

# Design Tips of OP Amplifier and TINA Simulation Tool

運算放大器設計小技巧 + TINA教學

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# Agenda

- Op Amp in Over Current Protection Circuit
  - Output swing limitation
  - Input ESD steering diodes
- Improve Thermal Performance Op Amp Circuit
  - Power Dissipation Calculation
  - Thermal Impedance and Junction Temperature
  - Consider Protection Response Time, Signal Latency, Spike Signal Rise Time
- Amplifier Major Parameters in Current Sensing Application
  - High Side Current Sensing Circuit Specifications
  - Rshunt Calculation
  - Offset Voltage and Drift
  - Slew Rate and Bandwidth
  - CMRR AC
- TINA Tutorial

# Op Amp in Over Current Protection Circuit (OCP)

# Op Amp for OCP - $V_{out\_swing}$ Limitation

Reference Design of Output Short-Circuit Protection for TPS61088 10A Boost Converter (PMP9779)

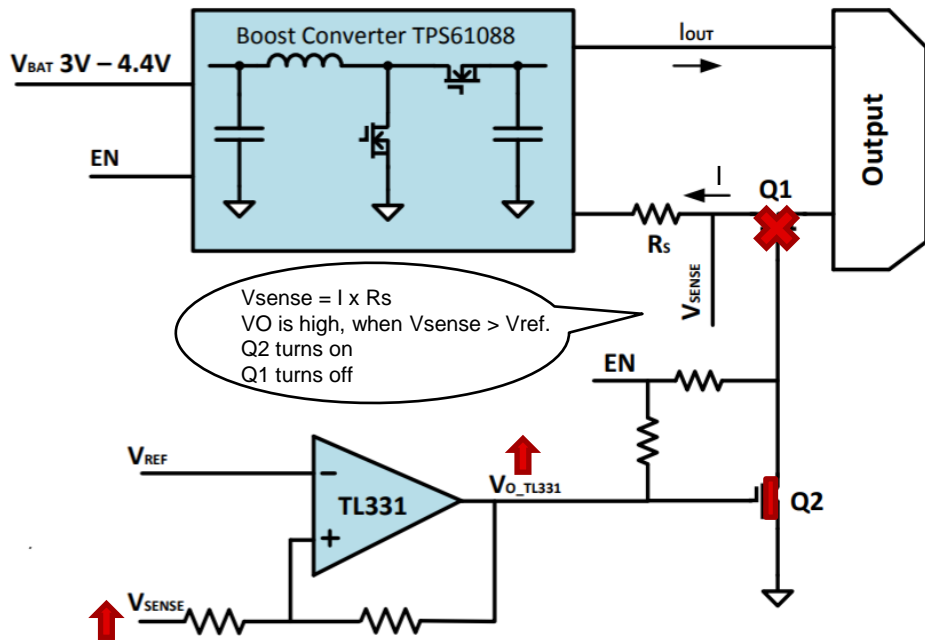


Figure 1. Block Diagram of PMP9779

- I've got an extra, not used channel of LM324 or TL074.
- Can I use it as the OCP comparator?

# Problems and Why

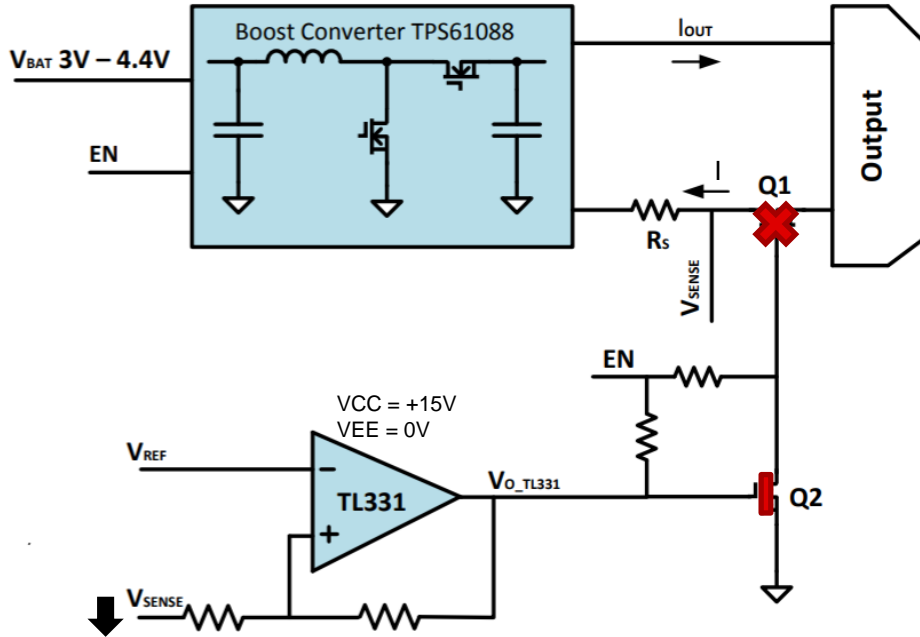


Figure 1. Block Diagram of PMP9779

- Problem:  
When set the load current within the normal operating range, the OCP circuit is **false triggered**,  $Q1$  is off and no path for current to flow.

# Problems and Why

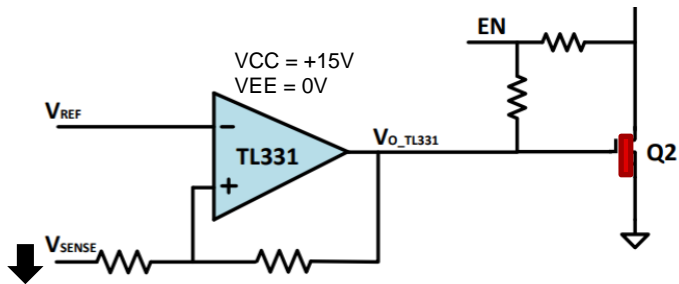


Figure 1. Block Diagram of PMP9779



www.ti.com

TL071, TL071A, TL071B  
TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL072M, TL074M

SLOS080N – SEPTEMBER 1978 – REVISED JULY 2017

## 6.10 Electrical Characteristics: TL071C, TL072C, TL074C

$V_{CC\pm} = \pm 15\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>(1)</sup> <sup>(2)</sup>		MIN	TYP	MAX	UNIT
$V_{IO}$	Input offset voltage	$V_O = 0$ $R_S = 50\ \Omega$		3	10	mV
					13	
$\alpha$	Temperature coefficient of input offset voltage	$V_O = 0$ $R_S = 50\ \Omega$		18		$\mu\text{V}/^\circ\text{C}$
$I_{IO}$	Input offset current	$V_O = 0$		5	100	pA
					10	nA
$I_{IB}$	Input bias current <sup>(3)</sup>	$V_O = 0$		65	200	pA
					7	nA
$V_{ICR}$	Common-mode input voltage range	$T_A = 25^\circ\text{C}$	$\pm 11$		-12 to 15	V
$V_{OM}$	Maximum peak output voltage swing	$R_L = 10\ \text{k}\Omega$		$\pm 12$	$\pm 13.5$	V
		$R_L \geq 10\ \text{k}\Omega$	$T_A = 25^\circ\text{C}$	$\pm 12$		
		$R_L \geq 2\ \text{k}\Omega$	$T_A = \text{Full range}$	$\pm 10$		

- Root cause:
  - Op Amp output swing limitation. Output swing range from -40C to +85C with Load  $\geq 2\text{k-ohm}$  is **VEE + 5V** and **VCC -5V**.
  - Output swing shrinks with load current increase. In Figure 6, with 2k-ohm load at  $T_A 25^\circ\text{C}$ , output swing is  $\pm 11.75\text{V}$ . 0.6k-ohm load shows VOM of  $\pm 10\text{V}$ .

