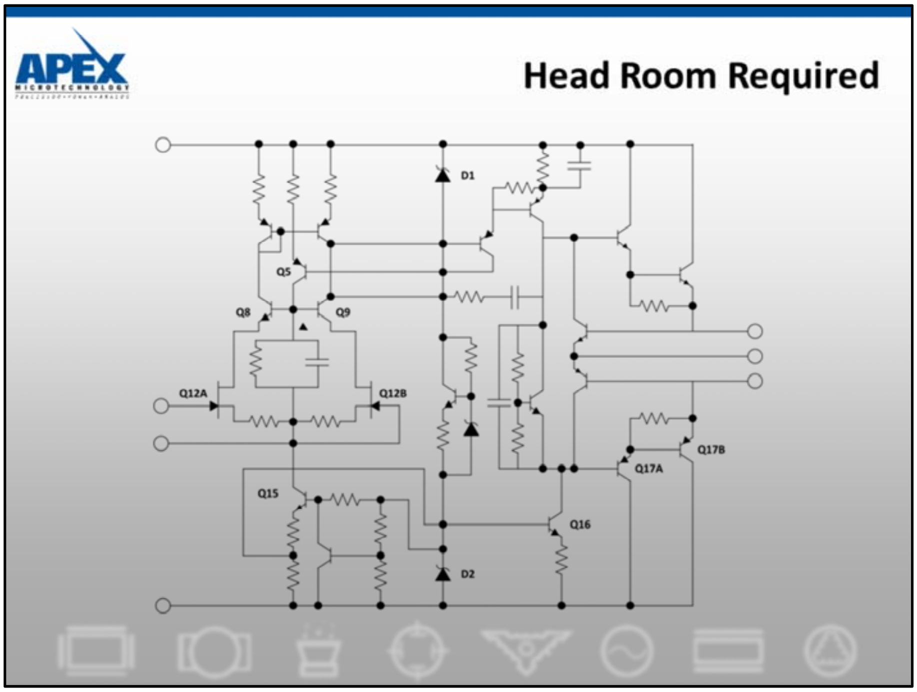
APEX MICROTECHNOLOGY
PRECISION • POWER • ANALOG

Tech Seminar Workbook

Single Supply Operation

The basic operational amplifier has no ground pin. It assumes ground is the mid-point of the voltages applied to the +Vs and –Vs pin. If voltages on the input pins deviate from the assumed ground, it labels this deviation as common mode voltage. If this common mode voltage is within the op amp's range and we don't ask the output to go out of range, the op amp is happy.

