LT1568 Fourth Order Active RC Filter IC

DESCRIPTION

Demonstration circuit DC675B is for the evaluation of filter circuits using an LT®1568. The LT1568 is a dual 2nd order active-RC filter building block with precision ±0.75% capacitors and low noise op amps with 180MHz GBW trimmed to ±10% maximum variation. The ±10% GBW variation of the LT1568 op amps allows for minimizing the higher frequency error by decreasing resistor values. The cutoff or center frequency (f_C) range of an LT1568 filter is 200kHz to 10MHz (5MHz for a bandpass filter). The low limit of 200kHz was chosen only to minimize resistor noise and DC offsets (using external capacitors the f_C frequency can be less than 200kHz).

For testing and evaluation, the DC675B assembly is configured as a single 4th order, 500kHz narrow passband bandpass filter.

For other possible LT1568 configurations, the DC675B has unused pads for 0805 surface mount resistors and capacitors preconfigured with PCB traces to allow for the following high accuracy LT1568 filter circuits:

1. 4th order lowpass filter
2. 5th order lowpass filter
3. 4th order narrow passband bandpass
4. 4th order wide passband bandpass
5. 4th order highpass filter

Refer to the LT1568 data sheet for additional information about filter circuit configurations.

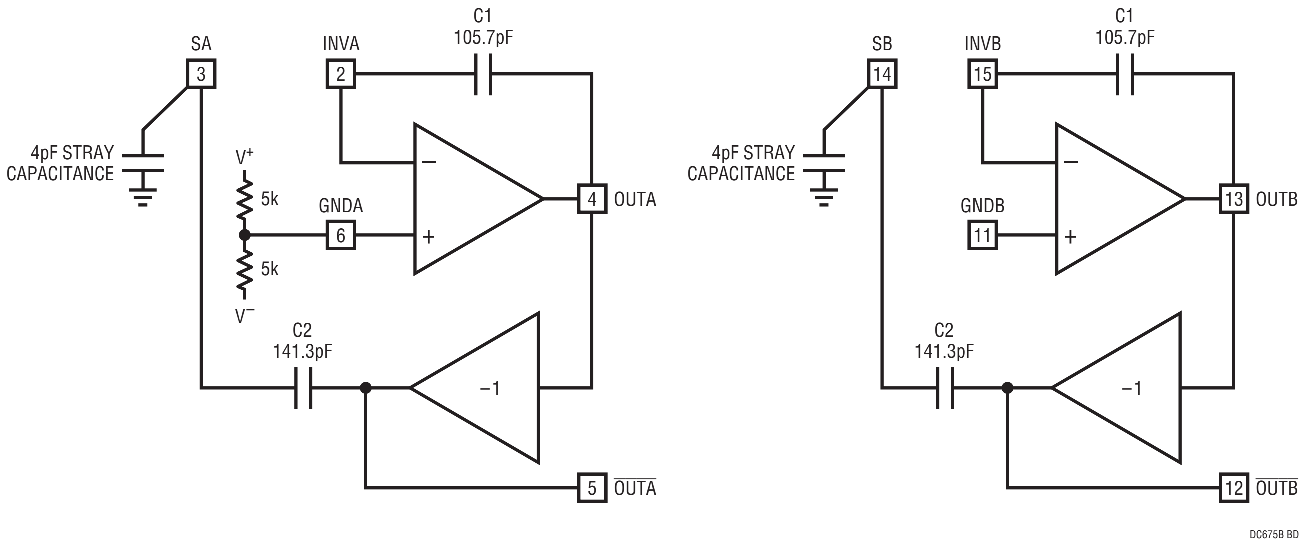
Design files for this circuit board are available at http://www.linear.com/demo/DC675B

PERFORMANCE SUMMARY

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_S	Total Supply Voltage		●	2.7		11	V
I_S	Supply Current	V_S = 3V V_S = 5V V_S = ±5V	● ● ●		24 26 28	35 36 38	mA mA mA
	Output Voltage Swing High (OUTA, $\overline{OUTA}$, OUTB, $\overline{OUTB}$ Pins)	V_S = 3V, R_L = 1k V_S = 5V, R_L = 1k V_S = 5V, R_L = 400Ω V_S = ±5V, R_L = 1k	● ● ● ●	2.75 4.60 4.50 4.60	2.85 4.80 4.65 4.75		V V V V
	Output Voltage Swing Low (OUTA, $\overline{OUTA}$, OUTB, $\overline{OUTB}$ Pins)	V_S = 3V, R_L = 1k V_S = 5V, R_L = 1k V_S = 5V, R_L = 400Ω V_S = ±5V, R_L = 1k	● ● ● ●		0.05 0.07 0.20	0.12 0.15 0.40 –4.7	V V V V
I_B	Op Amp Input Bias Current		●		0.5	–2	µA
V_{CM}	Common Mode Input Voltage Range (GNDA and GNDB Pins)	V_S = 3V V_S = ±5V			1 to 1.9 –3.4 to 2.7		V V
OA Input Voltage Noise Density		f = 100kHz			1.4		nV/√Hz
OA Input Voltage Noise Density		f = 100kHz			1.0		pA/√Hz

LT1568 BLOCK DIAGRAM



TYPICAL CAPACITOR SPECIFICATIONS: C1, C2 AND C2/C1 RATIO ±0.75%
SIDE A TO SIDE B CAPACITOR MISMATCH ±1%
PART TO PART CAPACITOR VARIATION ±2%

QUICK START PROCEDURE

See Figure 1 for proper measurement equipment setup and follow the procedure below.

1. Place jumpers in the following positions: JP1-DUAL SUPPLY, JP4-AB.
2. With power off, connect a dual 5V power supply to V^+ and $V^–$.
3. Connect a 500kHz, $2V_{P-P}$, sine wave at the V_{INA} and GND turrets.
4. Set the scaling of an oscilloscope to 1V/1µs per division.
5. Connect an SMA to BNC coax cable from V_{OUTB} and $–V_{OUTB}$ (V_{OUTB} bar) to oscilloscope channel 1 and 2 respectively.
6. Power up the system and the oscilloscope should show two $2V_{P-P}$ sine waves of opposite polarity (180 degrees phase shift).
7. To test stopband attenuation set the input frequency to 100kHz or 2MHz and the output voltage drops to ≤ $20mV_{P-P}$.