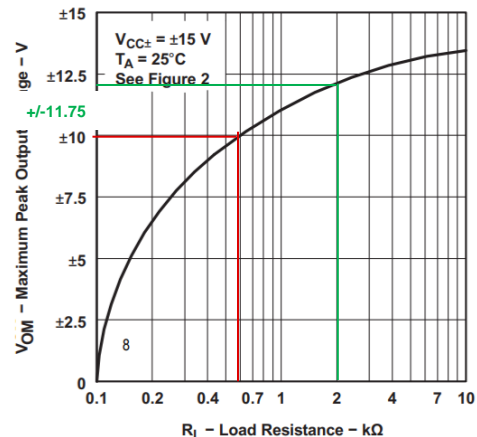
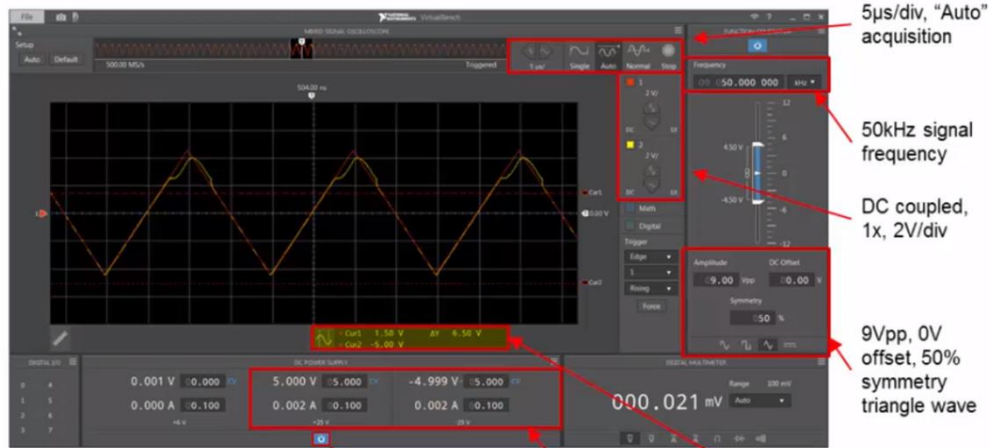


Figure 6. Maximum Peak Output Voltage vs Load Resistance

# TI Precision Labs – Op Amps: Input and Output Limitations

- <https://training.ti.com/ti-precision-labs-op-amps>

## VirtualBench Instrument Setup



5 $\mu$ s/div, "Auto" acquisition

50kHz signal frequency

DC coupled, 1x, 2V/div

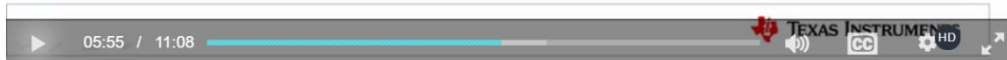
9Vpp, 0V offset, 50% symmetry triangle wave

Power supply enable/disable

$\pm$ 5V, 0.100A power supply

Set cursors to +1.5V and -5.1V to show valid common mode range.

13



# Op Amp for OCP– Input Clamping Diode

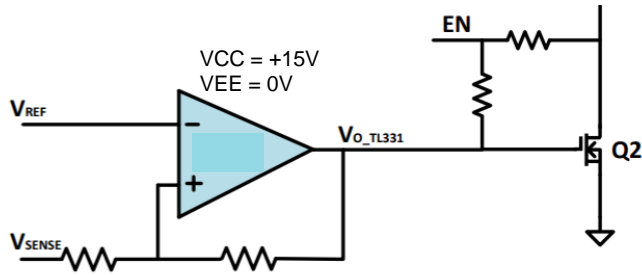


Figure 1. Block Diagram of PMP9779

- Problems:  
Op Amp IC has high failure rate and is damaged after turning on power for a while.
- Root cause:  
Input clamping diode is conducting and could be damaged without external current limiting resistor.

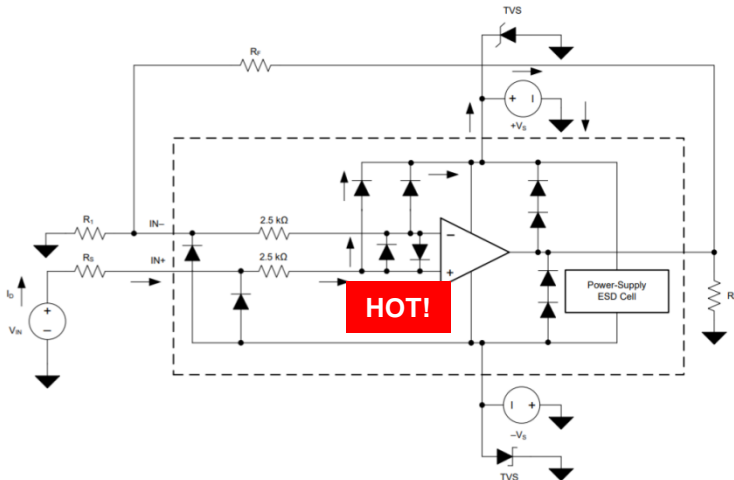
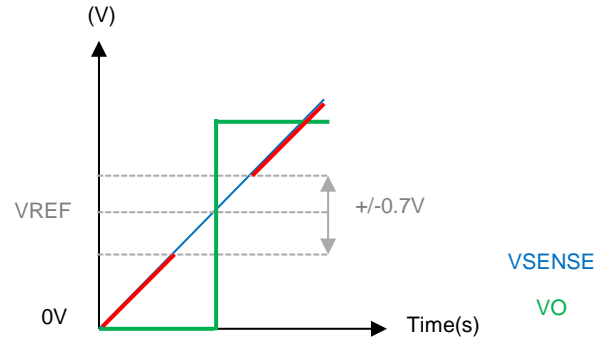


Figure 38. Equivalent Internal ESD Circuitry Relative to a Typical Circuit Application





# TI Precision Labs – Op Amps: Electrical Overstress (EOS)

- <https://training.ti.com/ti-precision-labs-op-amps>

The image consists of three video frames illustrating op-amp protection techniques:

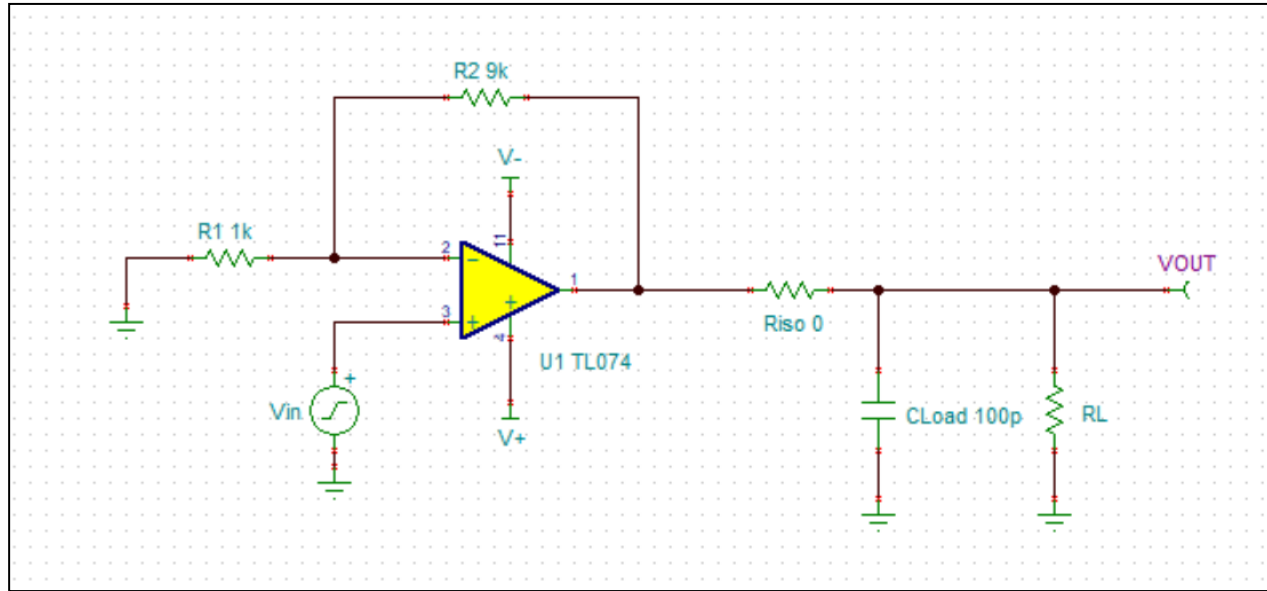
- Frame 1 (Left):** Shows a circuit with a "Simplified 5V LDO" and an "input overstress voltage" source. The op-amp is protected by a network of diodes (D1-D6) and an absorption device. A graph shows the input voltage  $V_{in}$  over time, with a peak labeled "Overvoltage Event may be fast (e.g. 1ms)" and a "Safe Operating Range" indicated. A note states: "The absorption device stays on after input returns to normal".
- Frame 2 (Middle):** Titled "Absorption Device Latches", it shows a similar circuit but with a "TVS Diode and Series Resistance" added to the input. A graph shows the input voltage  $V_{in}$  over time, with a peak labeled "Overvoltage Event may be fast (e.g. 1ms)" and a "Safe Operating Range" indicated. A note states: "The absorption device stays on after input returns to normal".
- Frame 3 (Right):** Titled "TVS Diode and Series Resistance", it shows a circuit with a "Simplified 5V LDO" and an "Unregulated 24V" supply. The op-amp is protected by a network of diodes (D1-D6) and an "Absorption Device". A graph shows the input voltage  $V_{in}$  over time, with a peak labeled "Overvoltage Event may be fast (e.g. 1ms)" and a "Safe Operating Range" indicated. A note states: "The absorption device stays on after input returns to normal".

Equation for current through the TVS diode and series resistor:

$$I_{IN} = (15\text{ V} - 0.7\text{ V} - 7\text{ V}) / 1\text{ k}\Omega$$
$$I_{IN} = 7.3\text{ mA}$$

# Improve Thermal Performance of Wide Voltage/ Dual Supply Op Amp

# +/-15V Op Amp Gain of 10 Circuit



# Power Dissipation Calculation

## Power dissipation calculation

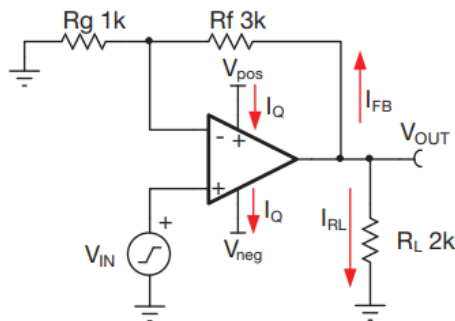


Figure 52: Current and power dissipation for non-inverting amplifier

Non-inverting amplifier power dissipation for specific  $V_{OUT}$

$$I_{RL} = \frac{V_{OUT}}{R_L} \quad (134) \text{ Current through load resistor}$$

$$I_{FB} = \frac{V_{OUT}}{R_F + R_g} \quad (135) \text{ Current through feedback network}$$

$$P_L = (|I_{RL}| + |I_{FB}|)(|V_{sup}| - |V_{OUT}|) \quad (136) \text{ Power dissipated inside op amp from load current.}$$

$V_{sup} = V_{pos}$  if the amplifier is sourcing.  
 $V_{sup} = V_{neg}$  if the amplifier is sinking.

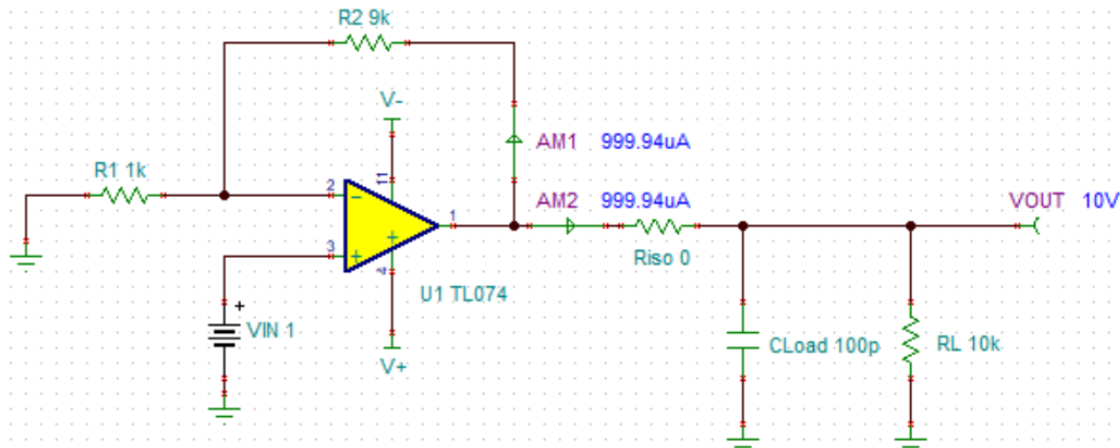
$$P_Q = (V_{pos} - V_{neg}) \cdot I_Q \quad (137) \text{ Total power from quiescent current}$$

