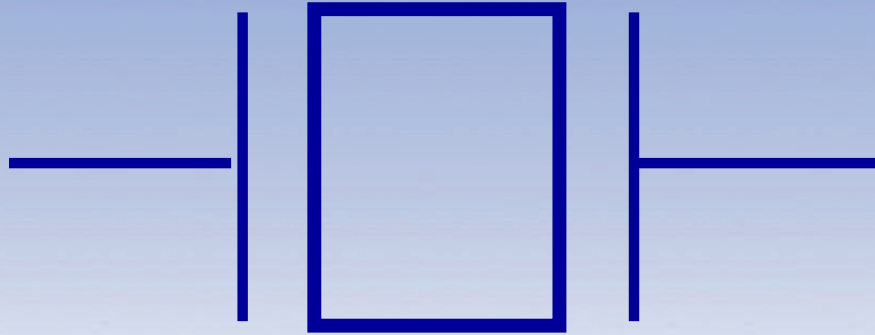


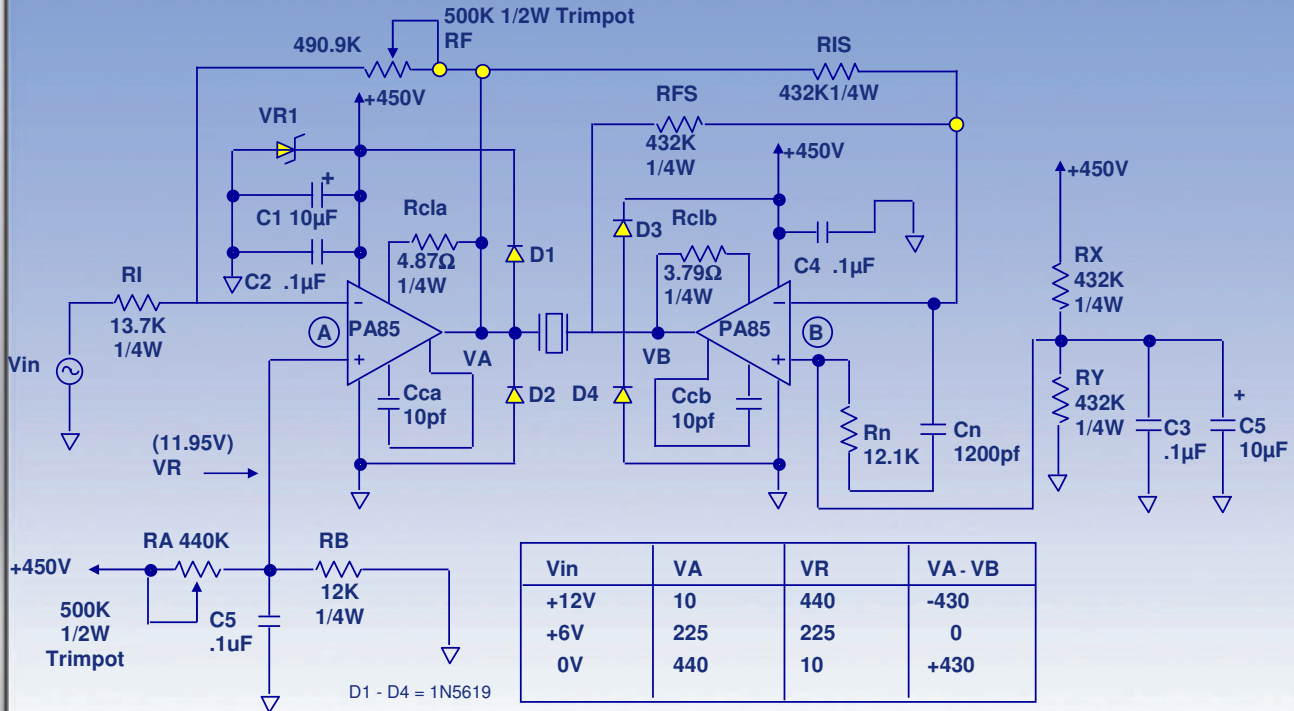


PIEZO DRIVE APPLICATIONS



860 Vpp PIEZO DRIVE

SINGLE SUPPLY BRIDGE



1. $V_{out} = V_A - V_B$

$$\begin{aligned} \text{Max } V_{out} &= V_s - V_{sata} - V_{satb} \\ &= 450V - 10V - 10V = 430V \end{aligned}$$