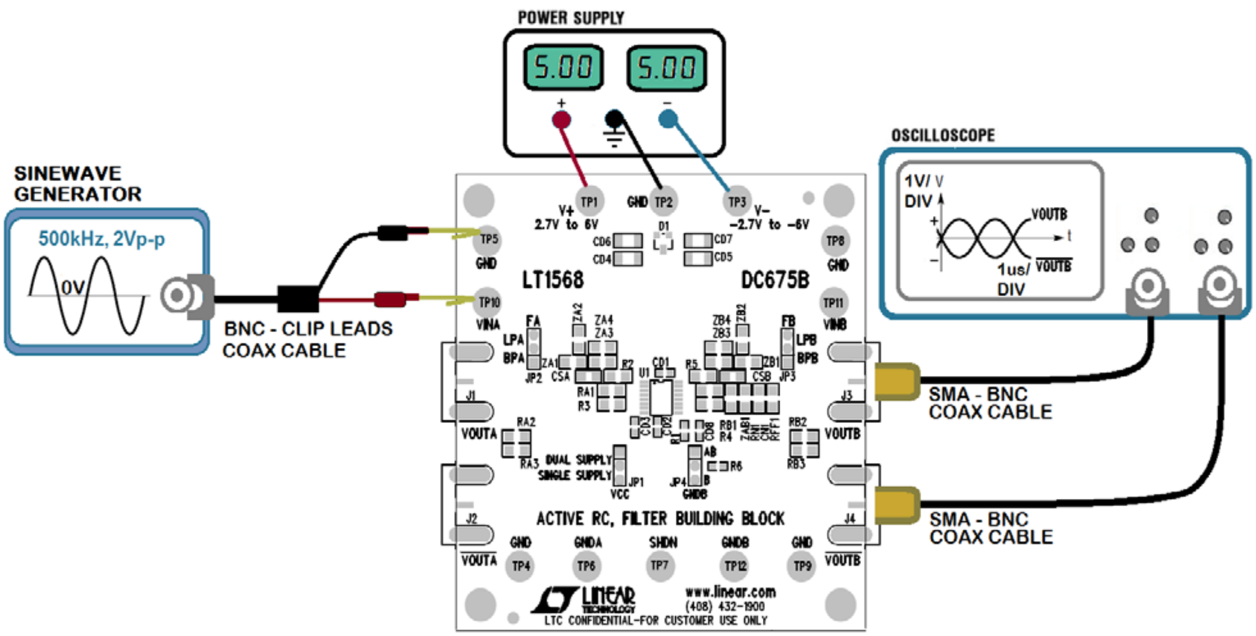


Figure 1. Quick Start Test Equipment Setup

QUICK START PROCEDURE

DC675B DEFAULT CONFIGURATION

For quick testing and evaluation, the DC675B default assembly is a single 4th order, 500kHz narrow passband bandpass filter as shown in Figure 1. This schematic was drawn and analyzed using LTspice[1] and shows the DC675B component designators.

Re-Configuring the DC675B

Removing the default passive components (ZA1, ZA3, R2, RA1, R3, ZAB1, R5, RB1 and R4) a variety of other LT1568 filter circuits can be implemented. The following figures highlight easy to design and evaluate LT1568 4th or 5th order filter circuits using a DC675B.

Figure 2 through Figure 9 show the LTspice schematic with simple equations to calculate the external passive components as a function of the filter's cutoff or center frequency (f_C) or passband gain.

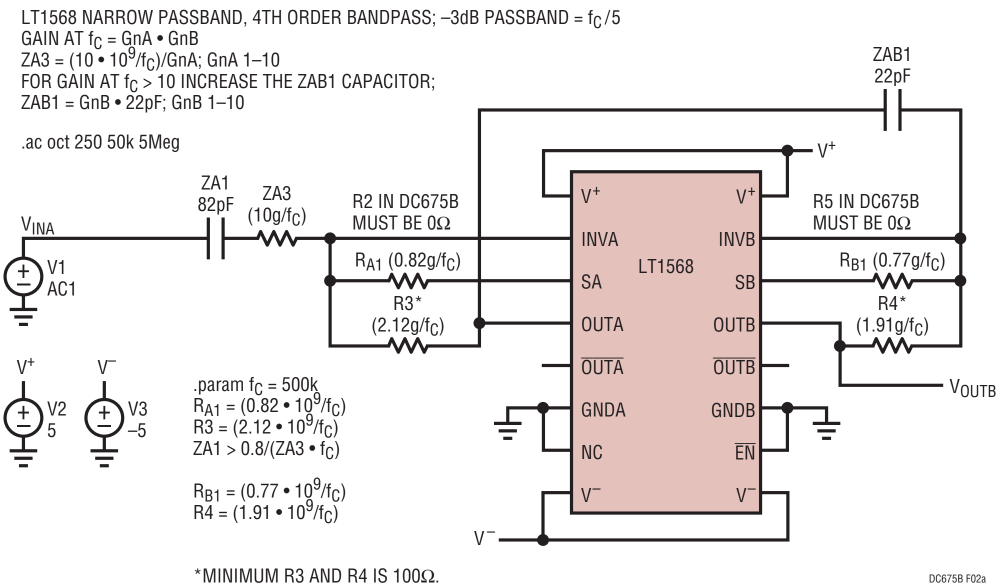
There are two f_C and gain error sources, the passive component tolerance (the internal and external passive component variation) and the GBW variation of the LTC1568 op amps.

1 LTspice is a high performance simulator, schematic capture and waveform viewer available for free download at www.linear.com/LTspice.

Specifying ≤ 0.5% resistors and ≤ 2% capacitors minimizes the fc and gain error due to the external passive components (the tolerance of an AC coupling capacitor can be 5%).