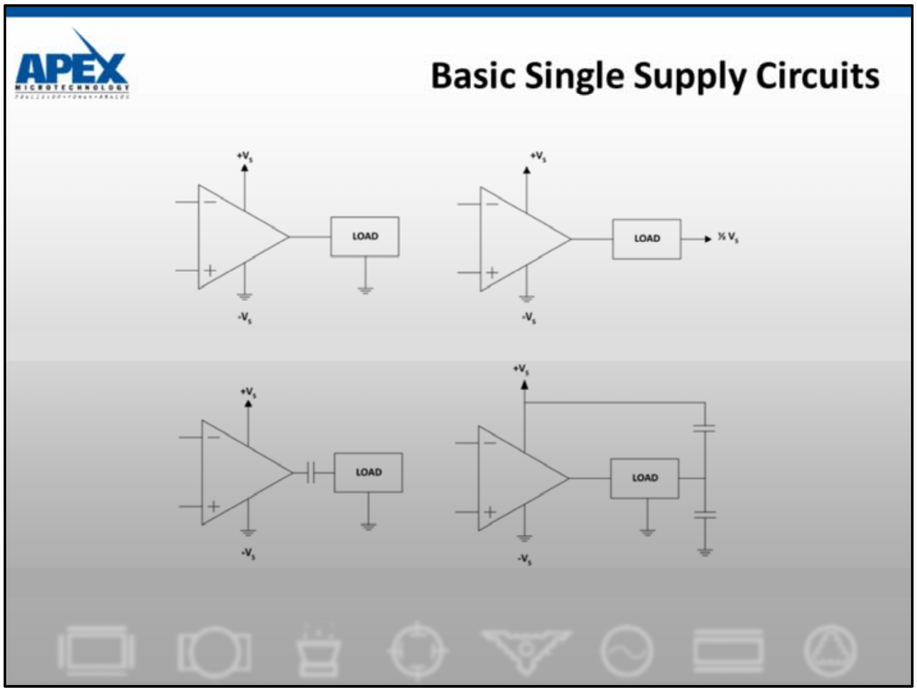


Notice that as the input pins approach the negative rail, the voltage across Q15 decreases. Minimum operating voltages for Q12 and Q15 along with the zener voltage place a limit on how close common mode voltage can get to the negative rail.

With inputs going positive Q5, Q8, Q9 and D1 place a similar limit on how close common mode voltage can get to the positive rail.

On the output side look at a fraction of the D2 zener voltage plus Q16 operating requirements and the Vbe of Q17 as all contributing to a limit of how close the output can approach the negative rail. This is the output voltage swing spec of the op amp. While this spec moves with output current, it never gets to zero even if current does. This means getting to zero output on a true single supply power op amp circuit is NOT going to happen.

While the actual voltages vary a lot, these type limitations are typical of all linear power amplifier output stages and most input stages. The Apex PA21, PA25 and PA26 family is an exception on the input side; common mode input goes below the negative supply rail making them ideal for some moderate power single supply applications.

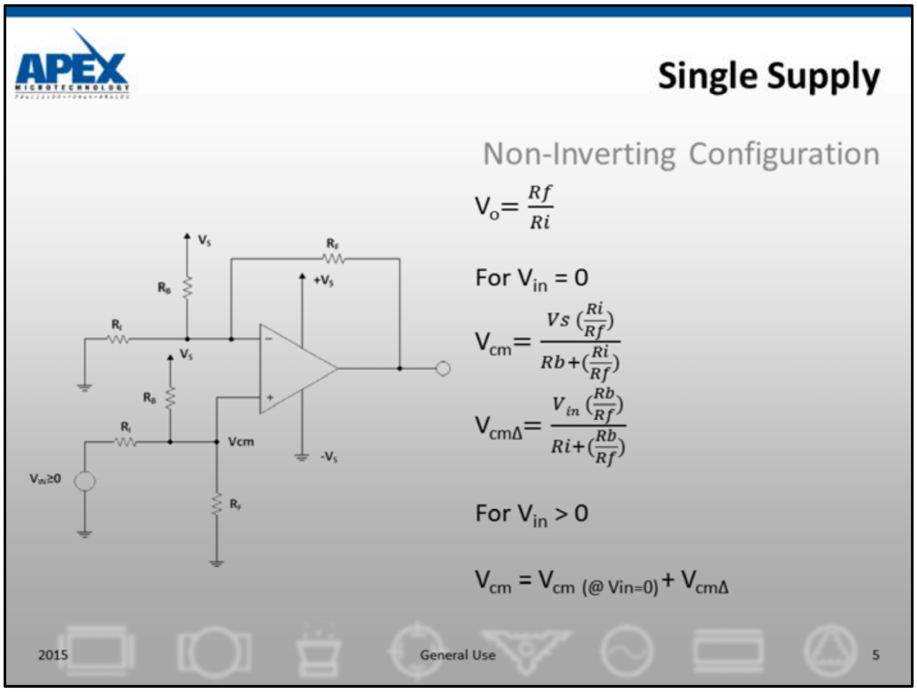


Circuit A is only suitable for unipolar and non-zero inclusive drives. These type applications might include Programmable Power Supply (PPS), heater controls and unidirectional speed controls.

Circuit B is practical only when the power supply has a mid-point capable of bidirectional current flow such as a stack of batteries. Even this is can be a problem due to battery impedance being in series with the load.

