflection of this instrument until an a. c. signal is applied to the control grid of the tube under test.

In Figure 3-A, the indicating instrument is a dynamometer-type a. c. milliammeter with one coil connected in the tube plate circuit, and the other to a winding of the signal transformer. But since this instrument is rather costly, it never is employed for transconductance testing outside of the laboratory. For service tube tests, the arrangement shown in Figure 3-B is favored. Here a standard rectifier-type a. c. milliammeter is connected through a large capacitance, C, (1 mfd. or higher) across a low-resistance, high-impedance choke coil, L. This arrangement is not as accurate an indicator of a. c. plate current as that of Figure 3-A, unless the entire combination (meter with capacitor and choke) is calibrated against another a. c. milliammeter and a special scale is drawn.

Upon application of the a. c. grid signal (by depressing pushbutton S), the plate meter will indicate the resulting a. c. plate current. If the grid signal is exactly 1 volt RMS, the tube transconductance in micromhos will be equal to the meter reading multiplied by 1000. The a. c. milliammeter thus easily may be made a direct-reading micromho meter. The same tube rejection values may be employed as indicated in the description of the static transconductance test.

If it is desired to employ the English scale (BAD-?-GOOD), the signal voltage must be made adjustable (for example, through use of a small potentiometer in parallel with the grid-voltage transformer secondary) and must be set for each tube type. These settings must be chosen such that 70% of a table transconductance value for a certain regular tube, or 60% of the value for a converter (oscillator section), will be read at the top of the BAD or REPLACE portion of the scale. For example: Let us assume that the plate meter has a range of 0-1 a. c. milliamperes and that a 6C5 type tube is to be tested. The table transconductance value for this tube is 2000 μmhos. The top of the BAD band on the meter scale will be at about 0.5 ma. It is desired to set the signal voltage to such a value that 70% of 2000 (or 1400 μmhos) will be indicated by a ½-milliampere deflection. This required voltage value will be proportional to the required plate current and to the rated transconductance of the tube, and may be determined by means of the equation:

(1) $$E_g = \frac{1000\, I_p}{0.7\, G_m} = \frac{1000\,(0.5)}{0.7\,(2000)} = 0.357\text{ V.}$$

When an 0-1 a. c. milliammeter is employed and the rejection point is at center scale, this equation becomes:

(2) $$E_g = \frac{500}{0.7\, G_m} = \frac{500}{0.7\,(2000)} = 0.357\text{ V.}$$