

## LT1568 Fourth Order Active RC Filter IC

### DESCRIPTION

Demonstration circuit DC675C is for the evaluation of filter circuits using an [LT<sup>®</sup>1568](#). The LT1568 is a dual 2nd order active-RC filter building block with precision  $\pm 0.75\%$  capacitors and low noise op amps with 180MHz GBW trimmed to  $\pm 10\%$  maximum variation. The  $\pm 10\%$  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 DC675C assembly is configured as a single 4th order, 500kHz narrow passband bandpass filter.

For other possible LT1568 configurations, the DC675C 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.](#)

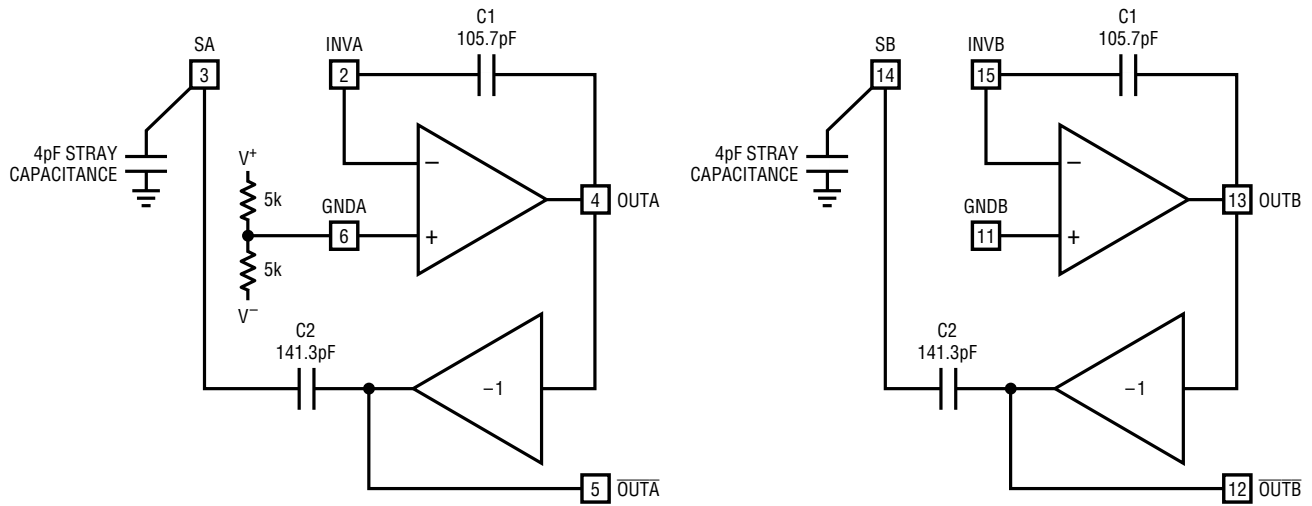
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### PERFORMANCE SUMMARY

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ\text{C}$

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

## LT1568 BLOCK DIAGRAM



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

DC675C BD

## 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  $1V/1\mu s$  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  $\leq 20mV_{p-p}$ .

