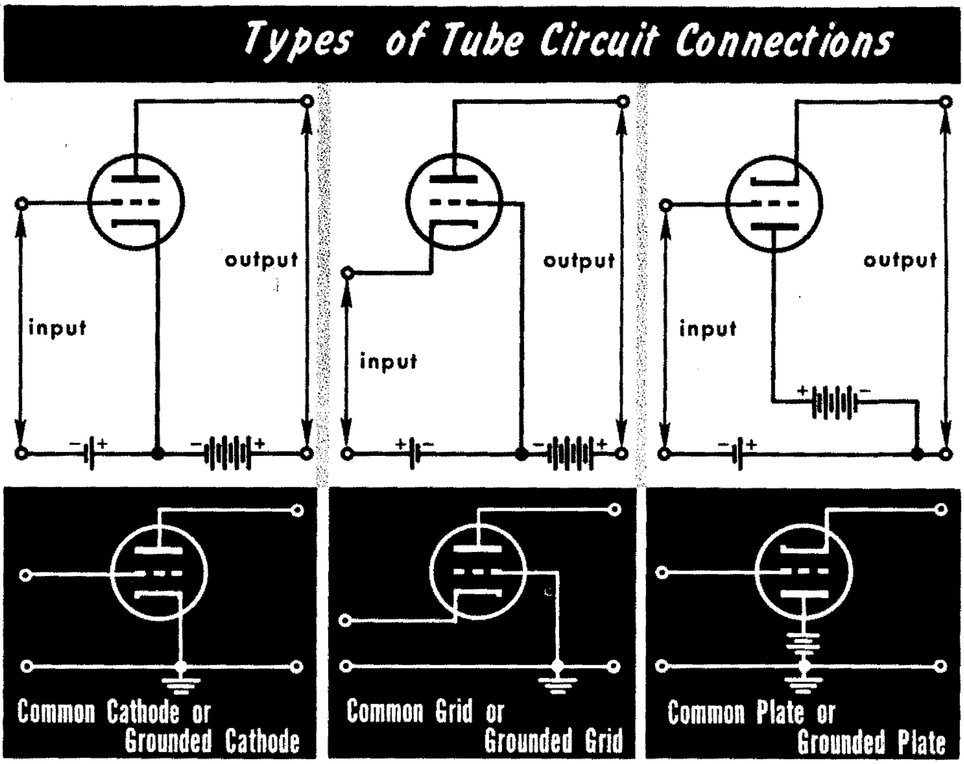
The Grounded-Cathode Amplifier

Thus far we have measured all voltages against the cathode of the tube. This assumes the cathode potential is zero, or in engineering language, the cathode is called the *reference* point, because everything is measured back to it. Because we also measure all potentials against the biggest reference body we can find—the earth—the part of the circuit to which everything is *referred* or measured, is called *ground,* although it may not always be literally connected to ground.



We encounter one more expression for this: because the point to which measurements are all made is *common* to both input and output circuits, this is called a common point. The way of working a tube we have described is called *common cathode,* or *grounded cathode.*

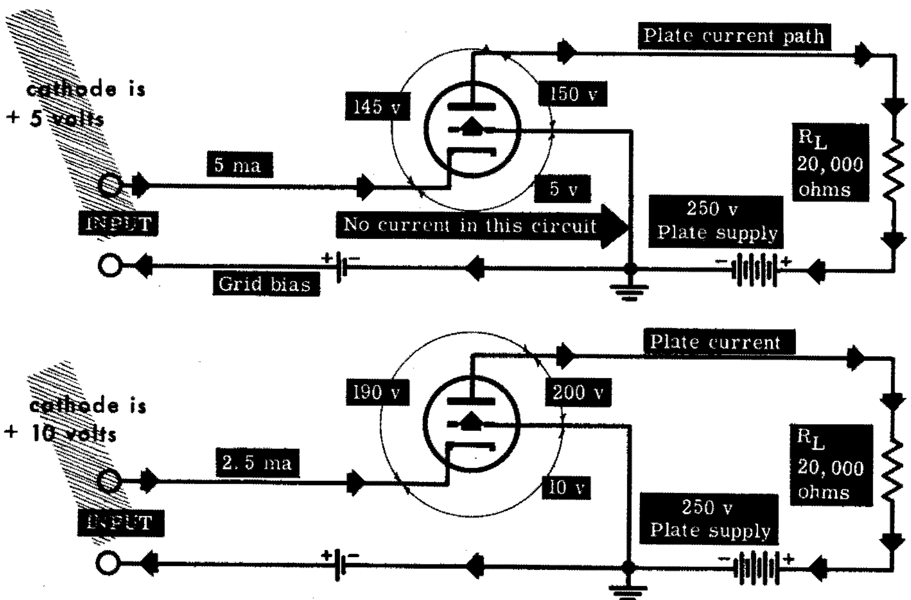
The grounded- or common-cathode circuit of a tube is the easiest to understand because it is the voltage between plate and cathode and between grid and cathode that controls the current between plate and cathode. Any other circuit is more complicated to understand, because we have to find out how it is related to this basic one.

