Single Power Supply Op-Amp Circuits

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Operational amplifiers have traditionally been operated using dual power supplies – often +15 volts and -15 volts. However, that is not a requirement. An op-amp will operate with any upper and lower power supply voltage provided the voltage across the amplifier is less than maximum ratings and voltages at the terminals are within the specification range relative to the power supply voltages. This means that we are free to do whatever we want as long as we follow a few basic specifications on the data sheet.

In a number of modern circuits it is convenient to use an op-amp with a single power supply – common voltages are +12 and +5. The lower power supply pin is connected to circuit ground. The mathematics of the op-amp are independent of the power supply voltages. So there is no difference in how we analyze a traditional dual power supply circuit or a single power supply circuit.

There is one technical difference regarding single supply circuits that we need to consider and that is that the op-amp can not output a negative voltage. This is not an issue in some circuits as we are only interested in positive values. But for other circuits we need to have negative values. They do not have to be negative absolutely as in -2 volts but need to be negative relative to a common reference. For this situation it is common to establish a ground reference voltage such as 2.0 or 2.5 volts in a 5 volt system or 5 or 6 volts in a 12 volt system. There is no requirement for the reference to be one-half the power supply voltage but that is often convenient. As an example of the -2 volts mentioned previously, this could be relative to a 2.5 volt ground reference and thus a positive 0.5 volts in such a system would represent -2 volts. This ground reference voltage is sometimes referred to as a bias voltage and names such as V_{ground} or V_{bias} and other similar names are used interchangeably in single supply circuits.

Figure 1 shows two common methods to create the ground reference voltage labeled VG. The method on the left is for non precision applications and will experience some variations as the power supply voltage varies. The capacitor forms a low-pass filter with the voltage divider to significantly reduce high frequency disturbances that may be on the power supply voltage. The unity gain op-amp buffer provides a low (practically zero) impedance source for the reference voltage. The method on the right is the preferred method using a precision voltage reference. A zener diode is shown as an example but any stable reference is fine.

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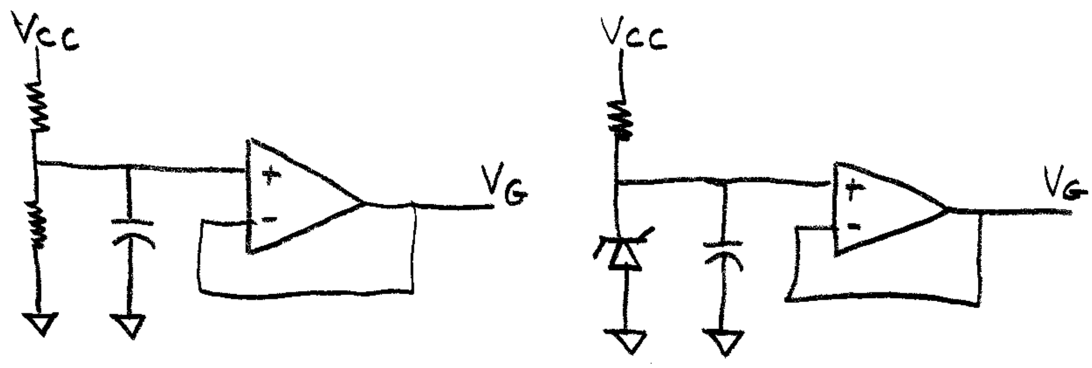

Figure 1: Methods of generating VG

Figure 2 shows a partial circuit with a non-inverting and inverting amplifier. The student should analyze this and note that Vo1 is simply Vin * (1 + R2/R1) if both voltages are measured with respect to VG. Likewise, Vo2 = -Vo1 * (R4/R3) if both voltages are measured with respect to VG. At first this might seem confusing since students are more familiar with measuring voltages relative to zero voltage ground. The familiar analysis method provides the identical result (it has to – there is only one possible result) – the only difference is that the term, VG, will appear in the result – but if that is subtracted then the result is the signal relative to VG – i.e. the intended result.