2. $\text{Gain} = \frac{V_{outp-p}}{V_{in p-p}} = \frac{(V_A - V_B)_{p-p}}{V_{in p-p}}$
 $860V_{p-p} / 12V_{p-p} = 71.67$

Gain = 2 RF/RI since we have a bridge configuration. That is the voltage gain across the load is twice that of the master amplifier, A, since +1V out of amplifier A yields -1V out of amplifier B, relative to the mid point power supply reference of +225V.

Therefore $RF/RI = 71.67/2 = 35.833$.

3. Offset:

$$V_A - V_B = V_s \left(2 \left(1 + \frac{R_F}{R_I} \right) \frac{R_B}{R_A + R_B} \right) - 1 - 2 \left(\frac{R_F}{R_I} \right) V_{in}$$

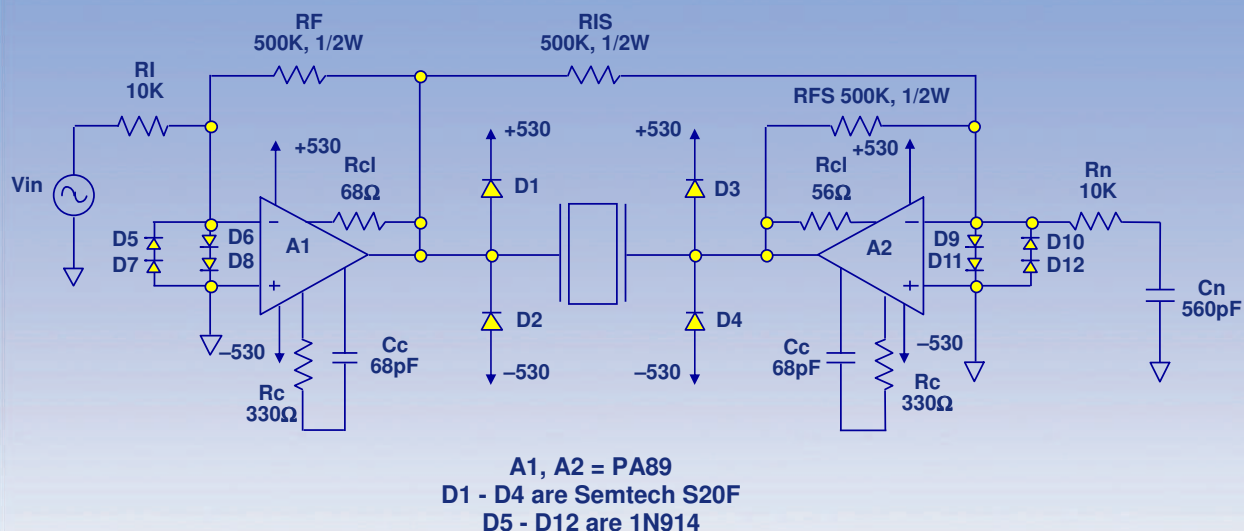
When $V_{in} = 0$ then $V_A - V_B = +430V$

Using $RF/RI = 35.833$ and solving above yields $RA = 36.669RB$

Choosing $RB = 12K$ implies $RA = 440K$.

4. Check for common mode voltage compliance: $11.95V > 10V$; OK.

+/- 1000V PIEZO BRIDGE



Piezo users appear to never have enough voltage. As soon as it was introduced the PA89 found its way into bridge circuits to drive piezos at +/-1100V and beyond.

In this application we use the dual supply bridge configuration to deliver up to almost twice the supply voltage of 530V across the load. A1 operates in a gain of 50 to translate the +/-10V input to +/-500V out of A1. A2 then inverts this output to add an additional +/-500V across the Piezo to yield a net +/-1000V.