The Grounded-Grid Amplifier

Let us first take the grounded- or common-grid circuit. If the input voltage is applied between cathode and grid, it is the same as placing an opposite voltage between grid and cathode. (Making the grid 5 volts *negative* to the cathode is the same as making the cathode 5 volts *positive* to the grid.) No current flows in the grid circuit because it is negative with respect to the cathode and repels all electron flow. Current does flow in the cathode circuit, and it is the same current that flows in the plate circuit.

With the same resistance in the plate circuit as before and a supply of 250 volts, with a fluctuation between +5 and +10 volts at the cathode, the current will fluctuate, as in the grounded-cathode arrangement, between 5 milliamperes and 2.5 milliamperes, respectively, while the plate-to-cathode voltage fluctuates between (150—5) or 145 volts and (200—10) or 190 volts. Thus the input fluctuates between +5 volts at 5 milliamperes and +10 volts at 2.5 milliamperes, the current in each case opposing the input voltage. This means the change in input current corresponding to a 5-volt change in input voltage is 2.5 milliamperes, which represents an *a-c* resistance for the input circuit of 5/.0025 or 2000 ohms.

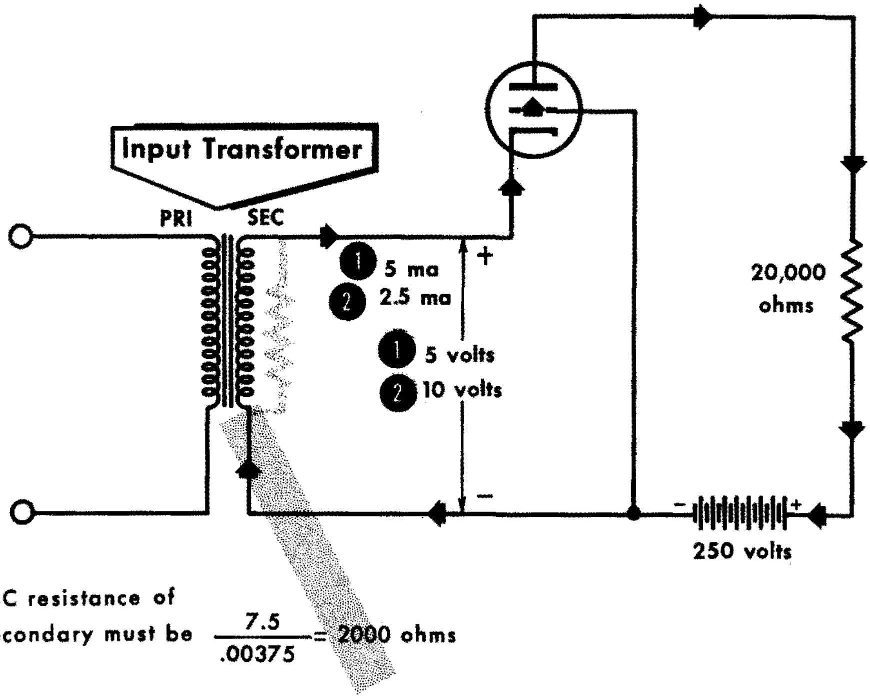
In the grounded-cathode arrangement, there is no current in the input circuit, hence the a-c input resistance is 5/0 or infinity. (Anything divided by zero is infinity.) Here, however, we have what in tube circuits is a low input resistance—in this example, 2000 ohms.



Grounded-grid amplifier

Input to the Grounded-Grid Amplifier

GROUNDED-GRID AMPLIFIER --



Use of an INPUT TRANSFORMER

With the grounded-cathode arrangement, the input circuit only needs to provide the right *voltage.* Current does not matter. In this circuit, however, we have to provide the right current *and* voltage fluctuations.