Circuit C is reasonably common in the audio world. Circuit D is sometimes used to reduce turn-on pops but must be matched to input signal circuits to be of much use.

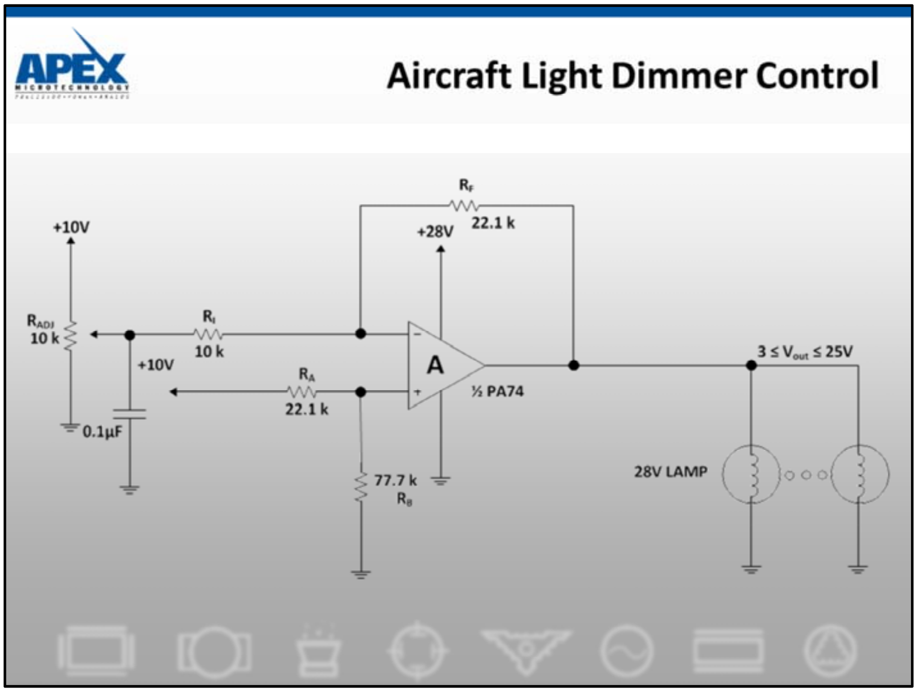
Ref. AN21



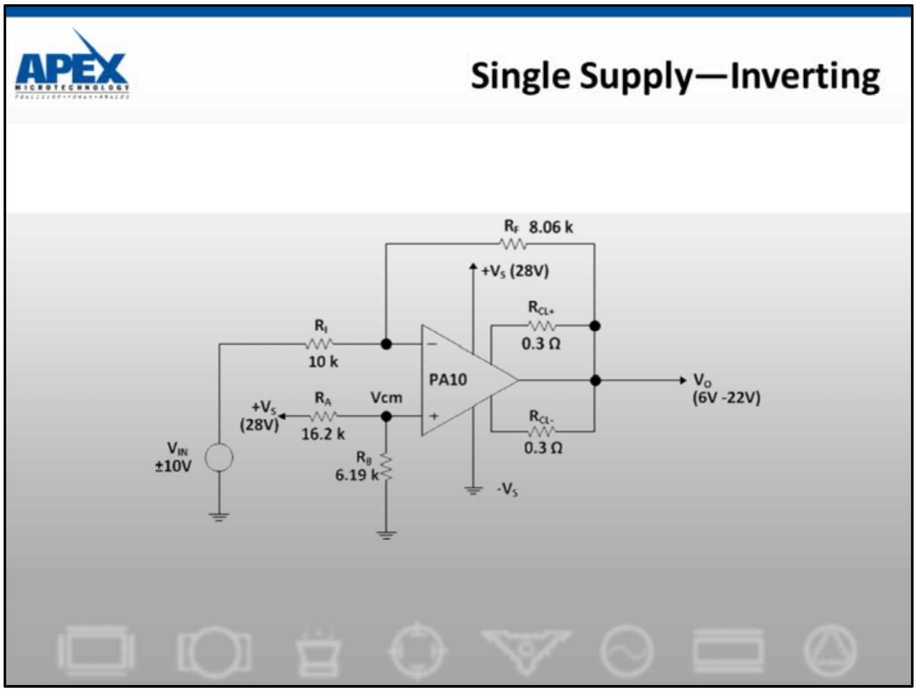
This configuration can easiest be viewed as a differential amplifier with an offset voltage summed in on both + and - input nodes. With this arrangement of resistors the transfer function is: Vout = Rf/Ri Vin.