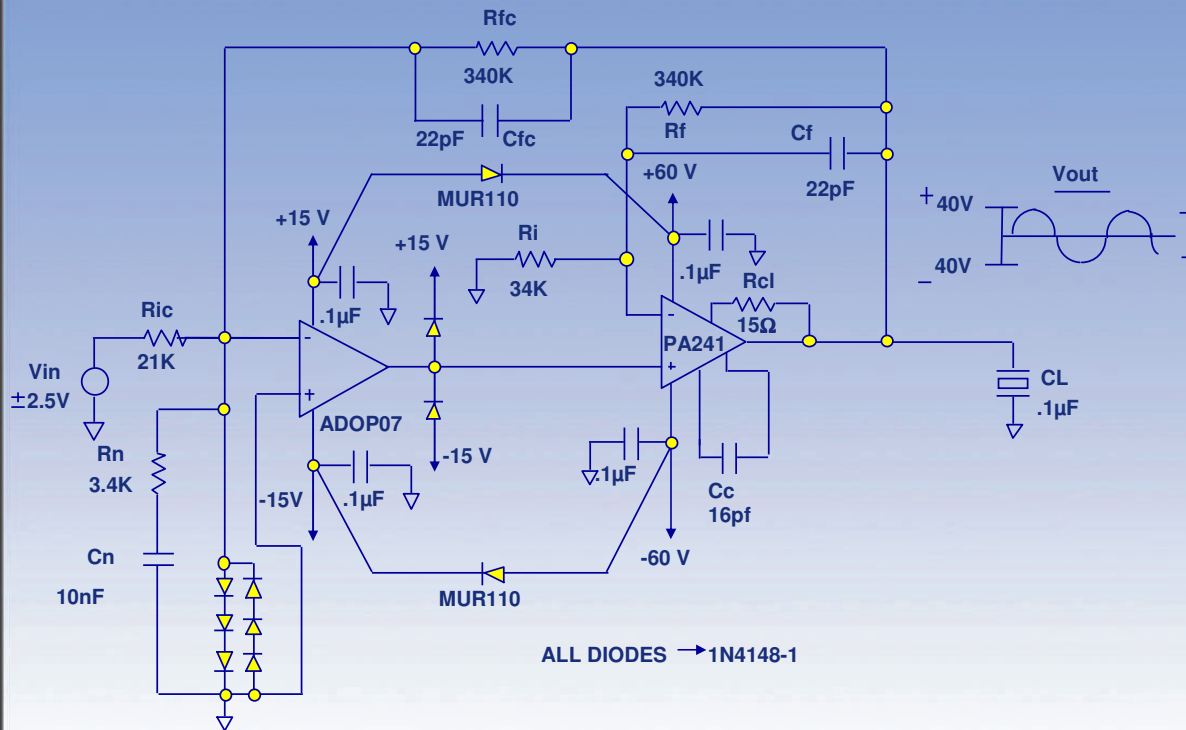
A2 uses noise gain compensation to allow its V_o/V_{in} transfer function to remain at -1, though its compensation capacitor C_c is set for a gain of 50. The noise gain will allow AC stability as well as a balanced bridge since both amplifiers are now compensated identically for the same slew rate.

Input protection diodes, output flyback diodes and proper component selection enhance reliability. Remember to select C_c capacitors with a voltage rating of at least 1100V, R_I , R_F , R_{IS} , and R_{FS} with proper power dissipation and voltage coefficient of resistance, and D1 - D4 with a PIV of at least 1100V.

As a final note remember to check the amplifiers for AC stability due to capacitive loading depending upon the capacitance of the piezo being driven.

Ref. AN25

PA141 COMPOSITE PZT DRIVE



This circuit is included as an example in Power Design.xls. It is different from most power op amps in that current limit from positive side to negative side does not match well at all.