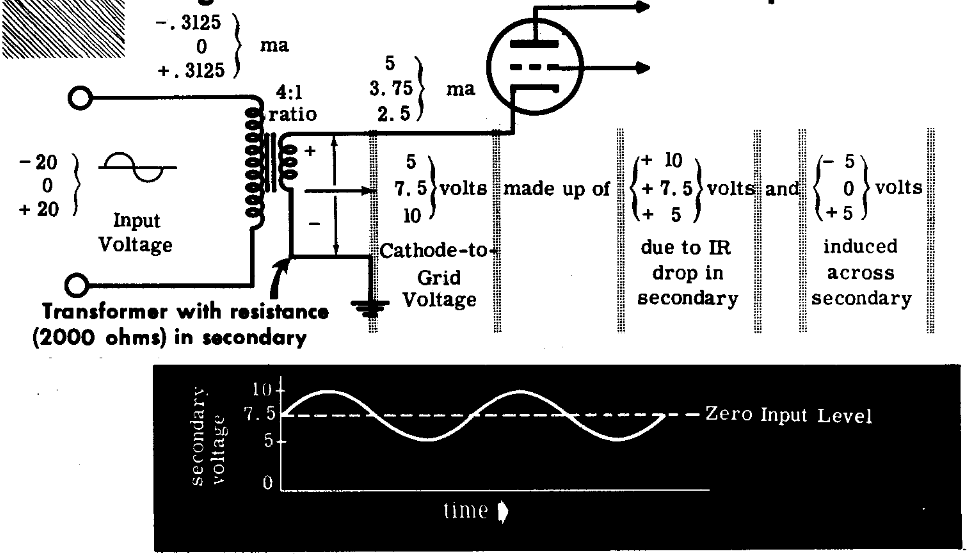
This is achieved by using a transformer. Assuming that the 5- and 10-volt figures are the two extremes of an alternating fluctuation, the average value will be 7.5 volts. Similarly the average current will be halfway between 2.5 and 5 milliamps, or 3.75 milliamps. Hence the d-c resistance in the path from cathode to ground needs to be 7.5/.00375 or 2000 ohms. This can be in the form of the winding resistance of the transformer secondary, or may include a separate resistor.

Input to the Grounded-Grid Amplifier (contd.)

Assuming that the transformer uses a 4:1 step-down ratio, we can work out the conditions of the input circuit. In the secondary of the transformer, there is a current that fluctuates up to 5 milliamperes and down to 2.5 milliamperes. The voltage drop due to this current (when no input is applied) is 7.5 volts. The change in voltage due to change in current will be from 10 volts (at 5 milliamperes) to 5 volts (at 2.5 milliamperes). For proper operation of the tube, however, the cathode-to-grid voltage must be +5 volts at 5 milliamperes and +10 volts at 2.5 milliamperes—just the reverse of what we have. These potentials must be provided by the induced voltage from the transformer.

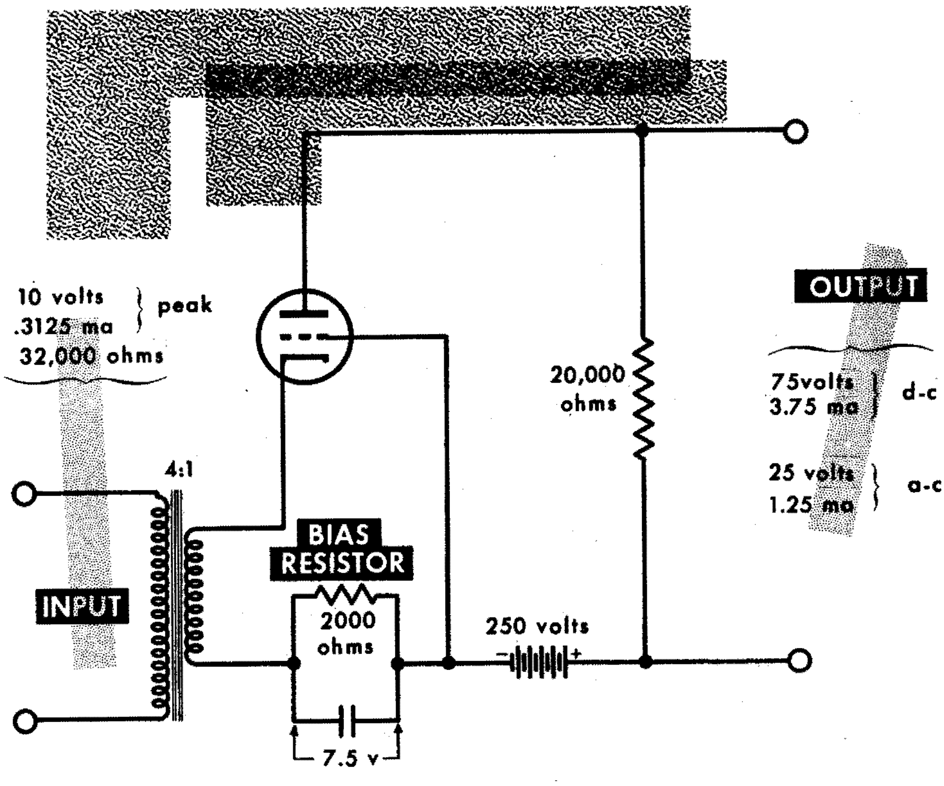
Thus the induced voltage will have to offset the change in voltage drop and also provide the extra voltage for the cathode. It will have to fluctuate 5 volts each way from zero. Of this fluctuation, 2.5 volts in each direction will be taken up by the change in voltage across the secondary resistance due to change in current, and 2.5 volts will change the cathode-to-grid voltage. To produce this induced voltage on the secondary, the primary will need four times as much (or 20 volts) fluctuation each way from zero. It will also have to offset the *change* in magnetization due to the *change* in secondary current. Since this change requires 1.25 milliamperes each way on the secondary, only one-fourth of this (0.3125 milliampere) will be needed in the primary. Thus, the effective primary input must be a 20-volt fluctuation each way, accompanied by a 0.3125-milliampere fluctuation each way.