Rb acts as a summation resistor to force the common mode voltage on the power op amp input to be within the common mode voltage specification. When Vin = 0, Vcm = ƒ(Vs*(Ri/Rf)//Rb + (Ri/Rf)). As Vin becomes greater than zero, one can easily calculate the change in common mode voltage using superposition. VcmΔ = ƒ(Vin*(Rb/Ri)//Ri+(Rb/Rf)). Adding these two functions produces Vcm for Vin>0. Always check Vcm for entire range of Vin to guarantee common mode range compliance and thereby linear operation of the power op amp.

Inverting operation is actually easier. Simply move the signal source to the -side and ground the +side Ri. Vcm is set up in the same manner as above but there is no VcmΔ to worry about at all. Since Ri and Rf will both go to ground, they could be replaced with a single resistor. For best accuracy keep two individual resistors; your are likely to get better ratios and tracking from +side to -side. Speaking of accuracy, model any current mismatch through the two Rb resistors as flowing through Rf producing an output error. Realize also that most current through Rb flows through the signal source producing an input error if the signal source is not zero impedance.
Ref. AN21



Accurate brightness control is provided in this aircraft panel light control circuit. A bank of several parallel connected lamps is driven by the PA74 which operates in a closed loop with a command voltage from a low power 10-turn pot. Offset is summed into the noninverting input of the PA74 to allow a zero to 10V input command on the inverting input to be translated into a 3 to 25V output voltage across the lamps. The 3V allowance for saturation voltage on the output of the PA74 assures an accurate low impedance output at 2.5 amps. The advantage of two power op amps in one package provided by the PA74 allows the design engineer to control two independent dimmer channels from one TO-3 power op amp package. The open loop gain of the PA74, along with its power supply rejection, force a constant commanded voltage across the lamps and thus a constant brilliance regardless of power supply line fluctuations, typical in an aircraft from 16 to 32 volts.



GIVEN: Vs= 28V

STEP 3: Offset: Set Vin =0, Vo=14V

Vin = ± 10V

Vo= -Vin(Rf/Ri) + {(Vs*Rb)/RA+RB)} {1+(Rf/Ri)}

Vo = 6V 22V

FIND: Scaling resistor values

14V = 0+ (Rf/Ri) + {28 *RB)/(RA+RB)} {1+0.8}

SOLUTION:

RB/(RA+RB) = 0.278   RA= 2.6 RB

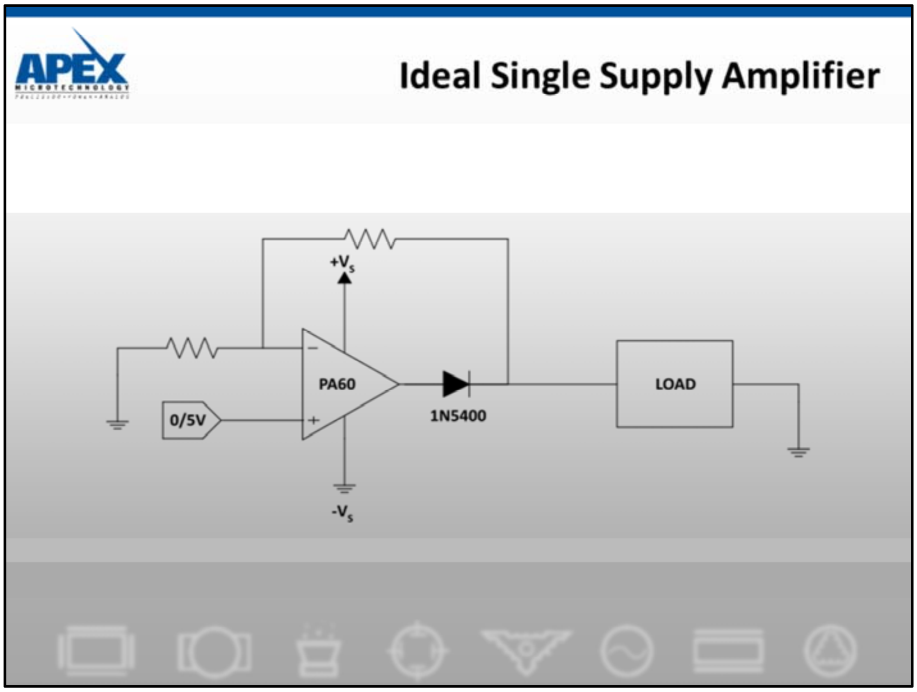
STEP1: Gain = (Rf/Ri)   Offset = {(Vs*RB)/(RA+RB)} {1+(Rf/Ri)}

STEP2: Gain = (Vo p-p)/(Vin p-p) = 16V/20V = 0.8

STEP4: For minimum offset set RA||RB = Ri||Rf

Choose RA = 16.2K, RB = 6.19K

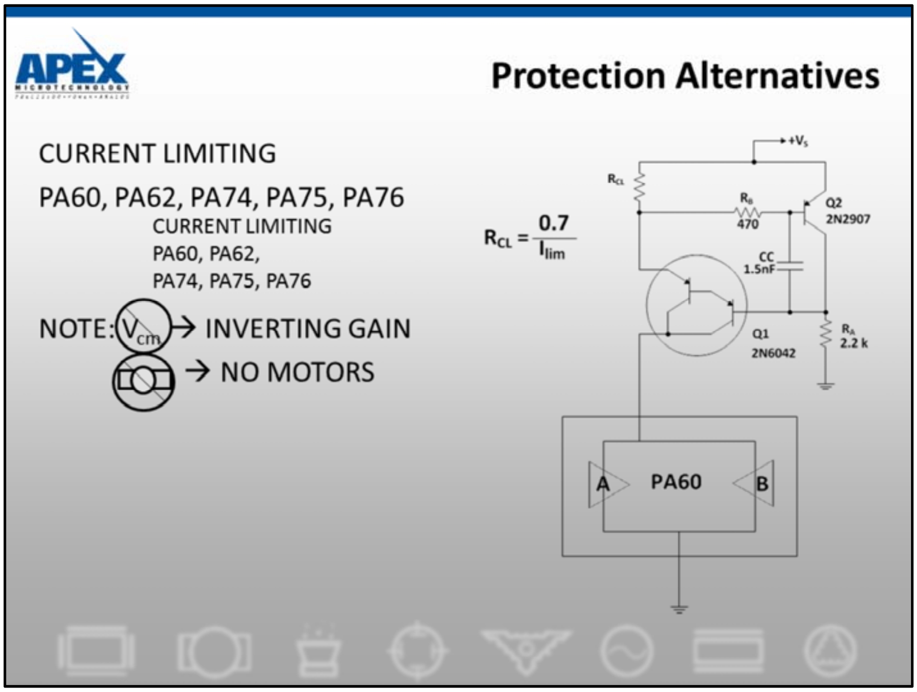
STEP5: Check for common mode: Vcm = 28 RB/(2.6RB+RB) = 7.78V (>6V OK)



The PA60 series amplifiers feature a common mode voltage range from 0.3V below the negative supply rail (ground in this case) to with in 2V of the positive rail. These amplifiers also swing to about 0.5V of the rail with very light loads making the diode level shifter above quite practical as long as the load is resistive. With the diode inside the feedback loop it contributes essentially no errors at the load.