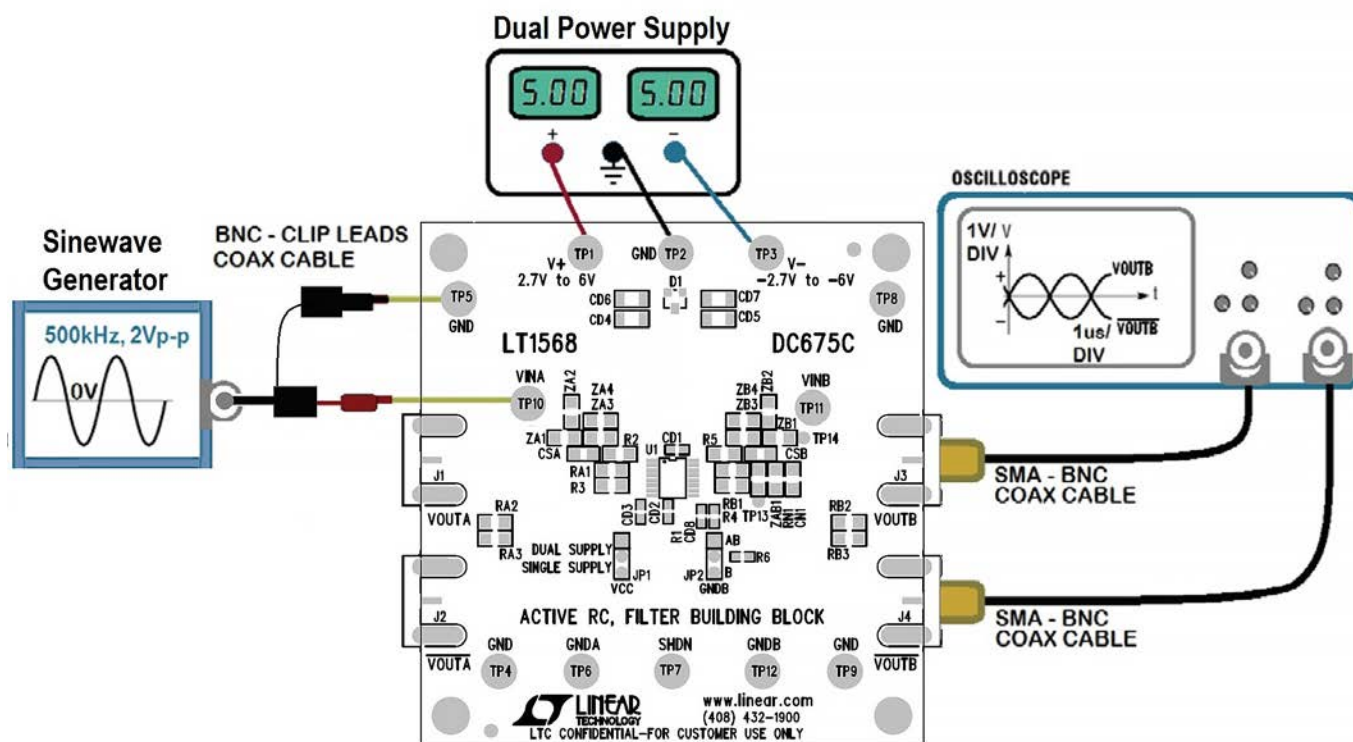


Figure 1. Quick Start Test Equipment Setup

## QUICK START PROCEDURE

### DC675B DEFAULT CONFIGURATION

For quick testing and evaluation, the DC675C 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<sup>1</sup> and shows the DC675C component designators.

### Re-Configuring the DC675C

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 DC675C.

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.

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

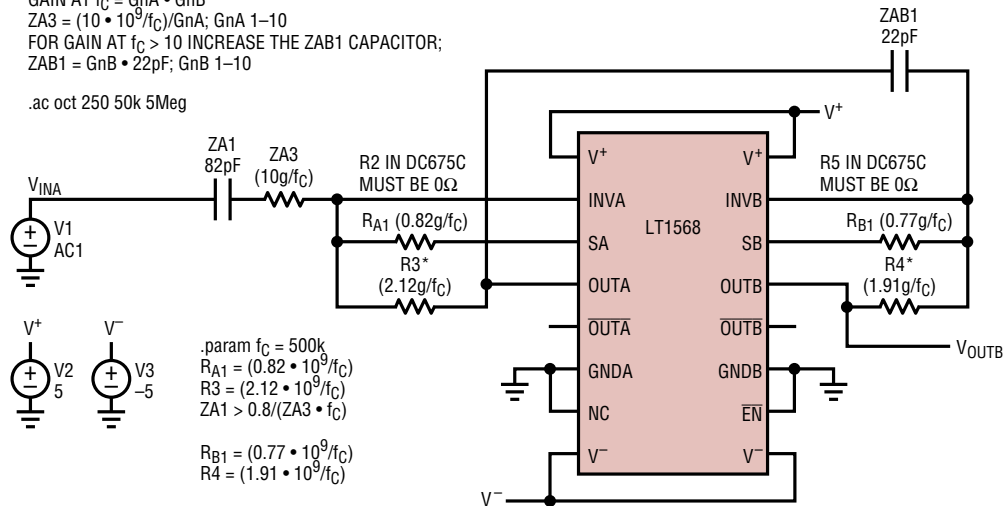
The GBW  $f_C$  error depends on the filter's gain, stopband attenuation and the steepness of the passband to stopband transition (filter circuits with high gain, high attenuation and very steep transition are very sensitive to the GBW variation). The  $\pm 10\%$  GBW variation of the LT1568 op amps 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  $f_C > 500\text{kHz}$ : 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.

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<sup>1</sup> LTspice is a high performance simulator, schematic capture and waveform viewer available for free download at [LTspice](http://www.linear.com/ltspice).

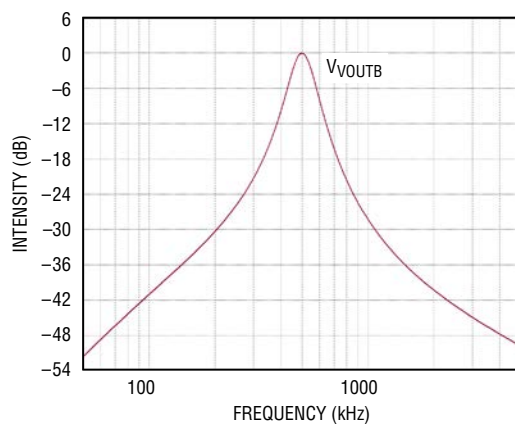
LTspice SIMULATIONS

LT1568 NARROW PASSBAND, 4TH ORDER BANDPASS;  $-3\text{dB PASSBAND} = f_c/5$   
 GAIN AT  $f_c = G_{nA} \cdot G_{nB}$   
 $Z_{A3} = (10 \cdot 10^9 / f_c) / G_{nA}$ ;  $G_{nA}$  1-10  
 FOR GAIN AT  $f_c > 10$  INCREASE THE ZAB1 CAPACITOR;  
 $Z_{AB1} = G_{nB} \cdot 22\text{pF}$ ;  $G_{nB}$  1-10



\*MINIMUM R3 AND R4 IS 100Ω.

DC675C F02a



DC675C F02b

Figure 2. LT1568 Fourth Order Bandpass Filter:  $f_c = 500\text{kHz}$ ,  $-3\text{dB BW} = 100\text{kHz} (f_c/5)$ . The Default DC675C Circuit

The LTspice file for this circuit is available.