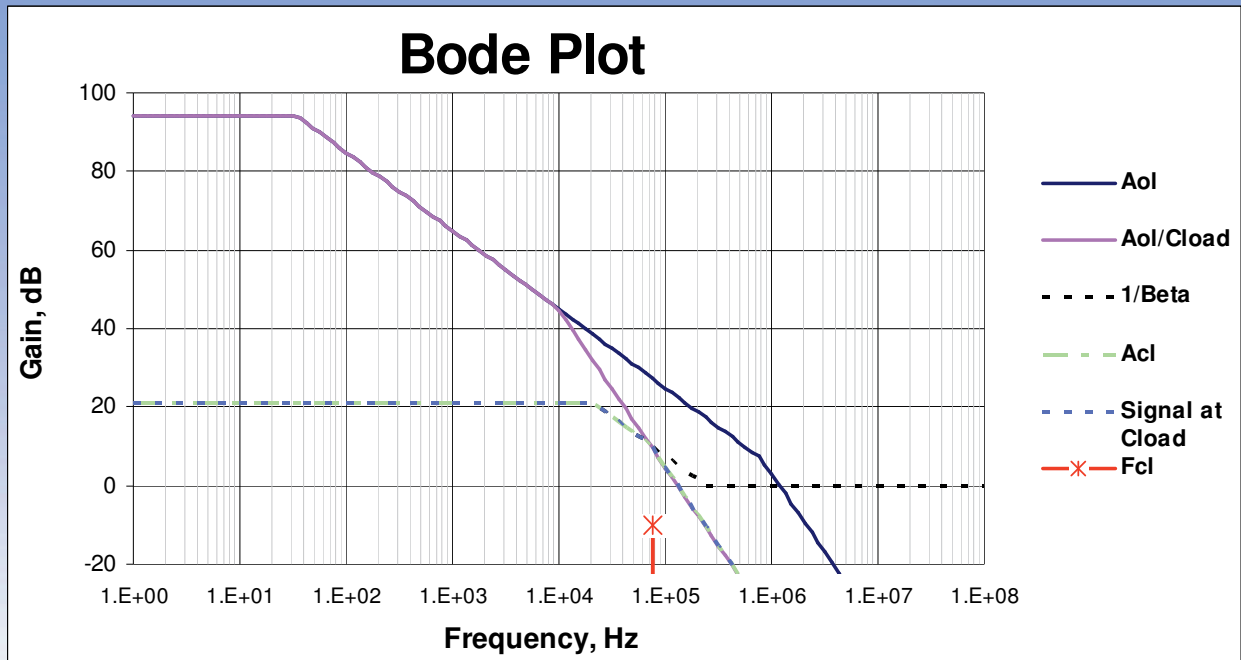
We will start by stabilizing the power stage, then the composite. Then we will examine current limit and frequency limitations imposed by this current limit.

1N4148 diodes on the input of the OP07 provide differential and common mode over voltage protection for transients through Cfc. Diodes on the output of the OP07 prevent over voltage transients that can occur through Cf, through the PA241 input protection diodes to the OP07 output through the PA241 internal input protection diodes.

Fast recovery diodes between pairs of supplies ensure that the PA241 input stage is protected from over voltage in the event the $\pm 15V$ supplies are up before the high voltage supplies.

Ref. AN19,AN25

POWER OP AMP MAGNITUDE PLOT



In any composite amplifier, make sure the power output stage is stable first. Any of the techniques we learned earlier can be used.

Ref. AN19,AN25

Composite Amplifier Set-up

Composite Circuits

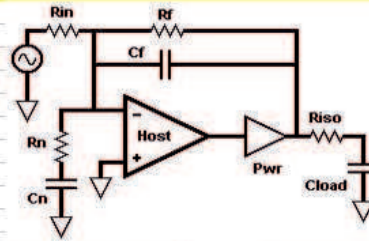
38 Goto Main Circuit

MODEL	OP07	READ ME			Estimated Closure Frequency =	56.23413 KHz
Aol =	135 dB	Pole 1 =	0.1 Hz		Suggested maximum bandwidth	5.623413 KHz
Pole 2 =	7.00E+05 Hz	Pole 3 =	7.00E+06 Hz		Estimated Closure Rate =	20.0 dB/decade
Rin	21 Kohms	Rn	3.4 Kohms		Estimated Phase Margin =	50.625 Degrees
Rf	340 Kohms	Cn	10 nF		Load Host Data	
Cf	22 pF	Using Look-Up data				