The non-inverting circuit shown is the most common but grounding the +input and using the -input in the normal summing junction fashion will work just as well.

Ref. PA60 DATA SHEET



This handy circuit can be used with the PA60 series amplifiers in a single supply application to provide external current limit with minimum components.

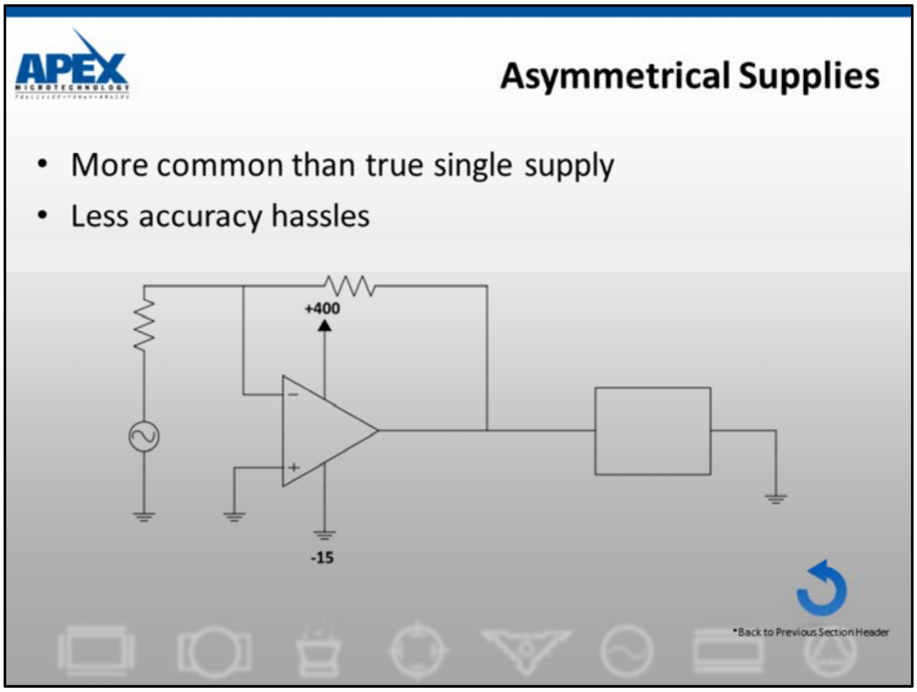
By lowering the PA60 current limit one can keep the operating conditions of the PA60 within its SOA.

Q1 is the series pass element providing voltage to the PA60. During current limit we will limit the current to the load by reducing the supply rail. Ra provides a constant biasing current to the base of Q1. When the current through Q1 is sufficient enough to develop a .7V drop across Rcl Q2 turns on and starts to turn off Q1 until current into the PA60 drops below Ilim = .7V/Rcl. Rb and Cc insure the stability of the current limit circuit.

To avoid common mode violations on the input to op amp A and op amp B, as the supply rail is lowered during current limit, it is important to configure both op amp A and op amp B in an inverting gain configuration.

The maximum additional drop through the current limit circuit is 1.7V at up to 3A. This will reduce the maximum output voltage swing available from the PA60.

In a split supply application the negative current limit circuit would replace Q1 with a 2N6045 and Q2 with a 2N2222.



There’s something very appealing about a circuit with only two gain setting resistors. Many times there is already a low voltage supply in the system just waiting to be used. This supply need only provide quiescent current of the op amp unless the op amp swings negative or in the case of reactive loads where current and voltage are not in phase.

There is nothing magic about having a high positive supply and a low negative supply. As long as the lower voltage supply satisfies the common mode voltage requirement it makes no difference if you turn things over using high negative and low positive. If you are allowed to reverse the load terminals, this could work to significant advantage. Say that the small signal portion of the system runs on +12V or +15V and you need to buy a high power supply to drive the load anyway. If you set up a negative high power rail, the existing low power supply will work fine