# DEMO MANUAL DC675C

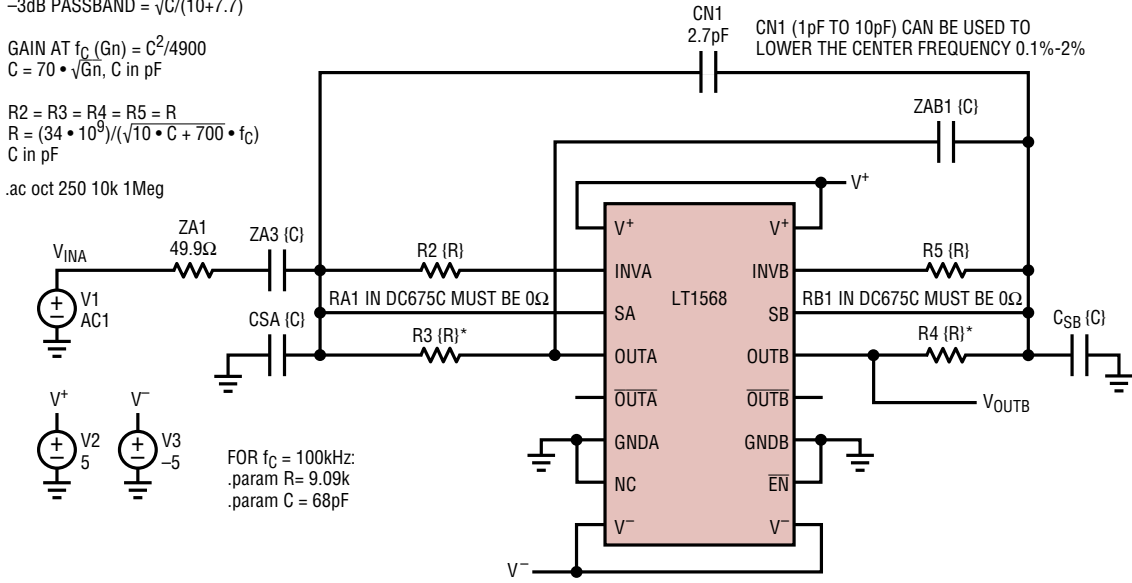
## LTspice SIMULATIONS

LT1568 4TH ORDER BANDPASS USING EXTERNAL CAPACITORS  
 -3dB PASSBAND =  $\sqrt{C/(10+7.7)}$

GAIN AT  $f_c$  ( $G_n$ ) =  $C^2/4900$   
 $C = 70 \cdot \sqrt{G_n}$ , C in pF

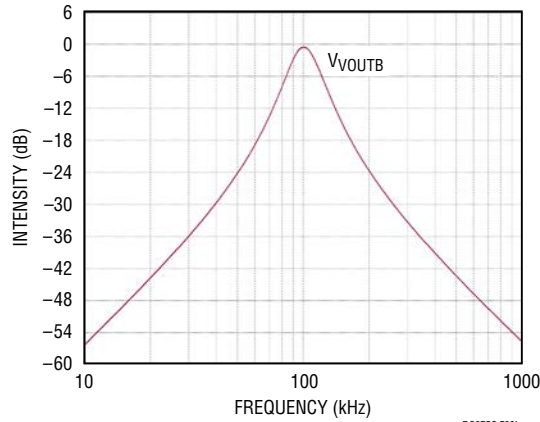
$R_2 = R_3 = R_4 = R_5 = R$   
 $R = (34 \cdot 10^9) / (\sqrt{10} \cdot C + 700 \cdot f_c)$   
 C in pF

.ac oct 250 10k 1Meg



\*MINIMUM R3 AND R4 IS 100Ω.

DC675C F03a



DC675C F03b

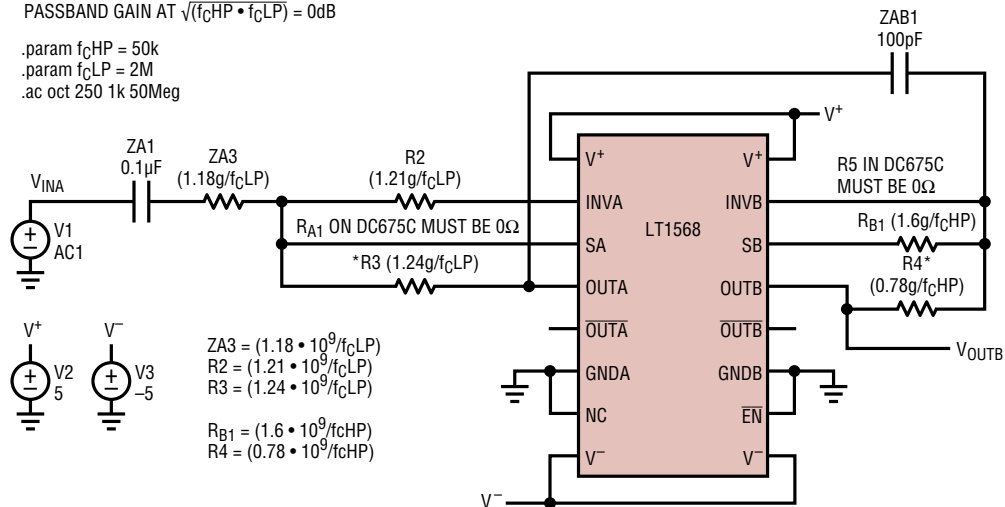
**Figure 3. LT1568 Fourth Order Bandpass Filter (Using External Capacitors for Center Frequencies Less Than 200kHz)**

The LTspice file for this circuit is available.