The GBW f_C error depends on the filter's gain, stopband attenuation and the steepness of the passband to stopband transition (filter circuits with high gain, high attenuation and very steep transition are very sensitive to the GBW variation). The ±10% GBW variation of the LT1568 op amps allows for reducing the f_C error at higher f_C frequencies by adjusting the calculated values by a few percent (for example: The typical f_C error of a 2MHz bandpass filter is –2.5%. Reducing the calculated resistor values by 2.5% will reduce the f_C error due to the GBW variation). The typical f_C and gain error can be evaluated by an LTspice frequency response simulation. Since the internal C1 and C2 capacitors in the LT1568 model are ideal, the errors in an LTspice simulation are due to the LT1568 op amps and the external passive components. Using LTspice, the following can be used as an empirical guideline for an LT1568 at f_C > 500kHz: An f_C error greater than 5% or a passband gain peak greater than 2dB is an indication that the circuit is operating beyond a reliable f_C frequency.

LTspice SIMULATIONS



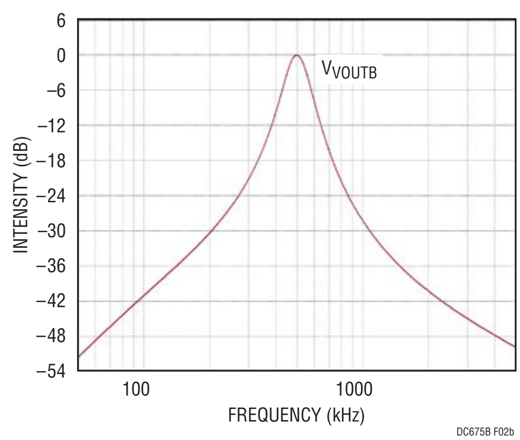


Figure 2. LT1568 Fourth Order Bandpass Filter: f_C = 500kHz, –3dB BW = 100kHz (f_C/5). The Default DC675B Circuit

The LTspice file for this circuit is available at www.linear.com/demo/DC675B

LTspice SIMULATIONS

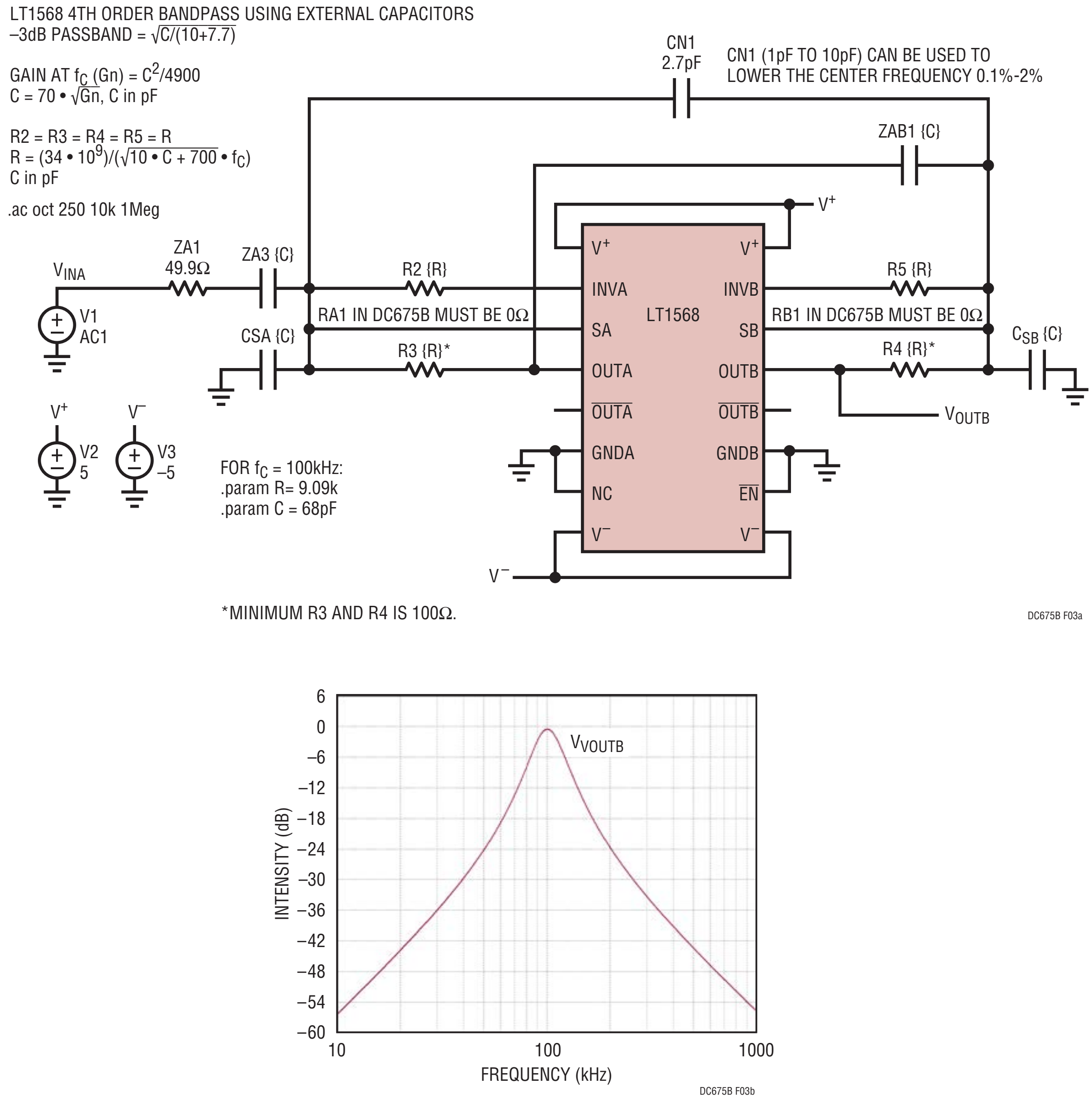
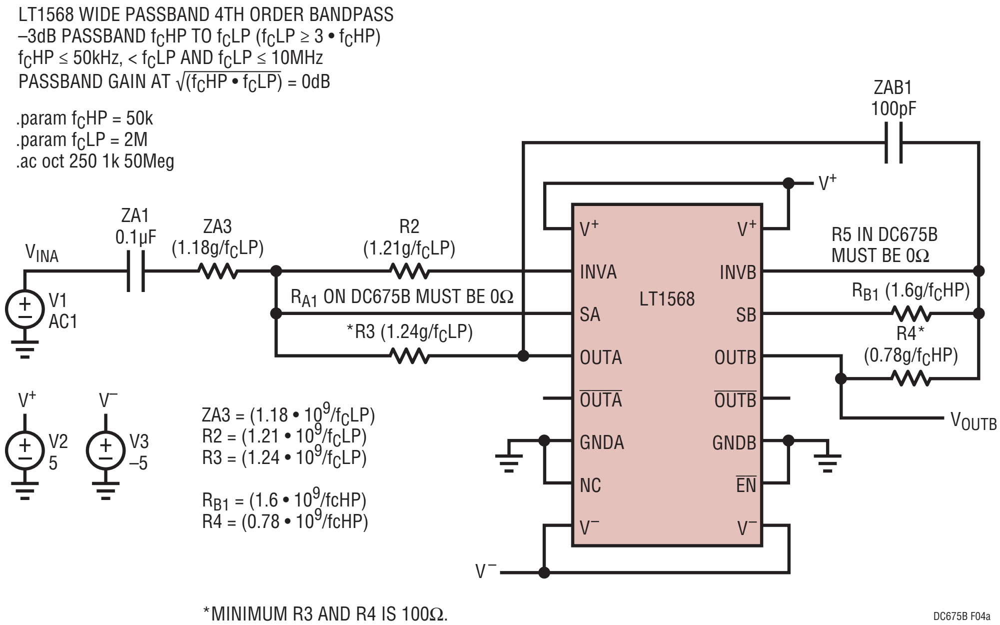