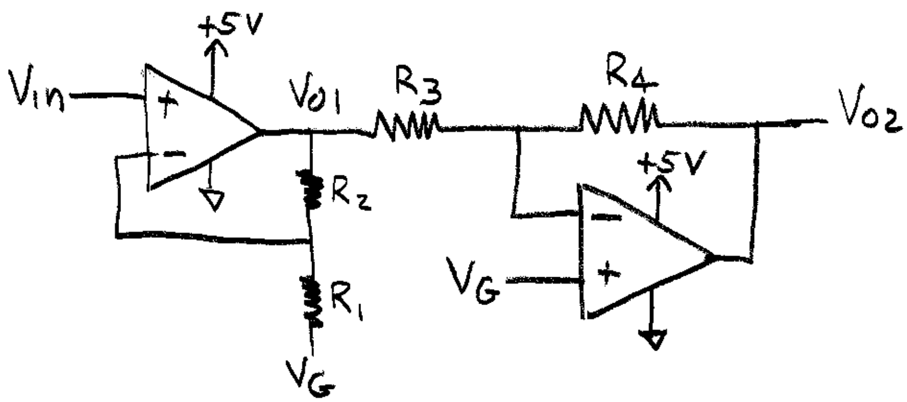

Figure 2: Typical single supply connections

Figure 3 shows one method to interface an input signal that can have real negative voltage to a single supply circuit. This circuit simply adds VG to the signal. The resistors can all be the same value or different values as required for a scaling factor other than 1.0. This particular method is fairly general. The circuit can be simpler in some specific cases.

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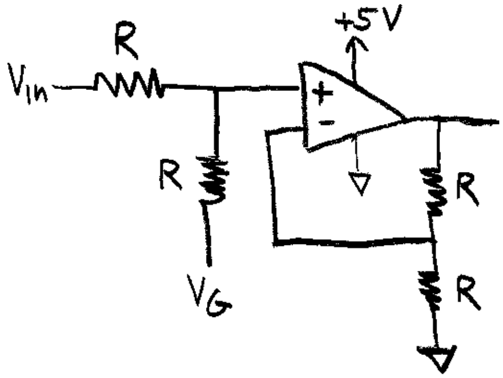

Figure 3: Translating external signals to single supply

Figure 4 shows one method to interface the output of a single supply circuit to a system with bipolar power supplies where the ground voltage is truly zero. This circuit simply subtracts VG from the signal. The resistors can all be the same value or different values as required for a scaling factor other than 1.0. This particular method is fairly general. The circuit can be simpler in some specific cases.

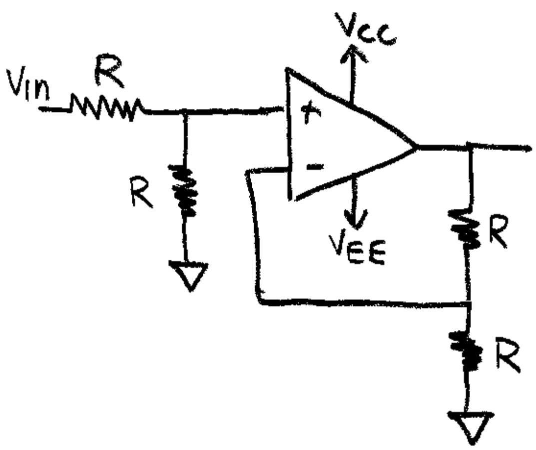

Figure 4: Translating single supply back to bipolar

AC Coupling

Sometimes the signal of interest is only AC and any DC component is just in the way. The general rule is that if DC gain is not needed then use coupling capacitors to block DC. Examples are shown in Figure 5. The inverting amplifier on the left has a DC gain of zero. The quiescent output voltage is VG. The non-inverting amplifier on the right also has a DC gain of zero and the quiescent output voltage is VG. In each case the time constant of the resistor-capacitor networks has to be long enough to pass the lowest frequency of interest.

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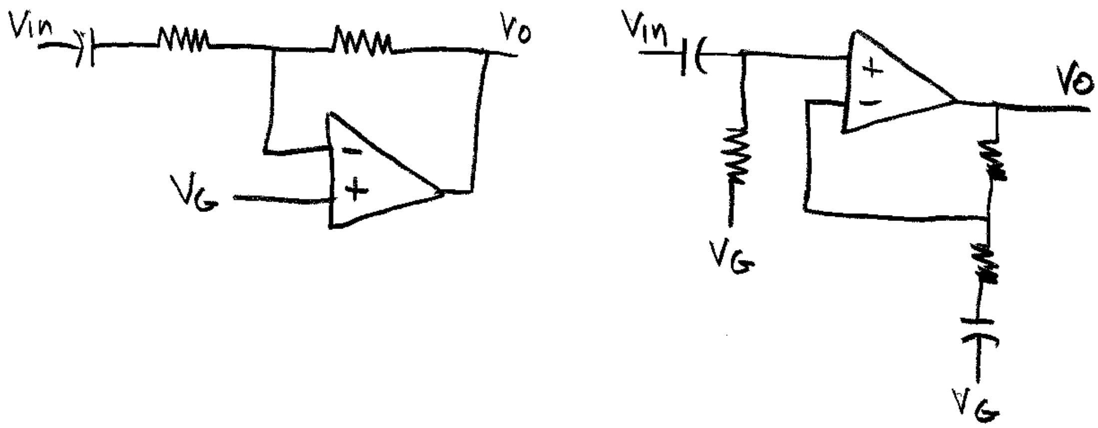