Notes:

R-C Pole Calculator:	
3.4 Kohms	47 Kohms
5 KHz	10 nF
9.36206 nF	0.338627538 KHz

1/Beta (DC)	24.7 dB
Noise Gain	16.7 dB
Pole Noise Gain	4.681027677 KHz
Zero Noise Gain	0.68665214 KHz
Pole Cf/Rf	21.27739871 KHz
Zero Rf/Cf	2493.508487 KHz

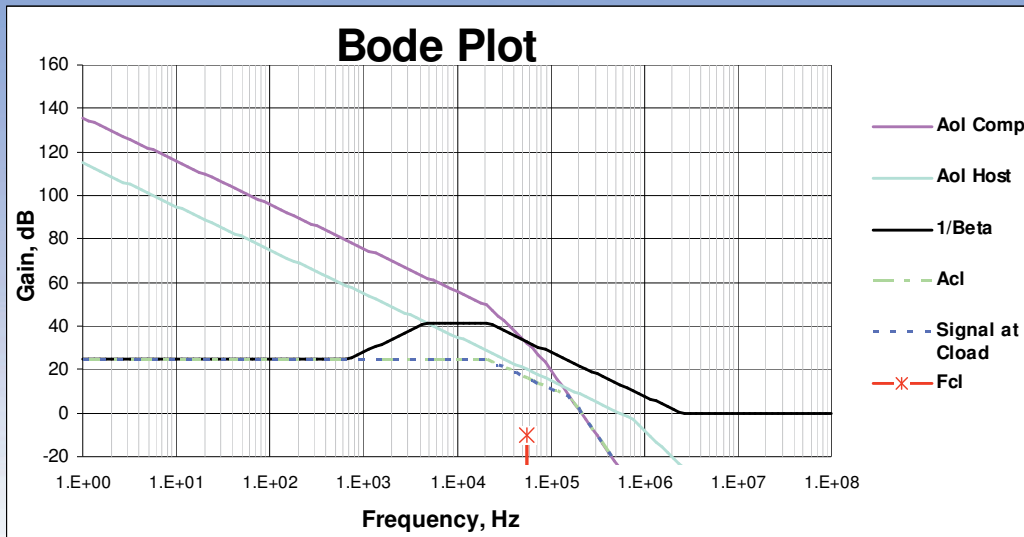


30 Print Data, Bode & Phase

31 Print Data, Bode, Phase & Parts

Ref. AN19,AN25,AN38

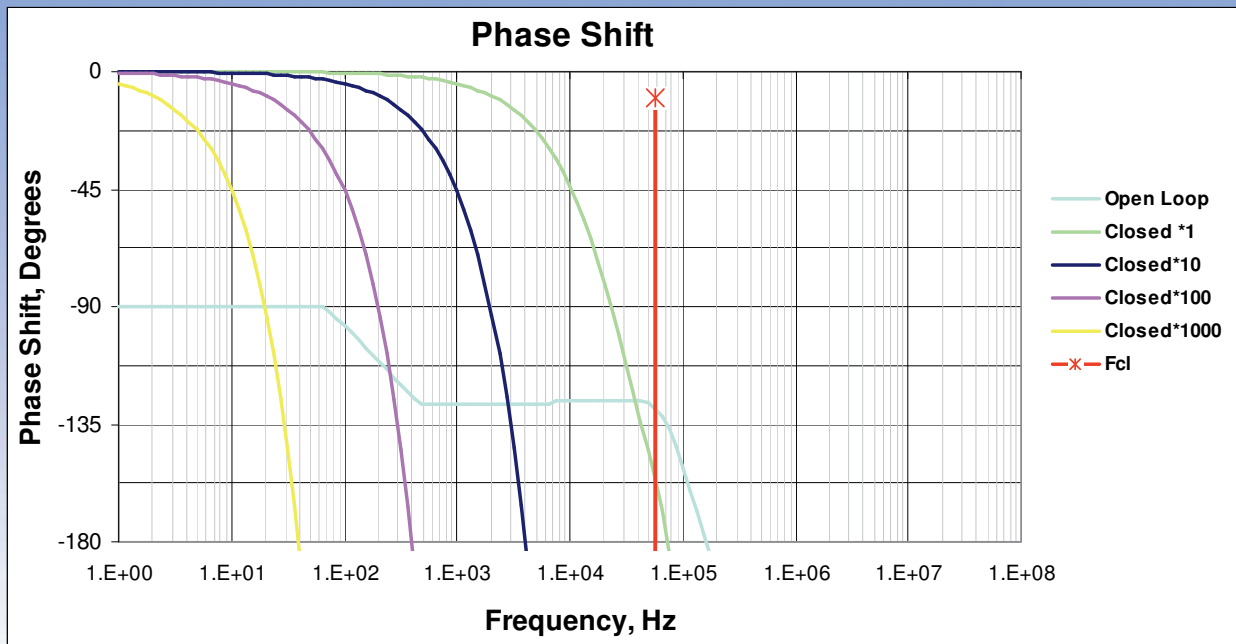
Composite Amplifier Magnitude Plot



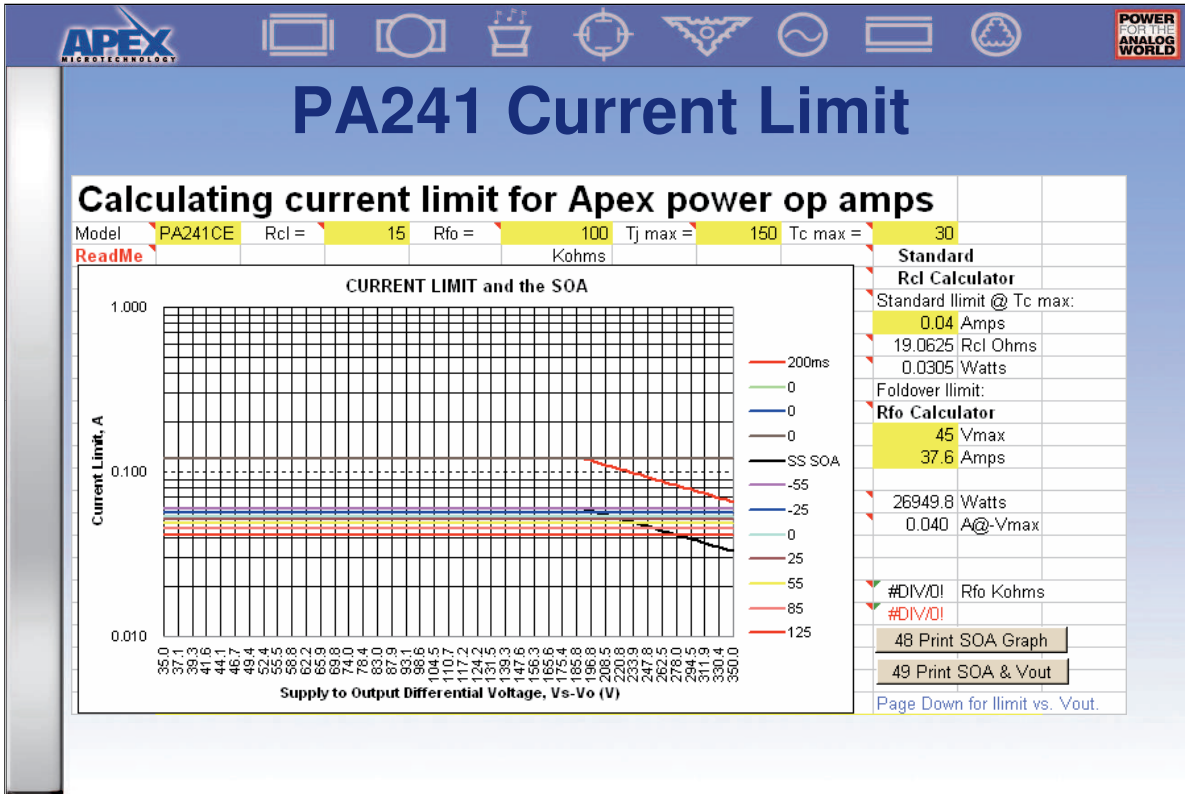
Ref. AN19,AN25,AN38



COMPOSITE AMPLIFIER OPEN LOOP PHASE PLOT



Ref. AN19,AN25,AN38



The amplifier selection, load and voltages have all been given. The only frequency that matters is the maximum (no current into a C load at DC). Our stability analysis suggested a maximum of about 10KHz (the Rf-Cf pole frequency).

Ref. AN37

Calculating Power Dissipation for Apex power op amps

Model	PA241CE	Ta max =	30	Tj max =	150	Tc max =	85
Power for Sine Wave Outputs							
Vs	60	Volts	Note/PA46				
Fmin	0.01	KHz	Note/Vboost				
Fmax	5	KHz	Bridge ckt?				
Sig	40	Units	No				
Sig as ?	V peak	Note/W					
Res	0	Ohms	# of Amps in parallel?				
Cap	0.1	uF	1				