# LTspice SIMULATIONS

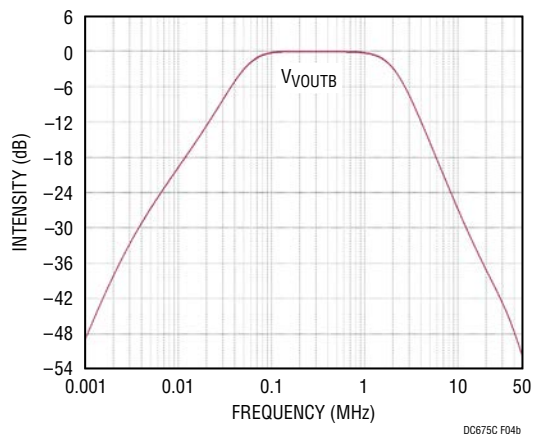
LT1568 WIDE PASSBAND 4TH ORDER BANDPASS  
 -3dB PASSBAND  $f_{cHP}$  TO  $f_{cLP}$  ( $f_{cLP} \geq 3 \cdot f_{cHP}$ )  
 $f_{cHP} \leq 50\text{kHz}$ ,  $< f_{cLP}$  AND  $f_{cLP} \leq 10\text{MHz}$   
 PASSBAND GAIN AT  $\sqrt{(f_{cHP} \cdot f_{cLP})} = 0\text{dB}$

.param  $f_{cHP} = 50\text{k}$   
 .param  $f_{cLP} = 2\text{M}$   
 .ac oct 250 1k 50Meg



\*MINIMUM R3 AND R4 IS 100Ω.

DC675C F04a

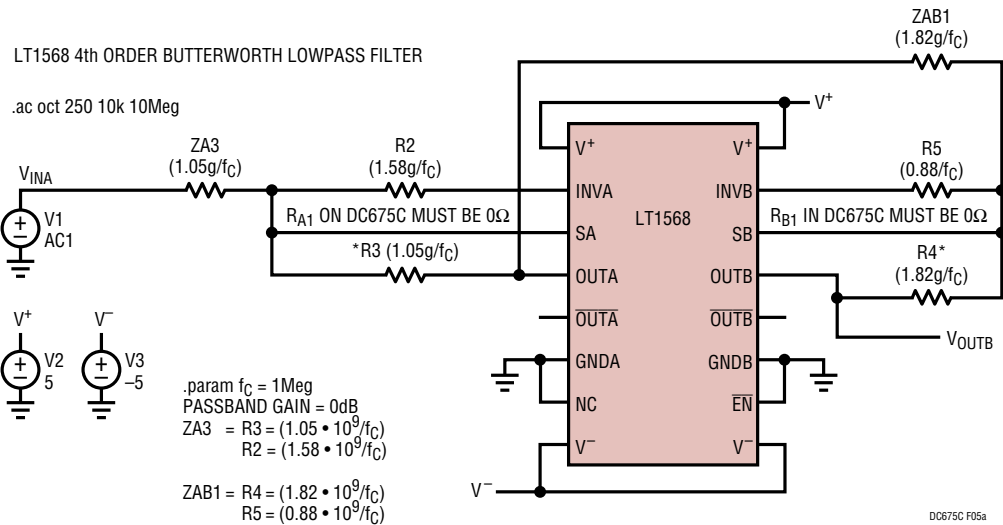


DC675C F04b

Figure 4. LT1568 Fourth Order Wide Passband Bandpass Filter

The LTspice file for this circuit is available.

## LTspice SIMULATIONS



NOTE: ANY IMPEDANCE IN SERIES OR PARALLEL WITH AN INPUT RESISTOR CHANGES THE FILTER'S POLES AND PASSBAND GAIN.

\*MINIMUM R3 AND R4 IS 100Ω.

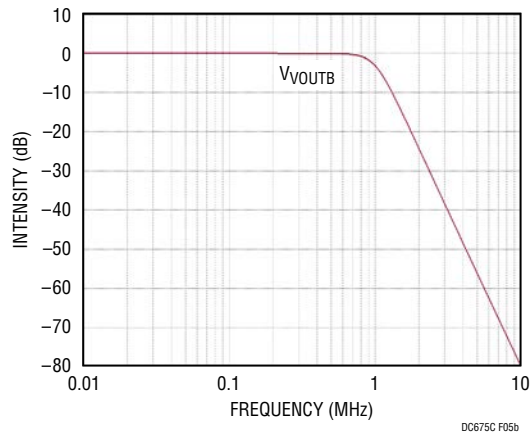
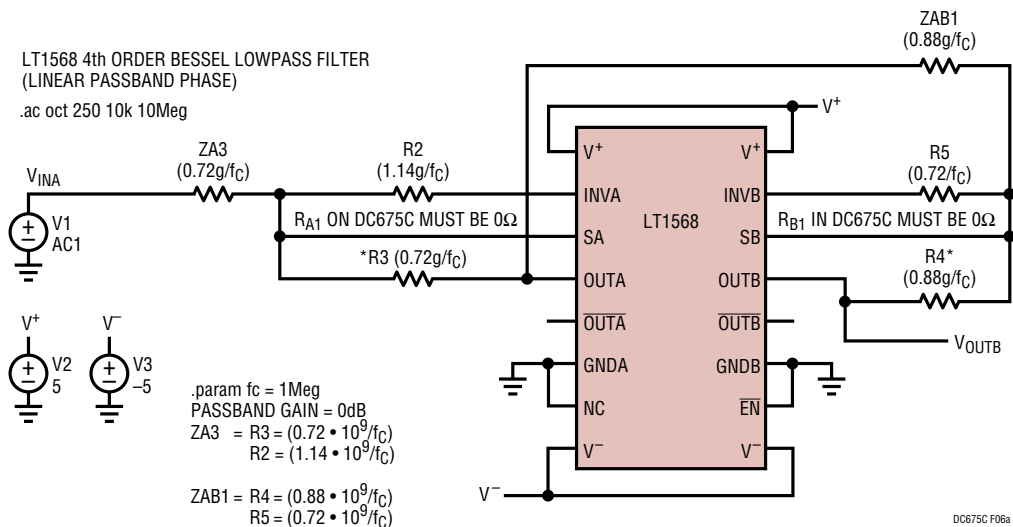


Figure 5. LT1568 Fourth Order Butterworth Lowpass Filter

The LTspice file for this circuit is available.