Figure 3. LT1568 Fourth Order Bandpass Filter (Using External Capacitors for Center Frequencies Less Than 200kHz)

The LTspice file for this circuit is available at www.linear.com/demo/DC675B

LTspice SIMULATIONS



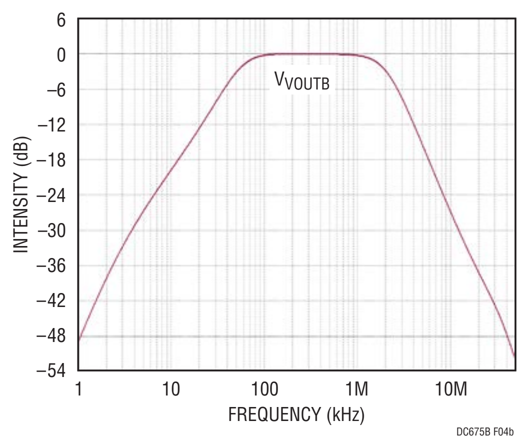
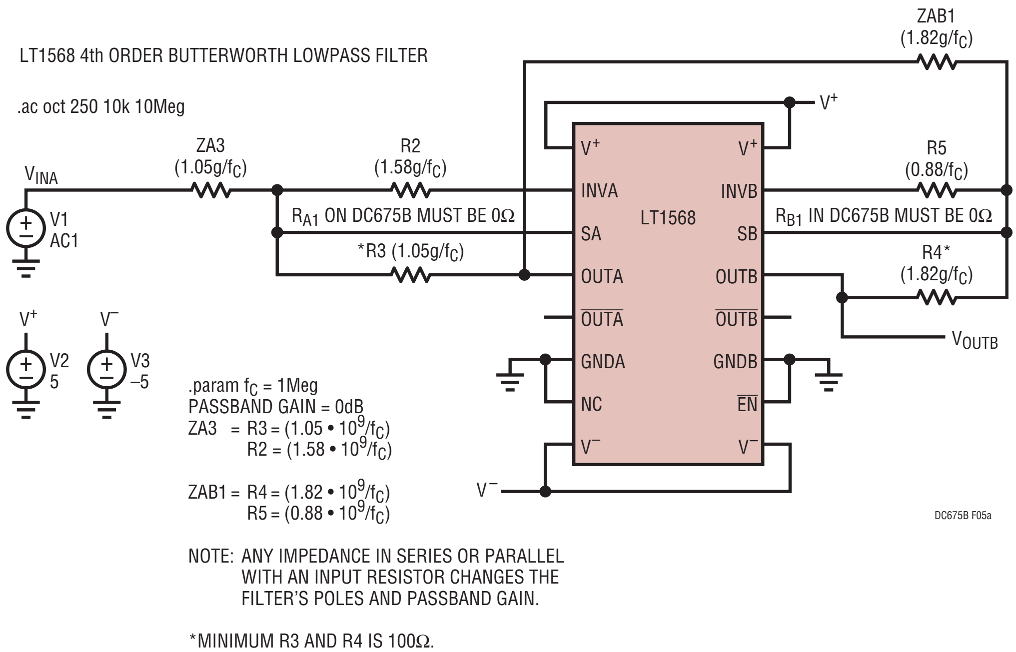