$$P_T = P_L + P_Q \quad (138) \text{ Total power dissipated inside the op amp}$$

Non-inverting amplifier maximum power dissipation

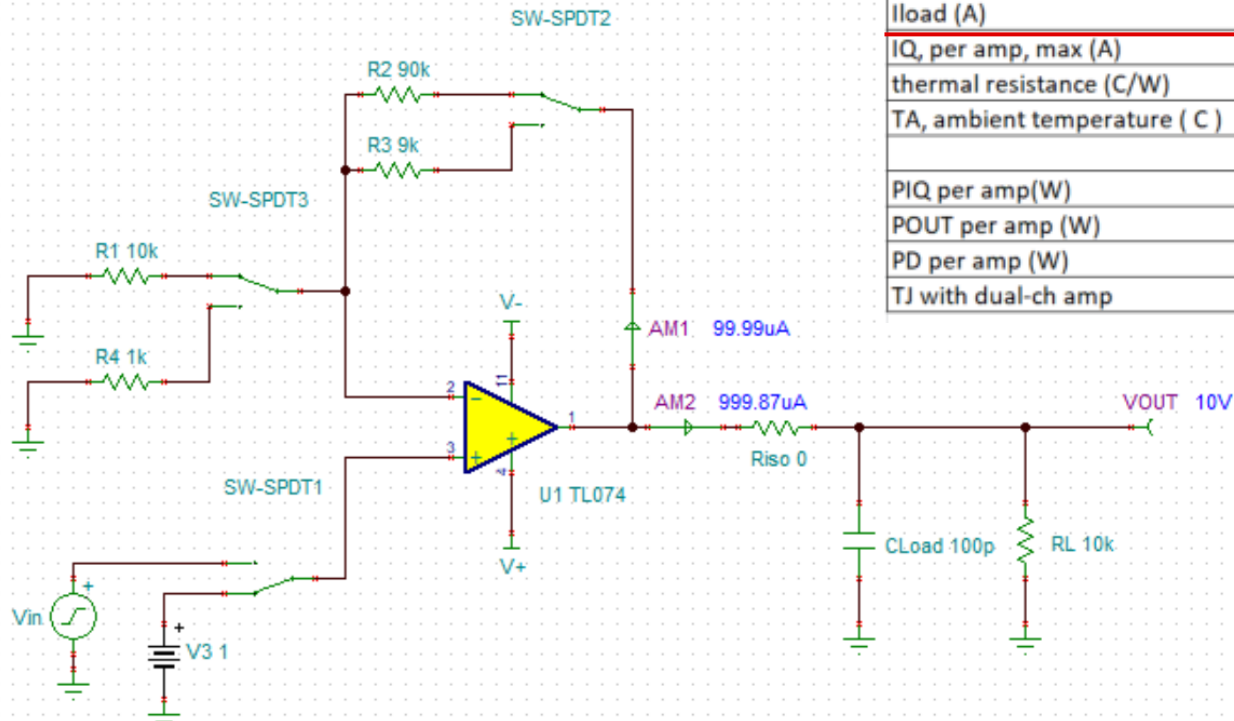
# Junction Temperature Calculation

	TL072 SOIC
V+	15
V-	-15
Vout (V)	10
Iload (A)	2.00E-03
IQ, per amp, max (A)	2.50E-03
thermal resistance (C/W)	97
TA, ambient temperature ( C )	40
PIQ per amp(W)	0.075
POUT per amp (W)	1.00E-02
PD per amp (W)	0.085
TJ with dual-ch amp	56.49



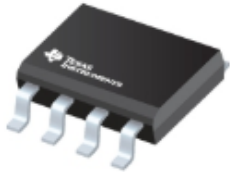
PARAMETER	TEST CONDITIONS <sup>(1)</sup> <sup>(2)</sup>	MIN	TYP	MAX	UNIT
I <sub>CC</sub>	Supply current (each amplifier) V <sub>O</sub> = 0; no load T <sub>A</sub> = 25°C		1.4	2.5	mA

# Reduce Heat, Reduce Power, Decrease Output Current



	TL072 SOIC
V+	15
V-	-15
Vout (V)	10
Iload (A)	1.10E-03
IQ, per amp, max (A)	2.50E-03
thermal resistance (C/W)	97
TA, ambient temperature ( C )	40
PIQ per amp(W)	0.075
POUT per amp (W)	5.50E-03
PD per amp (W)	0.0805
TJ with dual-ch amp	<b>55.617</b>

# Reduce Heat, Reduce Power, Decrease Current Consumption



DATASHEET

TLV930x 40-V, 1-MHz, RRO Operational Amplifiers for Cost-Sensitive Systems datasheet (Rev. A)

[View now](#) [Download](#)

## Electrical Characteristics (continued)

For  $V_S = (V+) - (V-) = 4.5 \text{ V to } 40 \text{ V}$  ( $\pm 2.25 \text{ V to } \pm 20 \text{ V}$ ) at  $T_A = 25^\circ\text{C}$ ,  $R_L = 10 \text{ k}\Omega$  connected to  $V_S / 2$ ,  $V_{CM} = V_S / 2$ , and  $V_{OUT} = V_S / 2$ , unless otherwise noted.

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
<b>OUTPUT</b>						
Voltage output swing from rail	Positive rail headroom	$V_S = 40 \text{ V}$ , $R_L = \text{no load}$		3		mV
		$V_S = 40 \text{ V}$ , $R_L = 10 \text{ k}\Omega$		50	75	
		$V_S = 40 \text{ V}$ , $R_L = 2 \text{ k}\Omega$		250	350	
	Negative rail headroom	$V_S = 4.5 \text{ V}$ , $R_L = \text{no load}$		1		
		$V_S = 4.5 \text{ V}$ , $R_L = 10 \text{ k}\Omega$		20	30	
		$V_S = 4.5 \text{ V}$ , $R_L = 2 \text{ k}\Omega$		40	75	
$I_{SC}$	Short-circuit current			$\pm 60$		mA
$C_{LOAD}$	Capacitive load drive		See <i>Typical Characteristics</i>			
$Z_O$	Open-loop output impedance	$f = 1 \text{ MHz}$ , $I_O = 0 \text{ A}$		600		$\Omega$
<b>POWER SUPPLY</b>						
$I_Q$	Quiescent current per amplifier	$I_O = 0 \text{ A}$		150	175	$\mu\text{A}$
			$T_A = -40^\circ\text{C to } 125^\circ\text{C}$			

	SOIC
V+	15
V-	-15
Vout (V)	10
Iload (A)	1.10E-03
IQ, per amp, max (A)	1.75E-04
thermal resistance (C/W)	97
TA, ambient temperature ( C )	40
PIQ per amp(W)	0.00525
POUT per amp (W)	5.50E-03
PD per amp (W)	0.01075
TJ with dual-ch amp	42.0855

# What else needs to be considered?

## SR, BW, Spike Signal Capture

TL07x Circuit			
→ SR = 2 x pi x F x Vout			
F	1.00E+04 Hz		
Vout	20 V		
SR	1.256 V/us		
			<b>TL07x 13V/us</b> <b>TLV930x 3V/us</b>
Topology	Non-inverting		
R1	1.00E+04 ohm		
R2	9.00E+04 ohm		
Noise Gain	10		
→ TL07x Unity Gain Bandwidth	3.00E+06 Hz	→ TLV930x Unity Gain Bandwidth	1.00E+06 Hz
Bandwidth	0.3 MHz	Bandwidth	0.1 MHz
0.35 = TR x BW			
BW	0.3 MHz	BW	0.1 MHz
→ Signal Rise Time (able to capture)	1.16666667 us	→ Signal Rise Time (able to capture)	3.5 us