LTspice SIMULATIONS



NOTE: ANY IMPEDANCE IN SERIES OR PARALLEL WITH AN INPUT RESISTOR CHANGES THE FILTER'S POLES AND PASSBAND GAIN.

\*MINIMUM R3 AND R4 IS 100Ω.

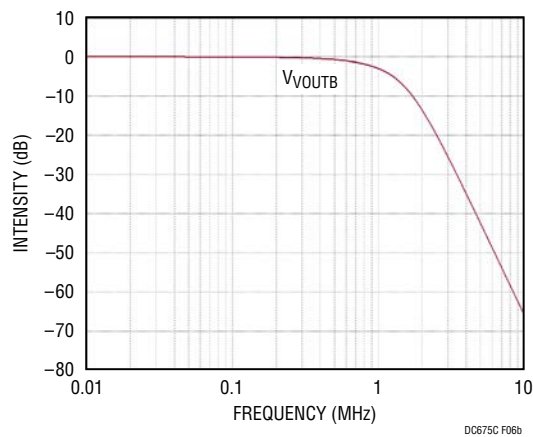
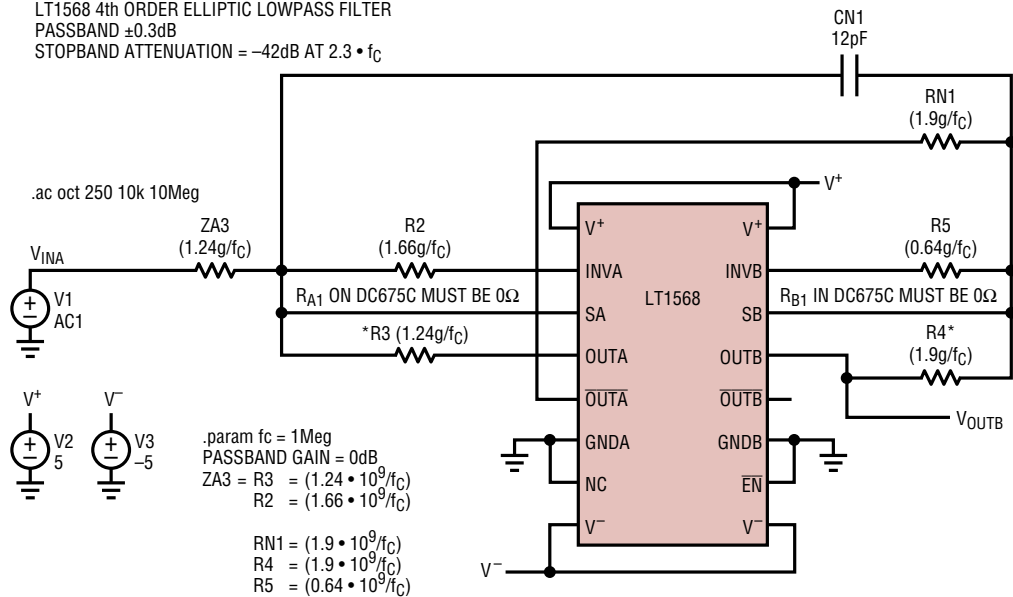


Figure 6. LT1568 Fourth Order Bessel Lowpass Filter (Linear Passband Phase)

The LTspice file for this circuit is available.

## LTspice SIMULATIONS

LT1568 4th ORDER ELLIPTIC LOWPASS FILTER  
 PASSBAND  $\pm 0.3\text{dB}$   
 STOPBAND ATTENUATION =  $-42\text{dB}$  AT  $2.3 \cdot f_c$



NOTE: ANY IMPEDANCE IN SERIES OR PARALLEL WITH AN INPUT RESISTOR CHANGES THE FILTER'S POLES AND PASSBAND GAIN.

\*MINIMUM R3 AND R4 IS 100Ω.

DC675C F07a

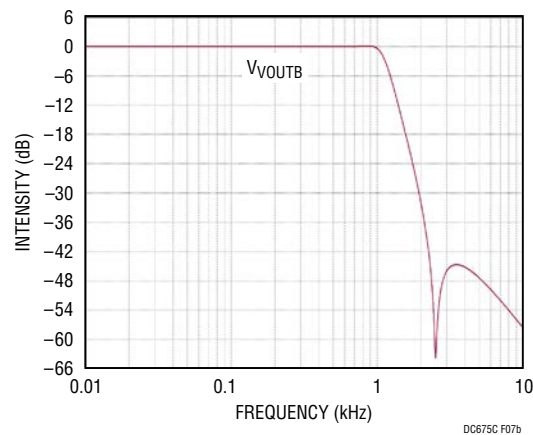


Figure 7. LT1568 Fourth Order Elliptic Lowpass Filter

The LTspice file for this circuit is available.