Figure 5: Examples of AC coupling

Homework problems

The following are an assortment of problems the student should work. Answers are provided but you should not use the answer to figure out the problem.

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SINGLE SUPPLY OP AMP CIRCUITS
HOMEWORK

12-31-97
K. KUHN

USING SUPPERPOSITION DERIVE THE TRANSFER FUNCTIONS OF THE FOLLOWING CIRCUITS. DO NOT USE THE GIVEN ANSWER IN THE DERIVATION.

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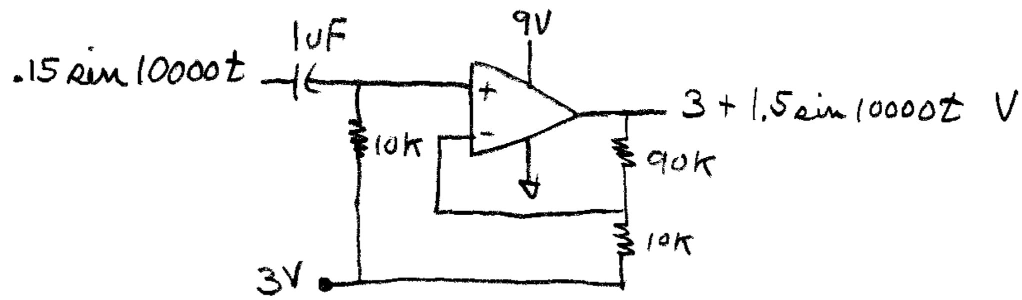

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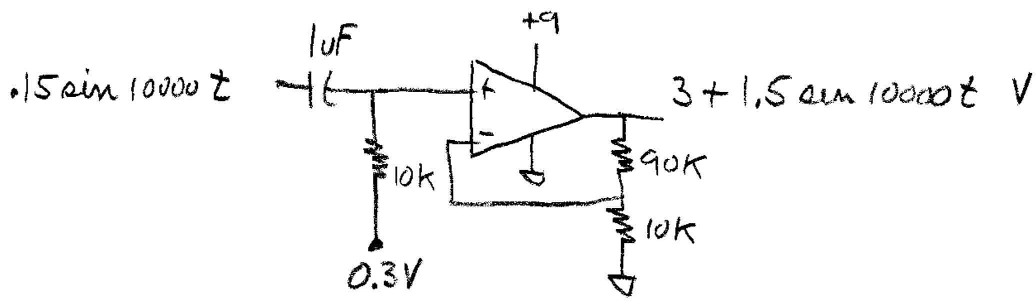

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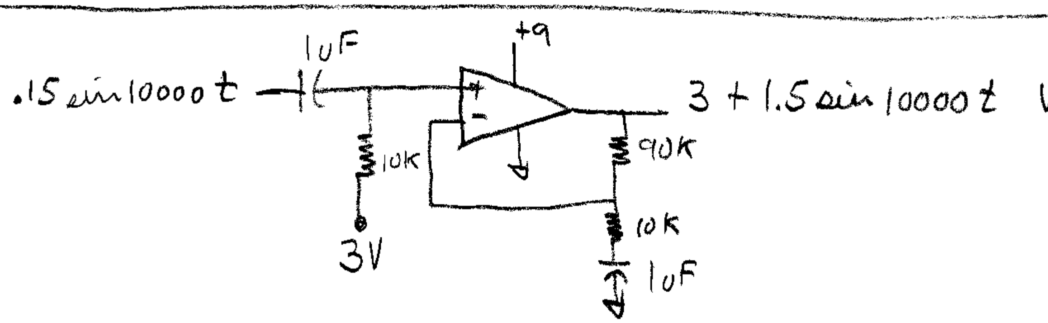