Figure 4. LT1568 Fourth Order Wide Passband Bandpass Filter

The LTspice file for this circuit is available at www.linear.com/demo/DC675B

LTspice SIMULATIONS



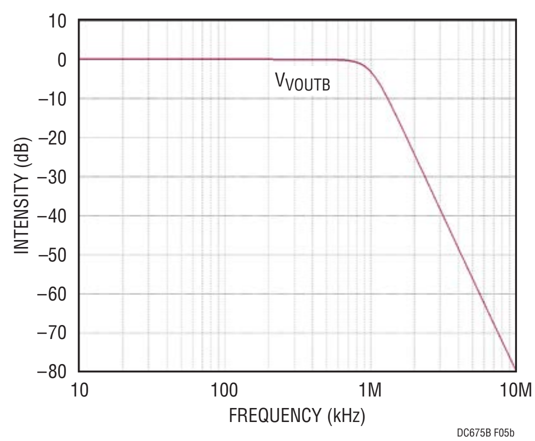
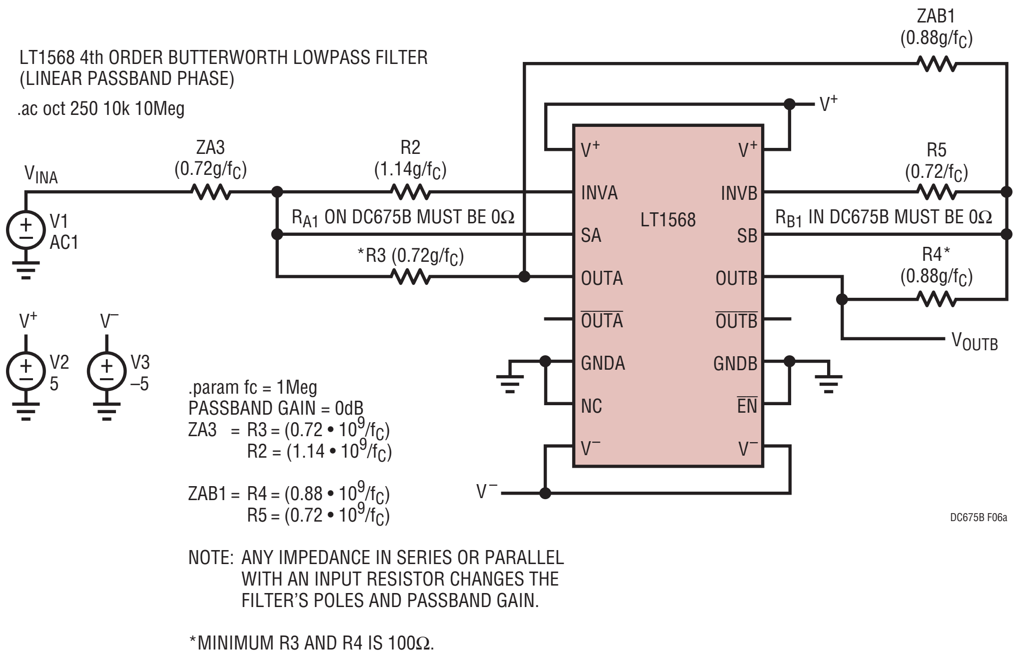


Figure 5. LT1568 Fourth Order Bandpass Lowpass Filter

The LTspice file for this circuit is available at www.linear.com/demo/DC675B

LTspice SIMULATIONS



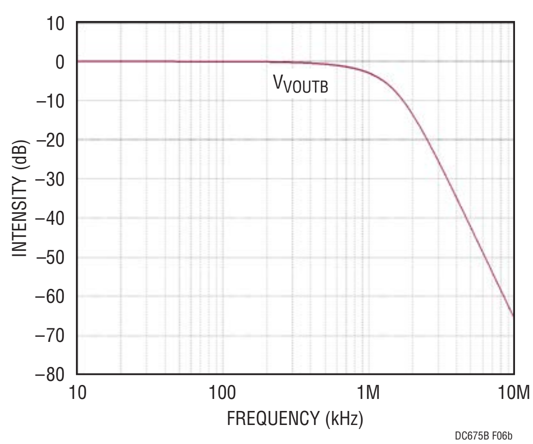
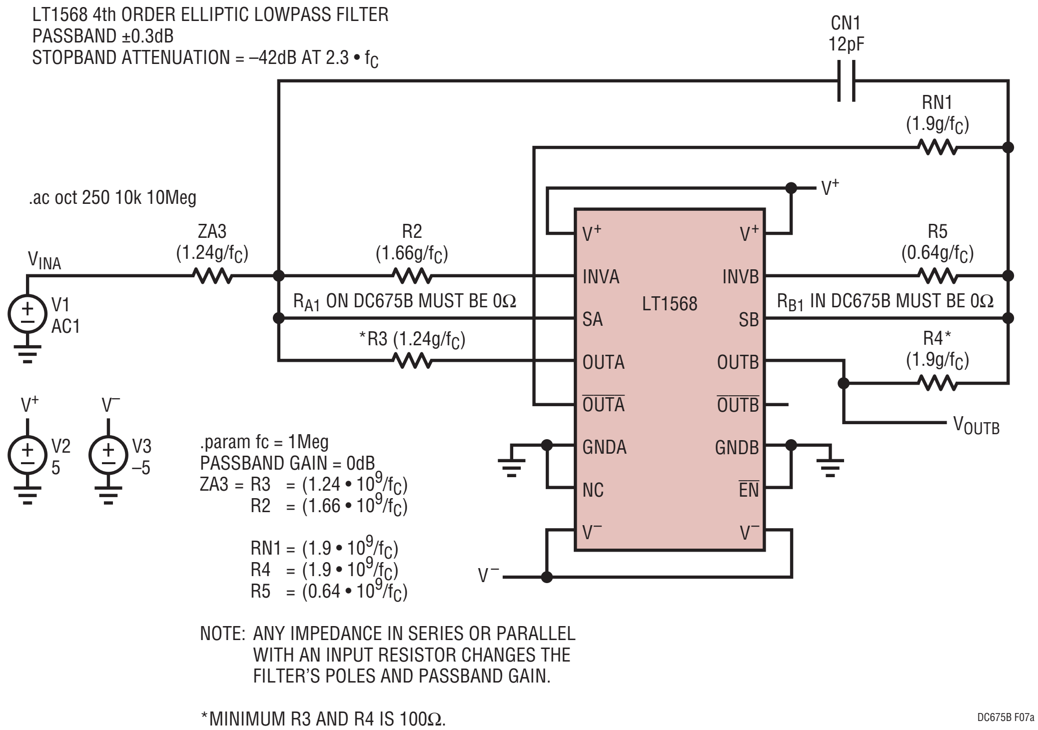


Figure 6. LT1568 Fourth Order Bessel Lowpass Filter (Linear Passband Phase)