# LTspice SIMULATIONS

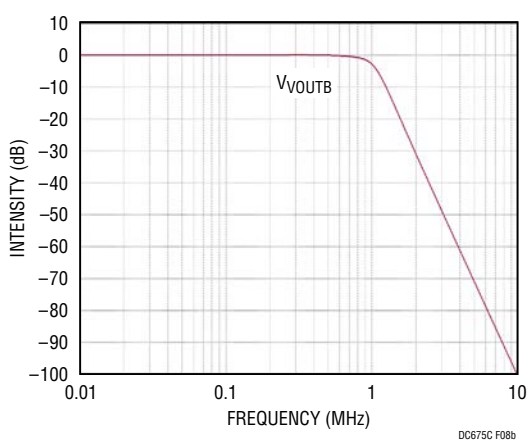
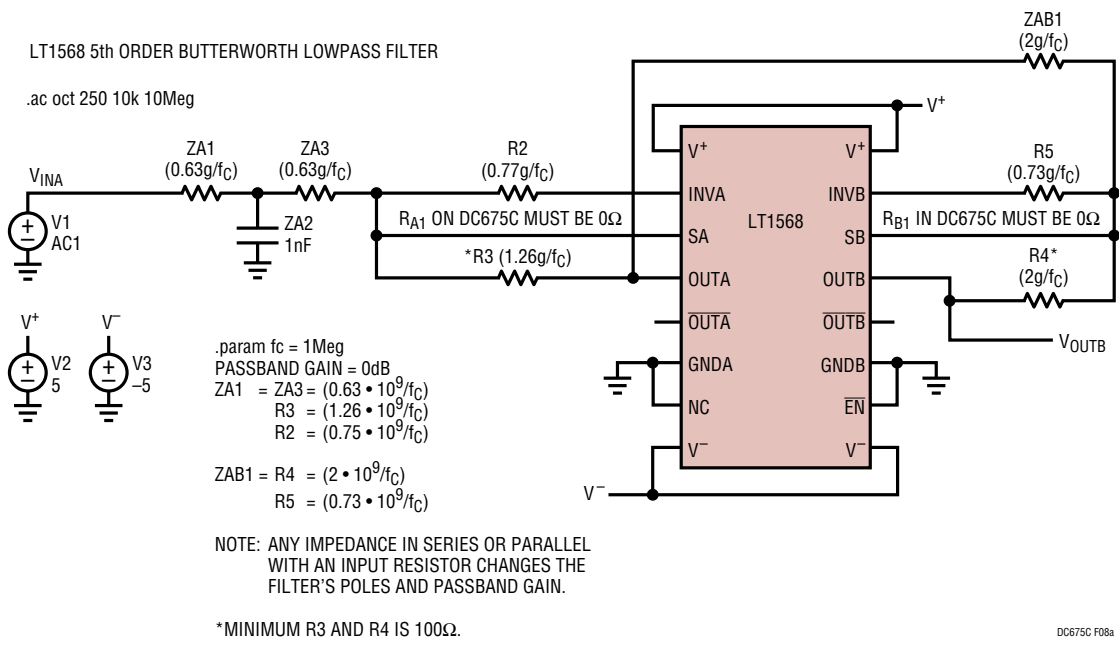


Figure 8. LT1568 Fifth Order Butterworth Lowpass Filter

The LTspice file for this circuit is available.

## LTspice SIMULATIONS

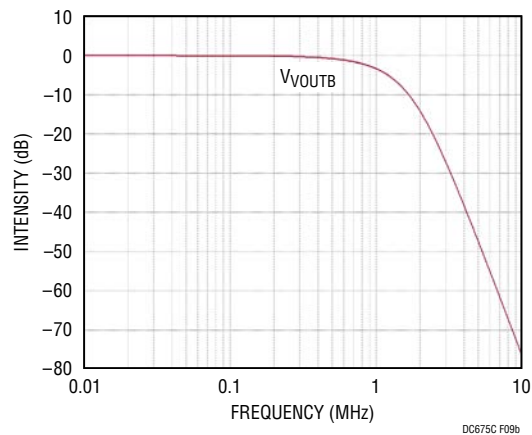
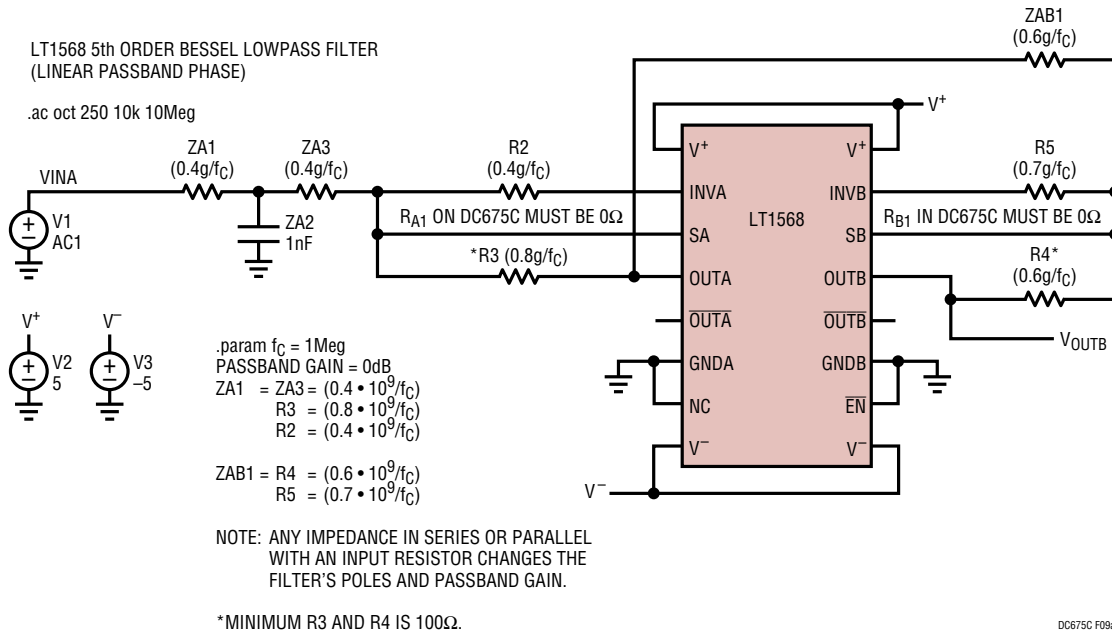


Figure 9. LT1568 Fifth Order Bessel Lowpass Filter (Linear Passband Phase)

The LTspice file for this circuit is available.