Ind	0	mH					
Rcap	19	Ohms	Unipolar or Bipolar?				
Rind	15	Ohms	Bipolar				
Piq	0.2484	Watts		32Results	33Results	34Results	35Results
Read Me				ERRORS?		37Define	
Resonant Frequency =	503292.12	KHz		Max delta Tj =		Sweep the Frequency	
At Fmax:		At Fmin:		120		65 View Last Frequency Sweep	
Xc hi =	318.30989	Xc lo =	159154.94	Max delta Tc =			
Xl hi =	3.142E-08	Xl lo =	6.283E-11	55			

The amplifier selection, load and voltages have all been given. The only frequency that matters is the maximum (no current into a C load at DC). Our stability analysis suggested a maximum of about 10KHz (the Rf-Cf pole frequency).

Ref. AN37

Speed is Limited by Iout

	At Fmin:	At Fmax:		At Fmin:	At Fmax:	
Z in Ohms	159154.94	318.30989		Maximum AC Pin		
Phase angle	-90.00	-90.00		60	60	Vpk
RMS Amperes	0.0001777	0.0888577		42.426407	42.426407	Vrms
Peak Amperes	0.0002513	0.1256637		0.0002666	0.1332865	Arms
RMS Volts	28.284271	28.284271		0.0113097	5.6548668	Wrms
Peak Volts	40	40		7.108E-15	1.777E-09	Wtrue
RMS Power	0.0050265	2.5132741		0.0143997	7.1998695	Pin
Peak Power	0.0100531	5.0265482		Minimum HS:	9.89	°C/W
Power factor	0.000	0.000		Actual HS:	5.2	°C/W