# Op Amp Selection Tips

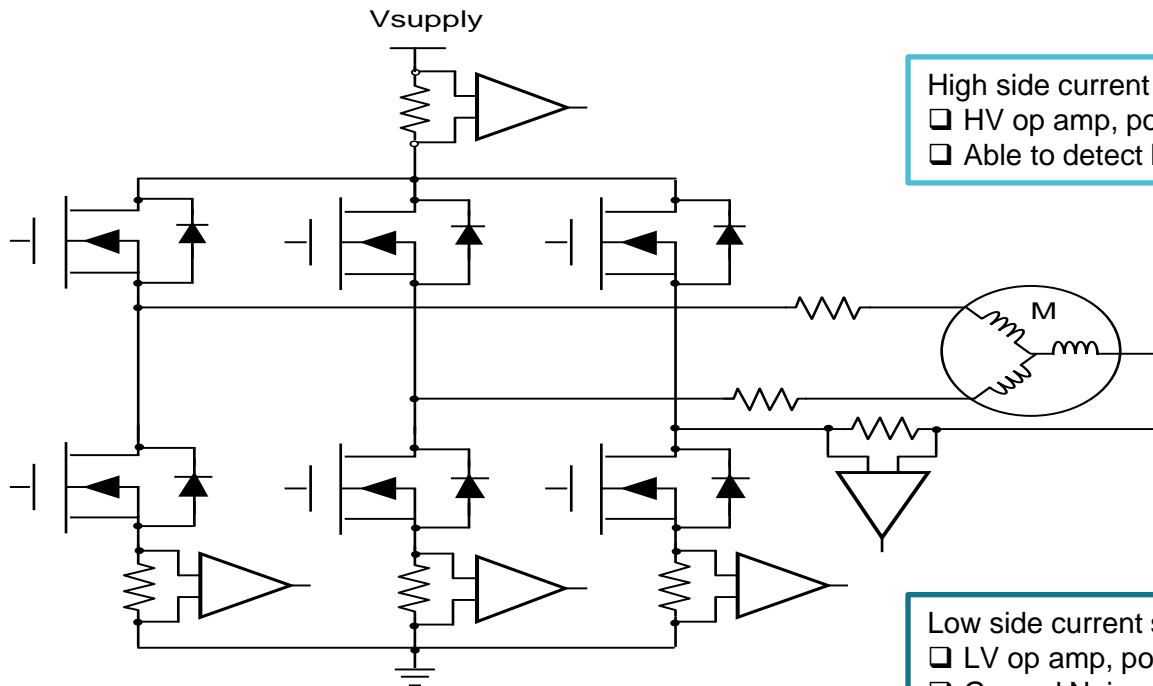
- Considering circuit function and important specs of it:
- Process sine wave/ care synchronization => Small signal latency => GBW
- Use as OCP/ OVP protection function => Large signal response time => Slew Rate
- Light load current monitoring/precision current sensing

Accuracy: Offset, drift, PSRR, CMRR, noise, potential external noise etc.

- AC-coupling cap may be required; differential cap may degrade performance since forming low impedance path for interference
- Surrounding circuits are noisy => EMIRR may help to suppress high frequency noise hence improving accuracy
- Power sources are from DC-DC with switching noise => High PSRR and wide bandwidth may be needed

# High Side Current Sensing Considerations

# High Side and Low Side Current Sensing



- High side current sensing:
- ❑ HV op amp, potential higher cost
  - ❑ Able to detect load short circuit/leakage

- Low side current sensing:
- ❑ LV op amp, potential lower cost
  - ❑ Ground Noise, Inaccuracy at light load
  - ❑ Not able to detect load short circuit/leakage

# High Side Current Sensing Example

# High Side Current Sensing Circuit Specifications

## Design Goals

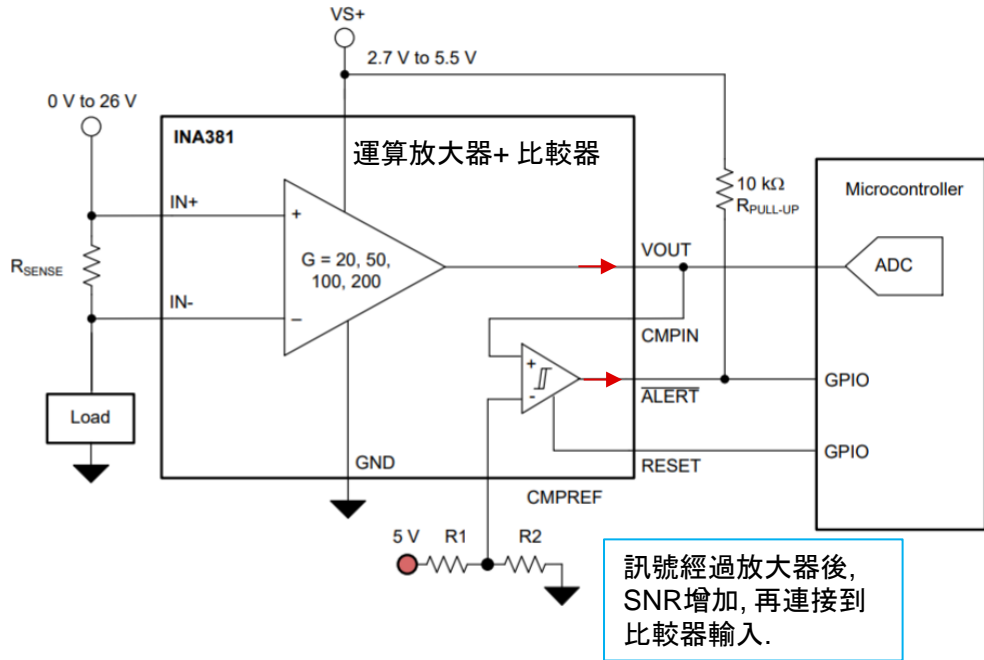
Input		Overcurrent Conditions		Output		Supply	
$I_{load\ Min}$	$I_{load\ Max}$	$I_{OC\_TH}$	$I_{Release\_TH}$	$V_{out\_OC}$	$V_{out\_release}$	$V_S$	$V_{REF}$
1.5A	40A	35A	32A	2.8V	2.61V	3.3V	2.8V

Light Load Accuracy  
@ 1.5A +/- 10%

OCP response time  
10us

Input signal max frequency sine  
10kHz

# INA381 Current Shut Monitor Overview



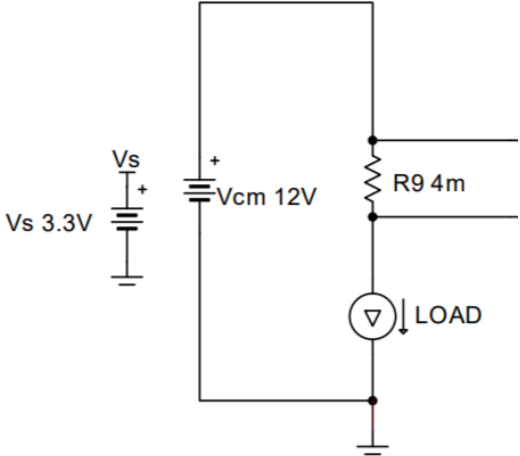
## 1 Features

- Common-Mode Input Range: -0.2 V to 26 V
- High Accuracy Amplifier:
  - Offset Voltage,  $V_{CM} = 12 V$ : 500  $\mu V$  (Maximum)
  - Offset Voltage,  $V_{CM} = 0 V$ : 150  $\mu V$  (Maximum)
  - Offset Voltage Drift: 1  $\mu V/^{\circ}C$  (Maximum)
  - Gain Error: 1% (Maximum)
  - Gain Error Drift: 20 ppm/ $^{\circ}C$  (Maximum)
- Available Amplifier Gains:
 

350	kHz
210	kHz
150	kHz
105	kHz
- Comparator Specifications:
  - Hysteresis: 50 mV
  - Response Time: 500 ns
  - Alert Threshold Set Through External Reference Voltage
- Open-Drain Comparator Output With Latching Mode
- Package: WSON-8 (2 mm × 2 mm)