The LTspice file for this circuit is available at www.linear.com/demo/DC675B

LTspice SIMULATIONS



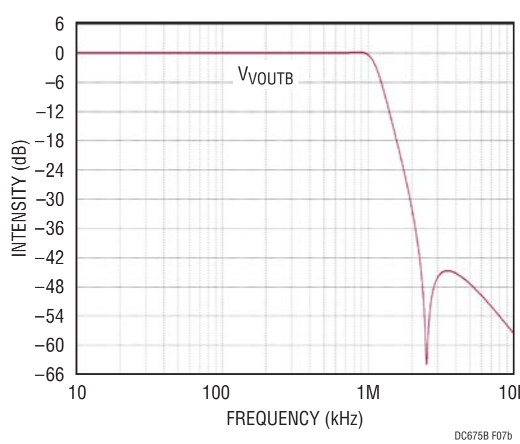
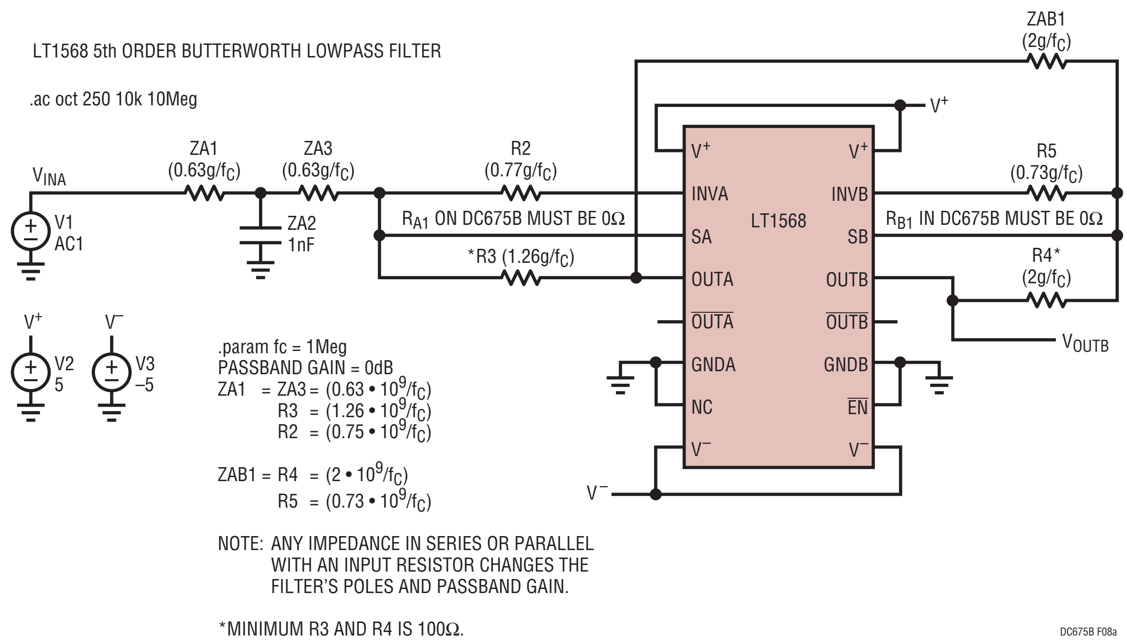


Figure 7. LT1568 Fourth Order Elliptic Lowpass Filter

The LTspice file for this circuit is available at www.linear.com/demo/DC675B

LTspice SIMULATIONS



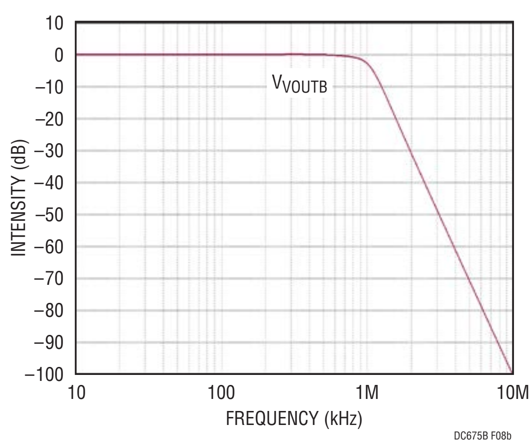
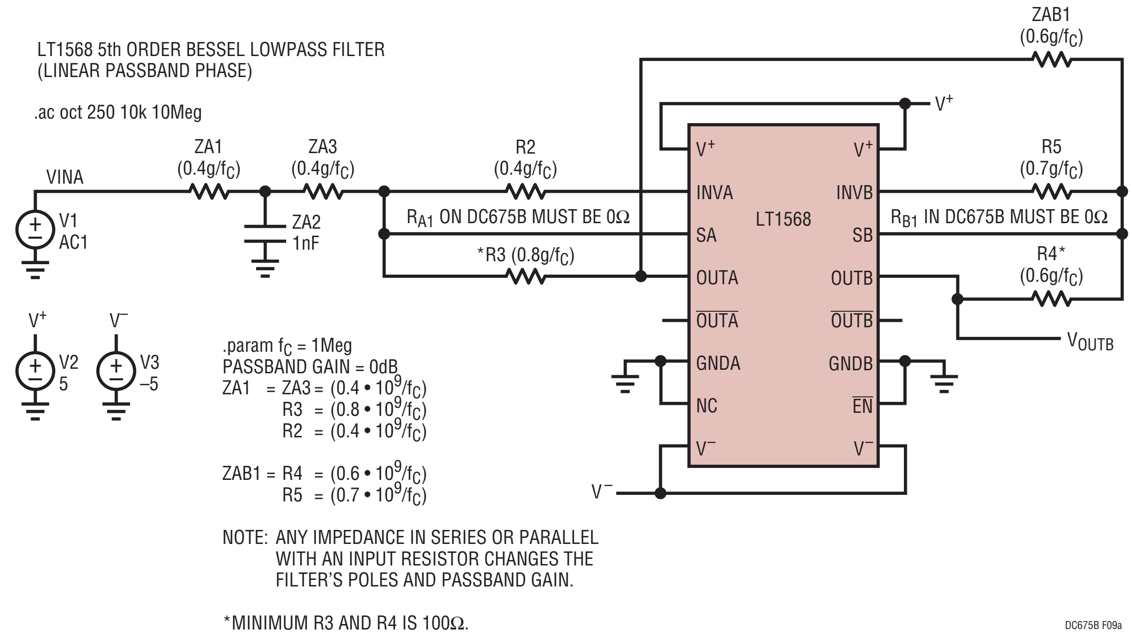