Input power	0.01	4.80		Results in Tjmax =	92.68	°C
True power	0.00	0.00		Results in Tcmax =	61.2995407	°C
Percent Efficiency =	1.95	49.78				
Vpk capability =	51.65	40.23				
Op amp internal dissipation:						
Input power	0.01	4.80				
Dissipation RMS	0.0095998	4.80				
Dissipation Peak	0.02	8.76				
Total in heatsink	0.27	5.05				
WC watts & Rth	5.048313	6.5				

	At Fmin:	At Fmax:	
HS/Tcase	9.8947286	16.55461	Larger
HS/Tj	9.89472857		

38 Data Input

39 Print Results

CURRENT TOO HIGH!

255mA would be required to drive the .1 μ F load at 10Kz! Notice the “CURRENT TOO HIGH!” flag at the lower right. This is based on data sheet maximum, not the current limit resistor used. Since this is 10x our capability, 1KHz will be the limit with a 75 Ω current limit resistor. When this is plugged in, we will find normal operation with no heatsink is possible. To analyze fault conditions, find the lowest impedance to be encountered, assume the current limit (47mA in this case) is driven into the load and calculate the output voltage. Subtract this from the supply voltage, compare to the SOA of the amplifier and calculate a larger heatsink as required.

Ref. AN37