# System Specs and INA381 Parameter Rshunt Calculation

Input		Overcurrent Conditions		Output		Supply	
I <sub>load Min</sub>	I <sub>load Max</sub>	I <sub>OC_TH</sub>	I <sub>Release_TH</sub>	V <sub>out_OC</sub>	V <sub>out_release</sub>	V <sub>S</sub>	V <sub>REF</sub>
1.5A	40A	35A	32A	2.8V	2.61V	3.3V	2.8V



Rshunt Calculation: Highest SNR

$$V_{out\_max} = I_{max} \times R_{shunt} \times Gain$$

$$R_{shunt} = \frac{V_{out\_max}}{gain \times I_{max}} = \frac{V_S - 0.02V}{gain \times I_{max}} = \frac{3.3V - 0.02V}{20V/V \times 40A} = 0.0041\Omega \quad \text{Rmax}$$

R<sub>standard shunt</sub> = 4mΩ (standard 1% value)

Considering power loss:

$$12V \times 40A = 480W$$

$$480W \times 0.1\% = 0.48W$$

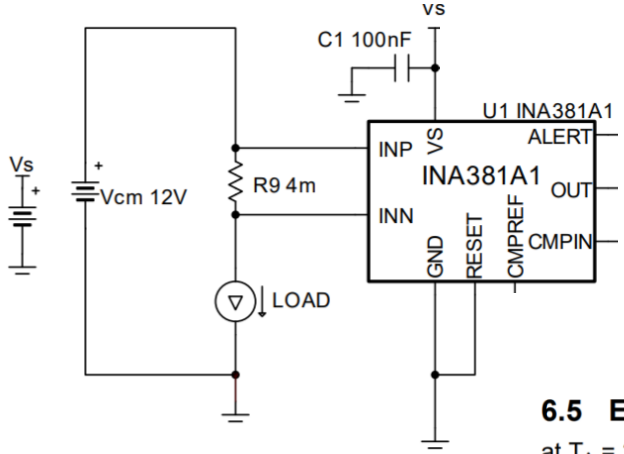
$$0.48W = I^2R$$

$$R = 0.48/1600 = 0.3m\text{-ohm}$$

# System Specs and INA381 Parameter

## Offset Voltage and Drift

Input		Overcurrent Conditions		Output		Supply	
$I_{load\ Min}$	$I_{load\ Max}$	$I_{OC\_TH}$	$I_{Release\_TH}$	$V_{out\_OC}$	$V_{out\_release}$	$V_S$	$V_{REF}$
1.5A	40A	35A	32A	2.8V	2.61V	3.3V	2.8V



Light Load Accuracy @ 1.5A +/-10%:

$V_{sense} = I_{min} \times R_{sense}$   
 $V_{sense} = 1.5A \times 4m\text{-ohm}$   
 $V_{sense} = 6mV$   
 Allowable Error = 6m-ohm x +/-10%  
 = +/-600uV

Drift calculation

Max ambient temperature 45C

$V_{os\_Drift}$   
 = 1uV/C x (delta T)  
 = 1uV/C x (45-25)  
 = 20uV

### 6.5 Electrical Characteristics

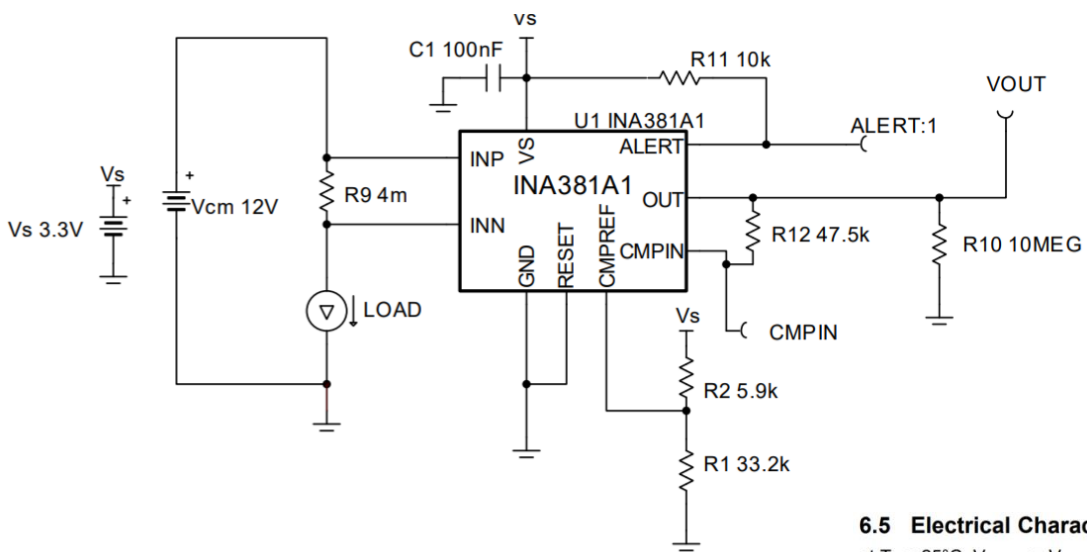
at  $T_A = 25^\circ C$ ,  $V_{SENSE} = V_{IN+} - V_{IN-} = 10\ mV$ ,  $V_S = 5\ V$ ,  $V_{IN+} = 12\ V$ , and  $CMPREF = 2\ V$ , (unless otherwise noted.)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT	
<b>INPUT</b>						
$V_{CM}$	Common-mode input voltage range	-0.2		26	V	
CMRR	Common-mode rejection ratio, RTI	$V_{IN+} = 0\ V\ to\ 26\ V$ , $T_A = -40^\circ C\ to\ +125^\circ C$		84	100	dB
$V_{OS}$	Offset voltage, RTI <sup>(1)</sup>	$V_{IN+} = 12\ V$ , $V_{IN-} = 12\ V$		±100	±500	μV
		$V_{IN+} = 0\ V$ , $V_{IN-} = 0\ V$		±25	±150	μV
$dV_{OS}/dT$	Offset voltage drift, RTI <sup>(1)</sup>	$T_A = -40^\circ C\ to\ +125^\circ C$		0.1	1	μV/°C



# System Specs and INA381 Parameter Slew Rate and Bandwidth

Input		Overcurrent Conditions		Output		Supply	
$I_{load\ Min}$	$I_{load\ Max}$	$I_{OC\_TH}$	$I_{Release\_TH}$	$V_{out\_OC}$	$V_{out\_release}$	$V_S$	$V_{REF}$
1.5A	40A	35A	32A	2.8V	2.61V	3.3V	2.8V



**Slew Rate Requirement:**

$$V_{out\_35A} = I_{OC\_TH} \times R_{standard\ shunt} \times gain$$

$$= 35A \times 4m\Omega \times 20V/V = 2.8V$$

OCP response time  
10us

Slew Rate  
=  $V_{out\_max} / time$   
=  $2.8V / 10us$   
=  $0.28V/us$

**Fin max**  
10kHz

## 6.5 Electrical Characteristics

at  $T_A = 25^\circ C$ ,  $V_{SENSE} = V_{IN+} - V_{IN-} = 10\ mV$ ,  $V_S = 5\ V$ ,  $V_{IN+} = 12\ V$ , and  $CMPREF = 2\ V$ , (unless otherwise noted.)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>FREQUENCY RESPONSE</b>					
BW	Bandwidth	INA381A1	350		kHz
		INA381A2	210		kHz
		INA381A3	150		kHz
		INA381A4	105		kHz
SR	Slew rate		2		V/ $\mu s$