Figure 8. LT1568 Fourth Order Butterworth Lowpass Filter

The LTspice file for this circuit is available at www.linear.com/demo/DC675B

LTspice SIMULATIONS



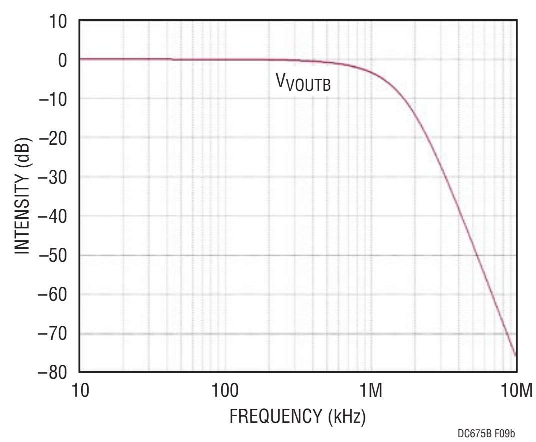
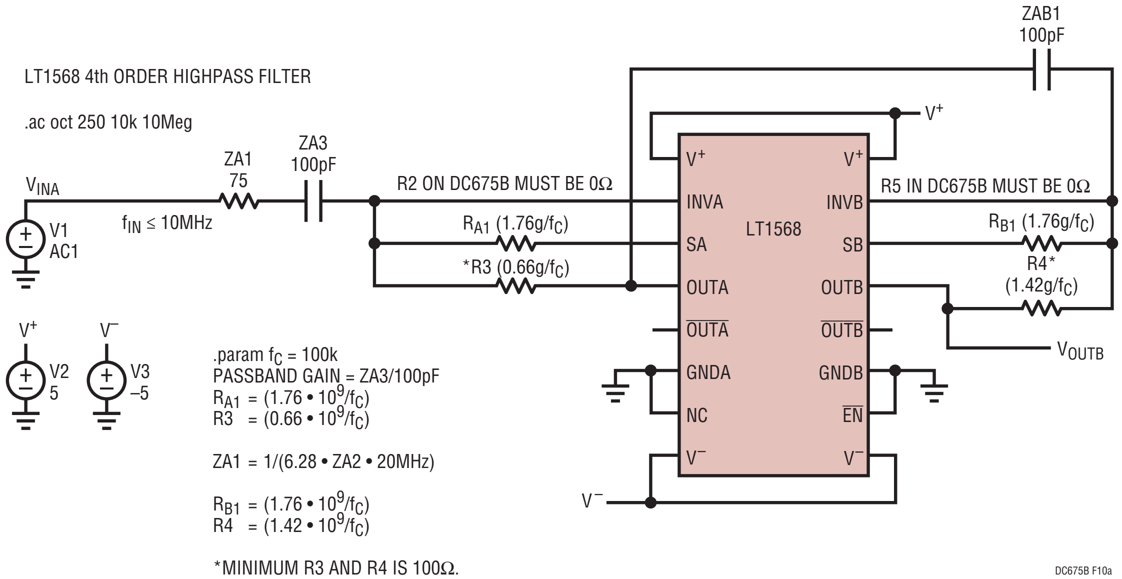


Figure 9. LT1568 Fifth Order Bessel Lowpass Filter (Linear Passband Phase)

The LTspice file for this circuit is available at www.linear.com/demo/DC675B

LTspice SIMULATIONS



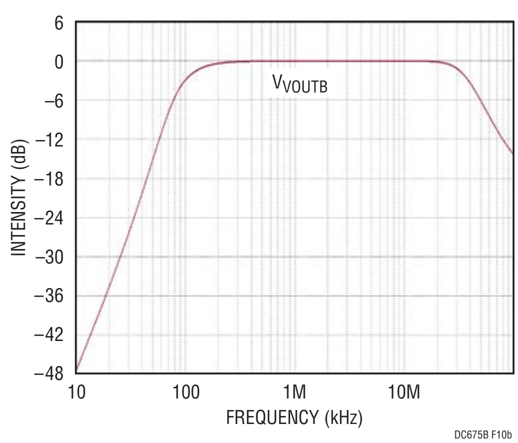
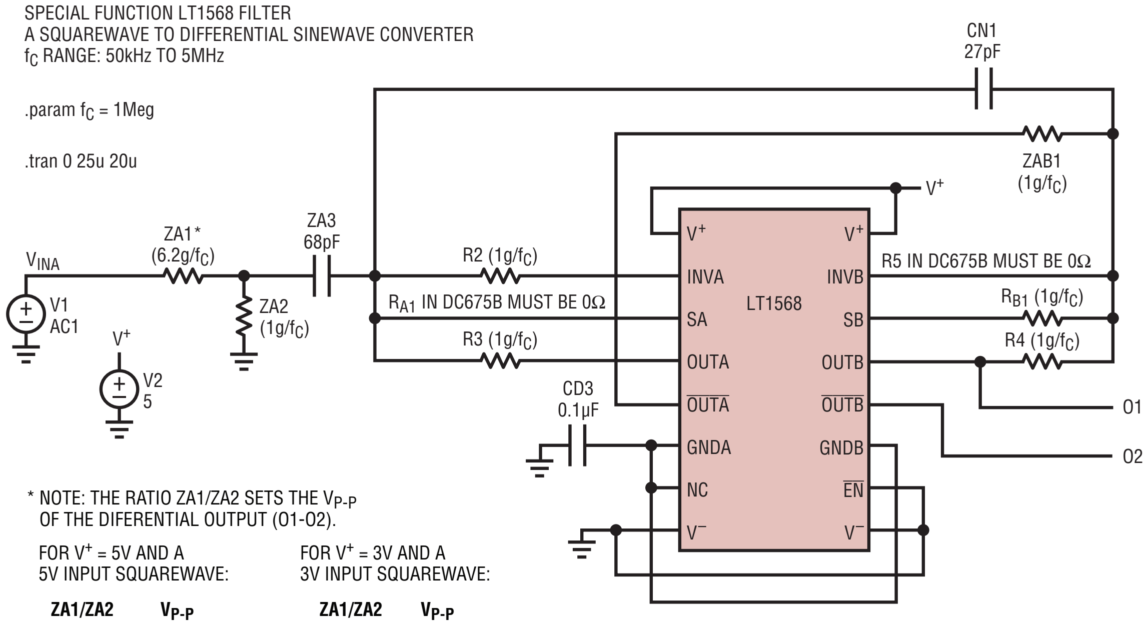


Figure 10. LT1568 Fourth Order Highpass Filter

The LTspice file for this circuit is available at www.linear.com/demo/DC675B

LTspice SIMULATIONS



* NOTE: THE RATIO ZA1/ZA2 SETS THE $V_{P\text{-}P}$ OF THE DIFERENTIAL OUTPUT (O1-O2).