LTspice SIMULATIONS

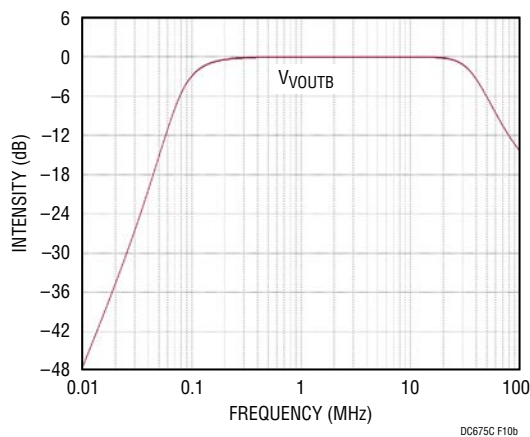
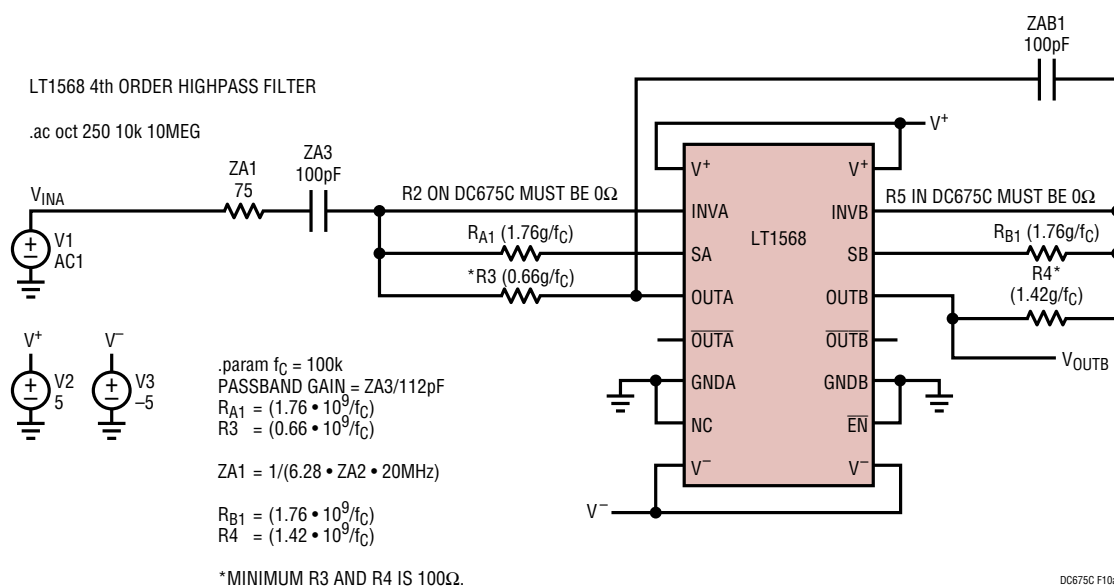


Figure 10. LT1568 Fourth Order Highpass Filter

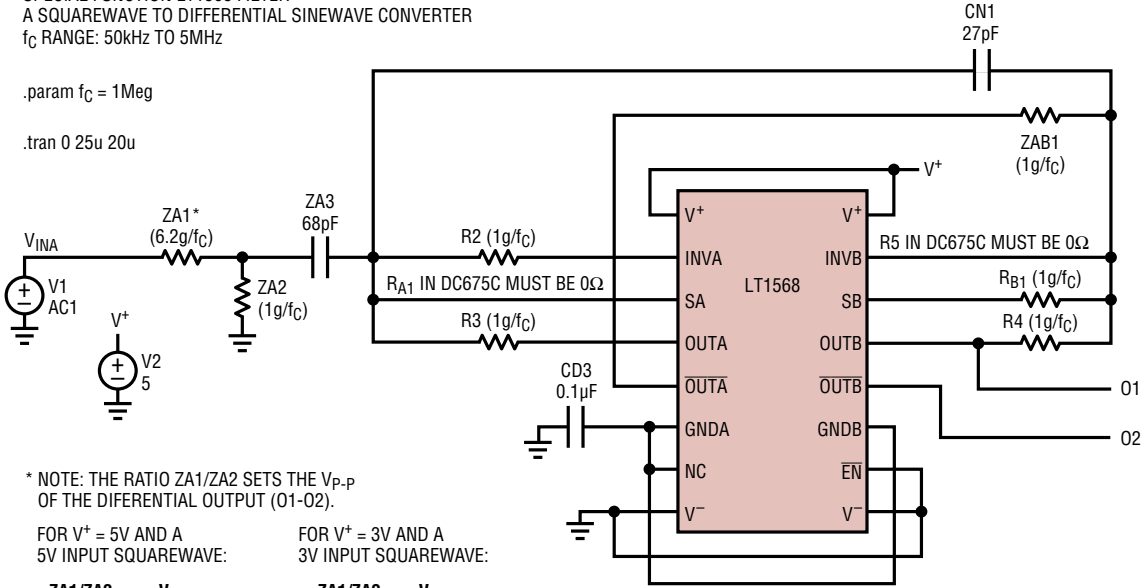
The LTspice file for this circuit is available.