# High Side Current Sensing Circuit Specifications

## Design Goals

Input		Overcurrent Conditions		Output		Supply	
$I_{load\ Min}$	$I_{load\ Max}$	$I_{OC\_TH}$	$I_{Release\_TH}$	$V_{out\_OC}$	$V_{out\_release}$	$V_S$	$V_{REF}$
1.5A	40A	35A	32A	2.8V	2.61V	3.3V	2.8V

Light Load Accuracy  
@ 1.5A +/-10%

Allowable Error :  
4m-ohm x 1.5A x  
+/-10% = +/-600uV

0.25m-ohm x 1.5A x  
+/-10% = +/-37.5uV

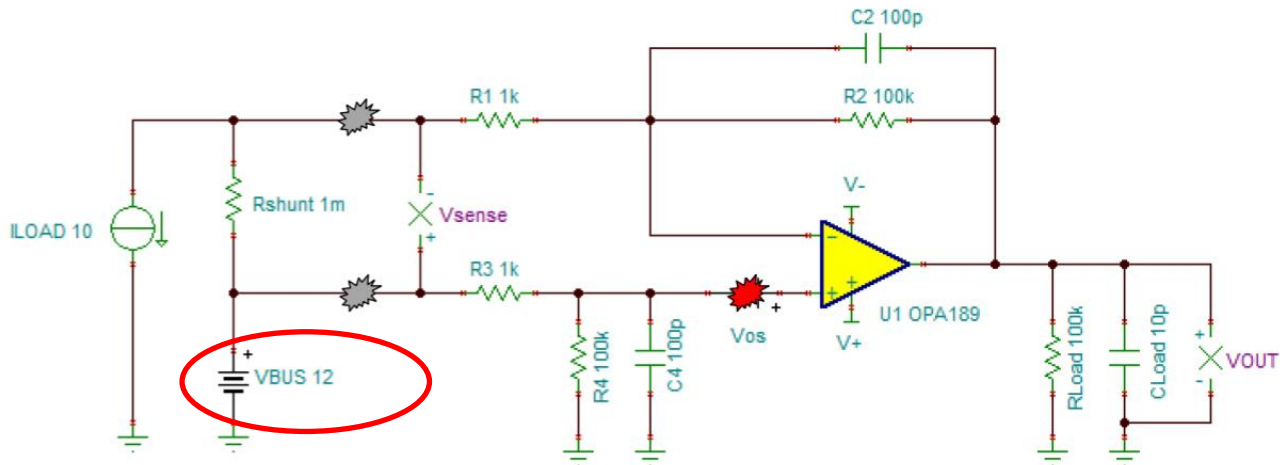
OCP response time  
10us

Slew Rate  
=  $V_{out\_max} / \text{time}$   
= 2.8V / 10us  
= 0.28V/us

Input Signal max frequency sine  
10kHz

Slew Rate (SR)  
Full power Bandwidth  
 $SR = 2 \times \pi \times F \times V_{pp}$   
 $SR = 2 \times 3.14 \times 10\text{kHz} \times 2.8$   
 $SR = 0.176\text{V/us}$

# Current Sensing Error Sources



**Shunt Resistor Tolerance**

**Trace Resistance**

- Op Amp Input Offset Voltage( $V_{os}$ ) Correlated:**
- $V_{os}$  at Room Temperature 25C
  - $V_{os\_Drift}$
  - $V_{os\_CMRR\_DC}$
  - $V_{os\_CMRR\_AC}$
  - $V_{os\_PSRR\_DC}$
  - $V_{os\_PSRR\_AC}$
  - Bias Current

- Noise**
- Extrinsic Noise
  - Intrinsic Noise

# VCM 12V Ripple and FFT



12V supply  
AC coupling  
mode

~7.3mV ~4.1mV  
50kHz 100kHz

~4.1mV  
280kHz

~4.1mV ~0.13mV  
460kHz 570kHz

~4.1mV  
520kHz

~0.13mV  
860kHz

~4.1mV  
920kHz

~13mV  
970kHz

# System Specs and INA381 Parameter CMRR AC



INA381

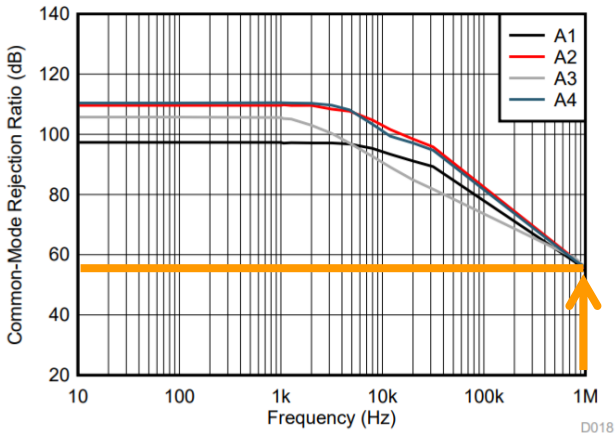
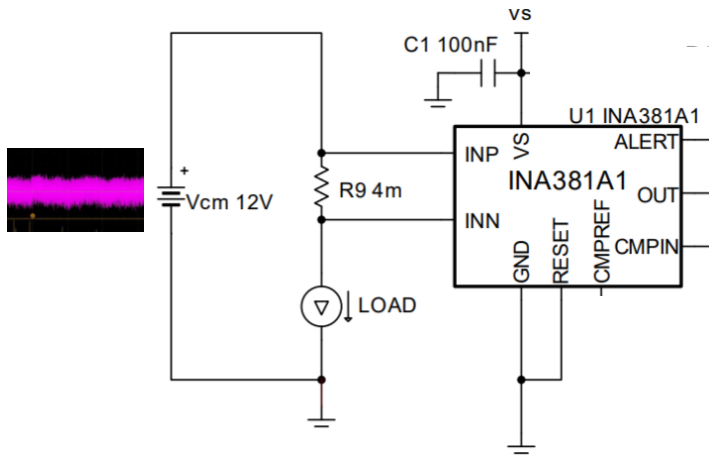
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SBOS848A – DECEMBER 2017 – REVISED APRIL 2018

## 6.5 Electrical Characteristics

at  $T_A = 25^\circ\text{C}$ ,  $V_{\text{SENSE}} = V_{\text{IN}+} - V_{\text{IN}-} = 10\text{ mV}$ ,  $V_S = 5\text{ V}$ ,  $V_{\text{IN}+} = 12\text{ V}$ , and  $\text{CMPREF} = 2\text{ V}$ , (unless otherwise noted.)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>INPUT</b>					
$V_{\text{CM}}$	Common-mode input voltage range	-0.2		26	V
CMRR	Common-mode rejection ratio, RTI $V_{\text{IN}+} = 0\text{ V to } 26\text{ V}$ , $T_A = -40^\circ\text{C to } +125^\circ\text{C}$	84	100		dB



- A1 CMRR is ~55dB@1MHz at 25-C.
- It has 1.78mV/V attenuation capability to the common mode noise.
- $V_{\text{OS\_CMRR\_AC}} = 13\text{mV} \times 1.78\text{mV} = 23.14\mu\text{V}$



# To see more circuit detail analysis:

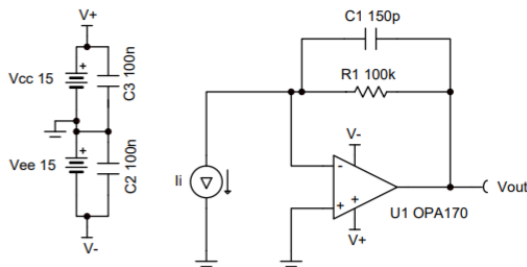
## Transimpedance amplifier circuit

### Design Goals

Input		Output		BW	Supply	
$I_{inMin}$	$I_{inMax}$	$V_{oMin}$	$V_{oMax}$	$f_p$	$V_{cc}$	$V_{ee}$
0A	50 $\mu$ A	0V	5V	10kHz	15V	-15V

### Design Description

The transimpedance op amp circuit configuration converts an input current source into an output voltage. The current to voltage gain is based on the feedback resistance. The circuit is able to maintain a constant voltage bias across the input source as the input current changes which benefits many sensors.