FOR V^+ = 5V AND A 5V INPUT SQUAREWAVE:

ZA1/ZA2	$V_{P\text{-}P}$
1	8
2	5
4.75	2.5
6.2	2
12.4	1

FOR V^+ = 3V AND A 3V INPUT SQUAREWAVE:

ZA1/ZA2	$V_{P\text{-}P}$
0.95	5
2	3
3.4	2
7.5	1

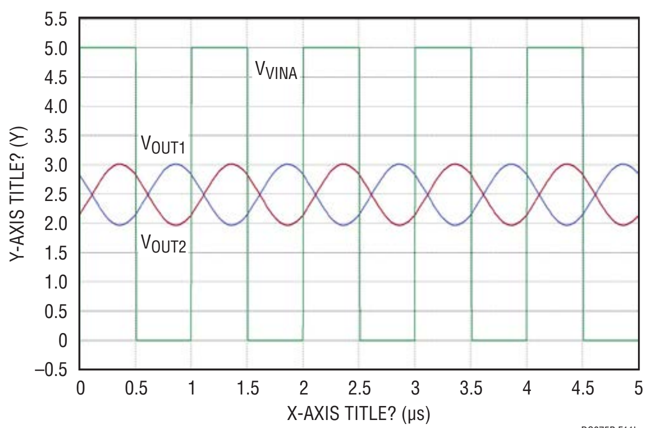
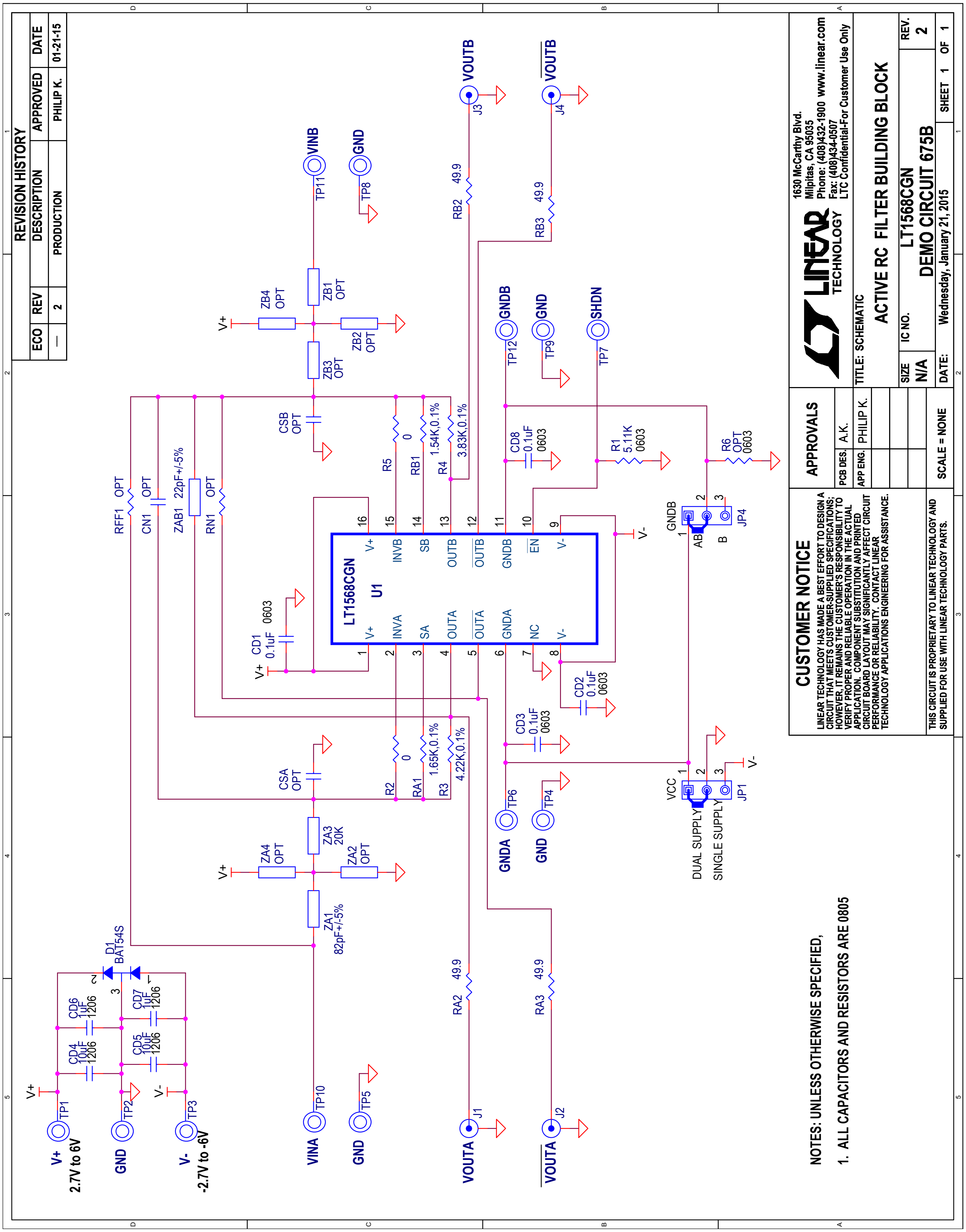


Figure 11

The LTspice file for this circuit is available at www.linear.com/demo/DC675B

SCHEMATIC DIAGRAM



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