# DEMO MANUAL DC675C

## LTspice SIMULATIONS

SPECIAL FUNCTION LT1568 FILTER  
 A SQUAREWAVE TO DIFFERENTIAL SINEWAVE CONVERTER  
 $f_c$  RANGE: 50kHz to 5MHz

```
.param fc = 1Meg
.tran 0 25u 20u
```



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

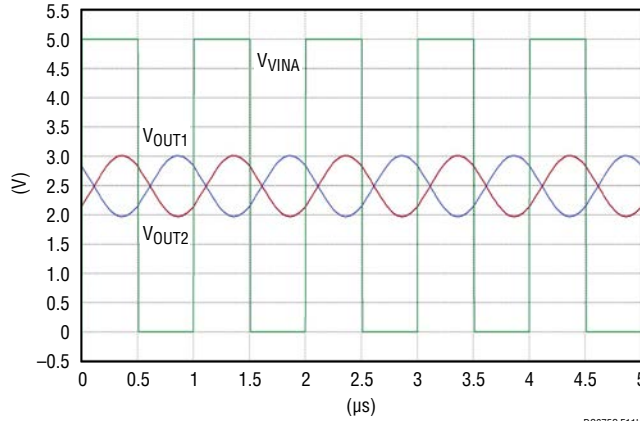
FOR  $V^+ = 5V$  AND A 5V INPUT SQUAREWAVE:

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

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

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

DC675C F11a



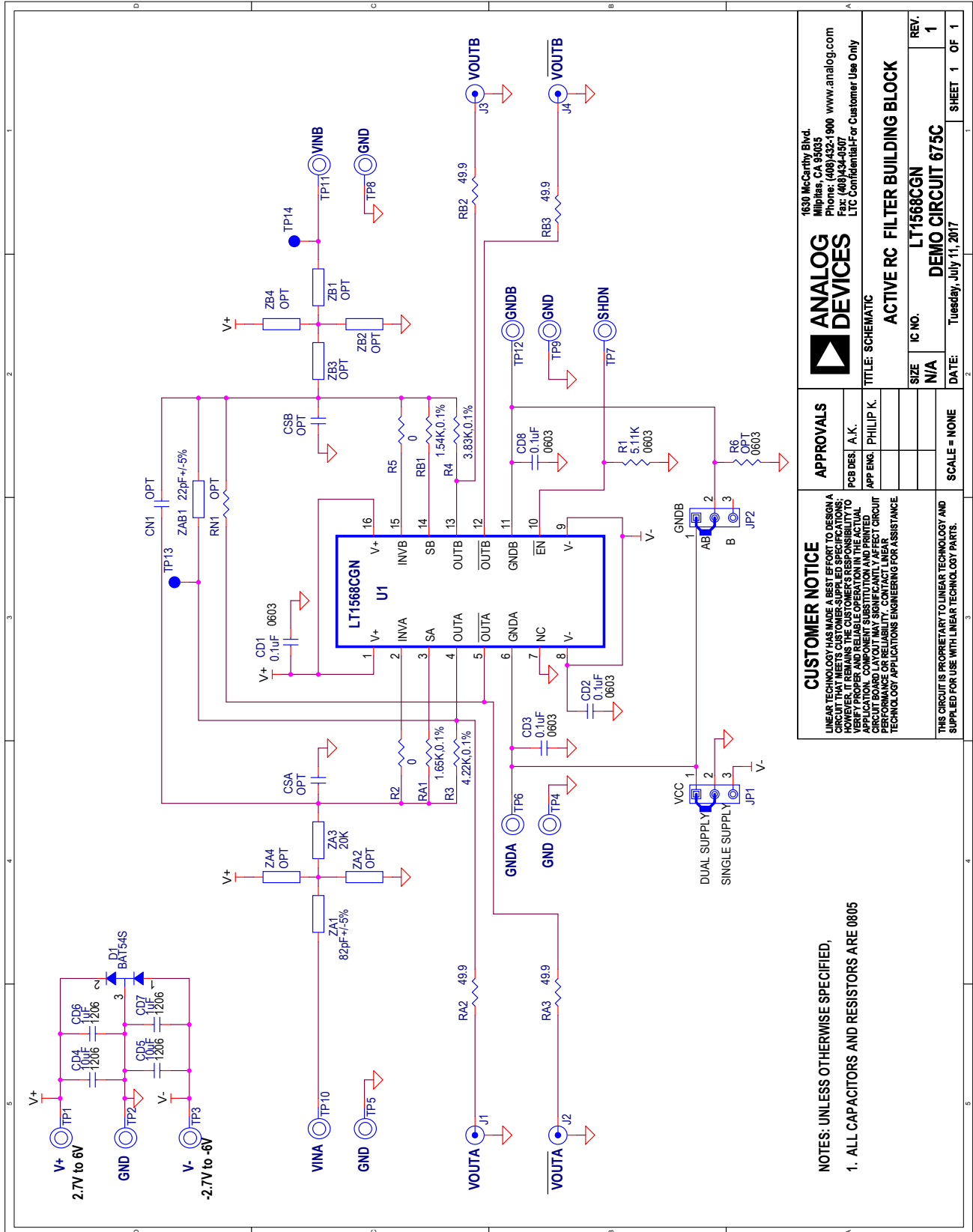
FOR  $V^+ = 5V$  AND ZA1/ZA2 = 6.2

DC675C F11b

Figure 11.

[The LTspice file for this circuit is available.](#)

**SCHEMATIC DIAGRAM**



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**ACTIVE RC FILTER BUILDING BLOCK**

IC NO. **LT1568CGN** REV. **1**

DATE: **Tuesday, July 11, 2017** SHEET **1** OF **1**

TITLE: **SCHEMATIC**

SCALE = **NONE**

APPROVALS

PCB DES.	A. K.
APP ENG.	PHILIP K.

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# DEMO MANUAL DC675C

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