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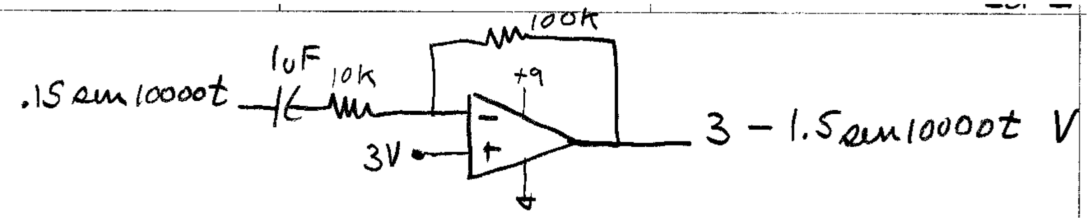

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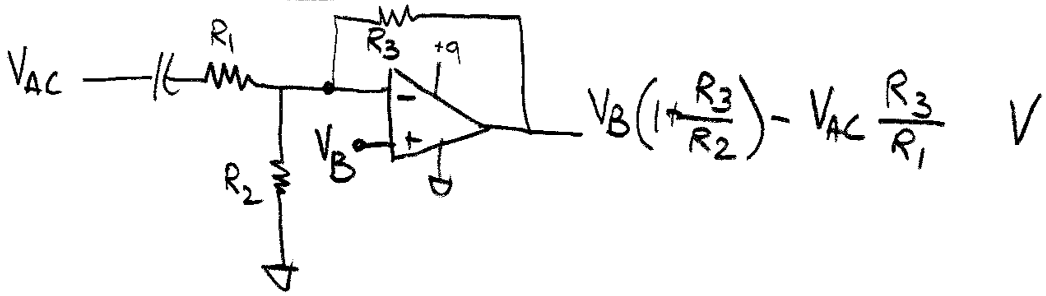

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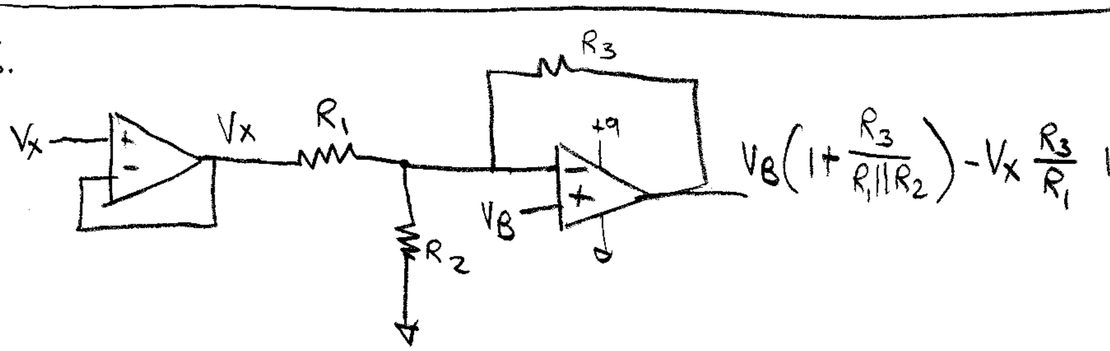

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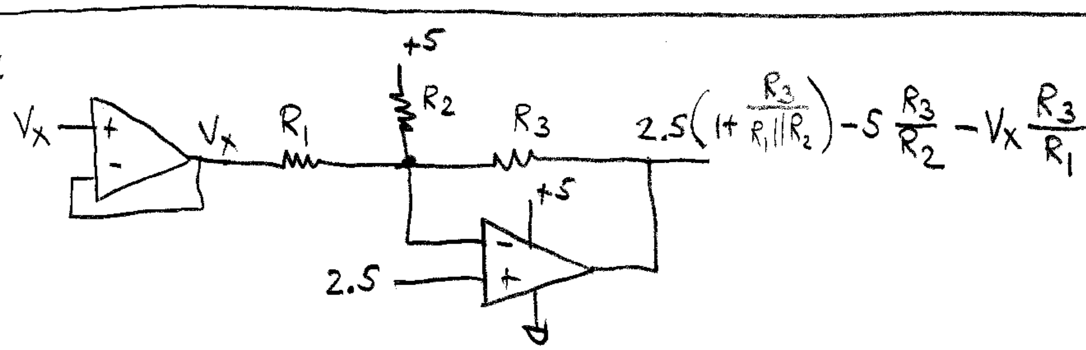

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