Voltages and Currents in a Grounded-Grid Amplifier



Input to the Grounded-Grid Amplifier (contd.)

The basic grounded-grid circuit can be improved by using a separate resistor in the cathode connection to provide bias. Its value should be 2000 ohms, so that 3.75 milliamperes provide the correct middle potential of 7.5 volts. A large capacitor is connected across this resistor, so that when the current through the circuit changes, the capacitor will absorb some of it before the voltage can change. If the capacitor is big enough, the voltage will stay almost fixed at 7.5 volts.

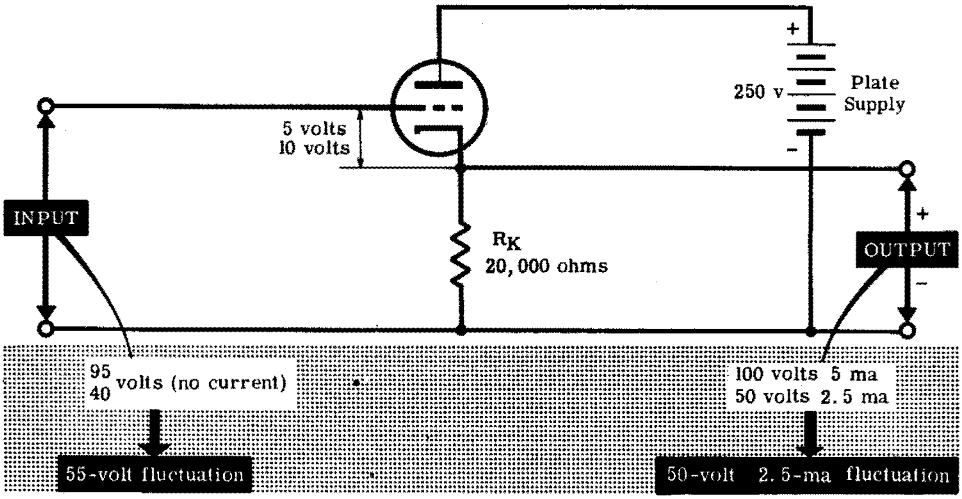


Adding a Bias Resistor improves grounded-grid amplifier circuit

This means the secondary has only to provide a voltage fluctuation of 2.5 volts each way and the primary has to receive only a 10-volt fluctuation in each direction. The input resistance thus is 10/.0003125 or 32,000 ohms.

The Cathode Follower

The Basic Common-Plate (Cathode Follower) Circuit



The third way to connect a tube makes the plate common. We do this by connecting the 20,000-ohm resistor in the cathode circuit. Now the change of —5 volts to —10 volts between grid and *cathode* results, as before, in a change in current through the tube between plate and cathode, from 10 milliamperes to 5 milliamperes. Thus the cathode will fluctuate between 100 volts and 50 volts, respectively, due to the different currents flowing in the 20,000 resistor.

Adding these voltages together, we can find what input voltages we have to use to get these output voltages. With —5 volts between grid and *cathode*, the voltage from cathode to ground is 100 volts, so the voltage from grid to *ground* must be (100—5) or 95 volts. With —10 volts from grid to *cathode*, the cathode to ground voltage is 50 volts, hence the grid to *ground* voltage must be (50—10) or 40 volts. Thus, this circuit requires an input fluctuation between 95 and 40 volts (55 volts) to get an output fluctuation of only 50 volts, between 50 and 100. How can this be amplification?

The answer is that the cathode follower does not give *voltage* amplification. Because the grid input does not require any current to cause the output circuit to give a current fluctuation of 5 milliamperes, we can see that this arrangement can be regarded as a *current* amplifier. Because the output voltage at the cathode is almost the same as the input voltage at the grid (although more current fluctuation is available at this voltage), this circuit is called a *cathode-follower*, the idea being that the cathode voltage *follows* the grid voltage.