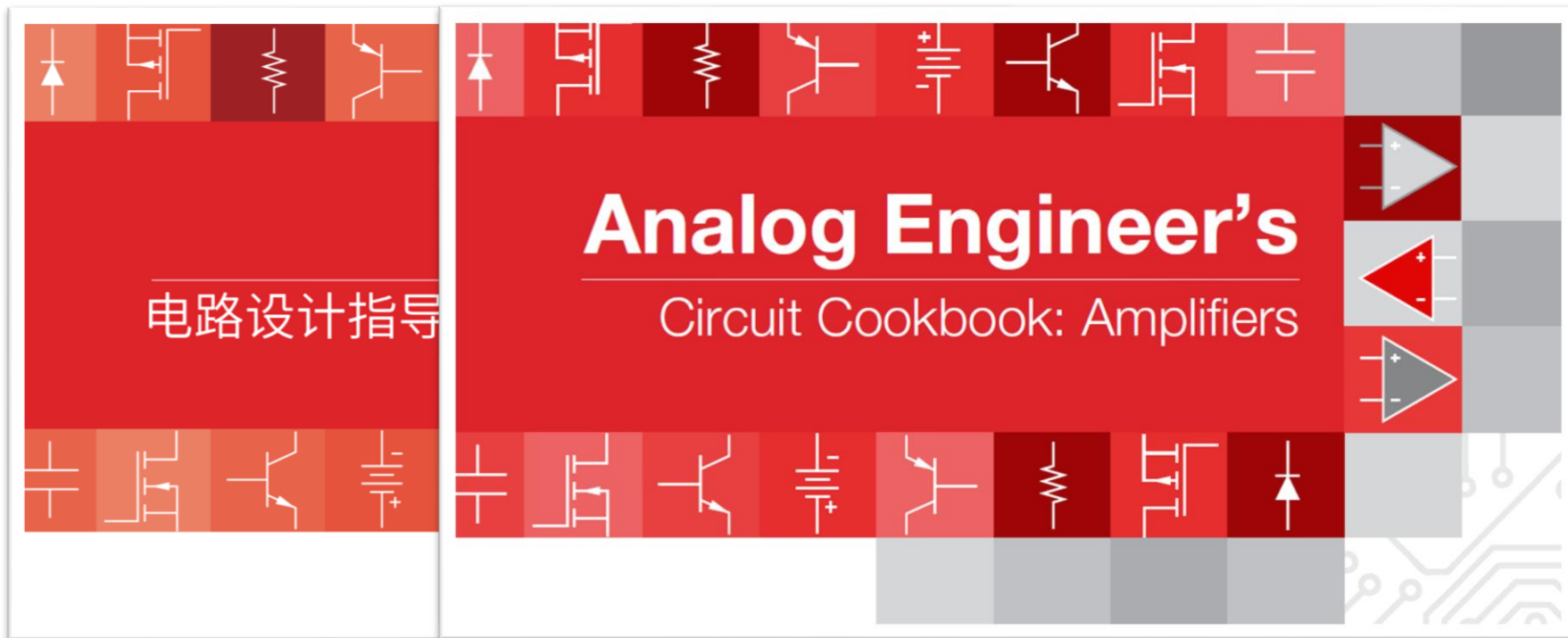


Copyright © 2018, Texas Instruments Incorporated

### Design Notes

1. Use a JFET or CMOS input op amp with low bias current to reduce DC errors.
2. A bias voltage can be added to the non-inverting input to set the output voltage for 0-A input currents.
3. Operate within the linear output voltage swing (see  $A_{vo}$  specification) to minimize non-linearity errors.

# 類比工程師 電路設計指導手冊



<https://www.ti.com/seclit/sl/zhcy082a/zhcy082a.pdf>

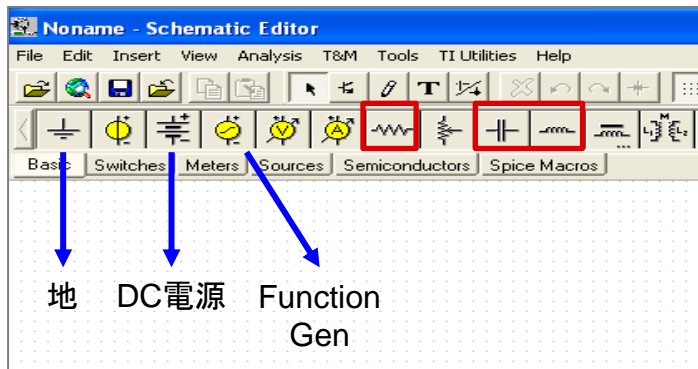
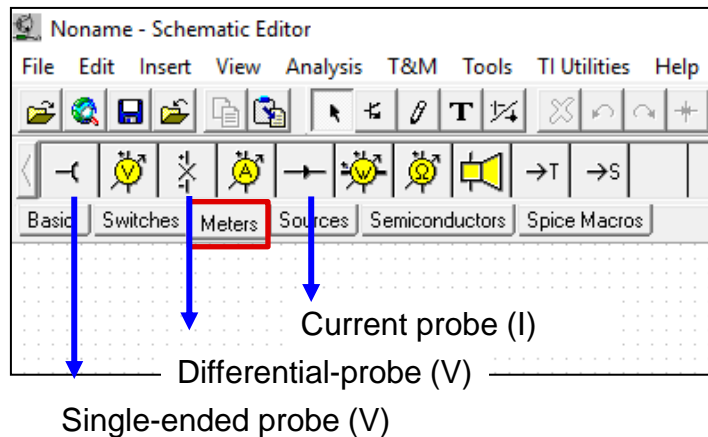
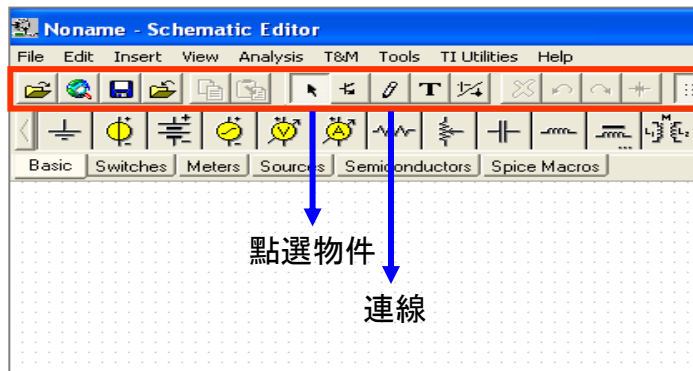
<https://www.ti.com/seclit/sl/slyy137a/slyy137a.pdf>

# Introduction to TINA-TI Simulations

## OPA189 Circuit



# TINA-TI Editor/Tool Bar



# DC, Transient, and AC Simulation

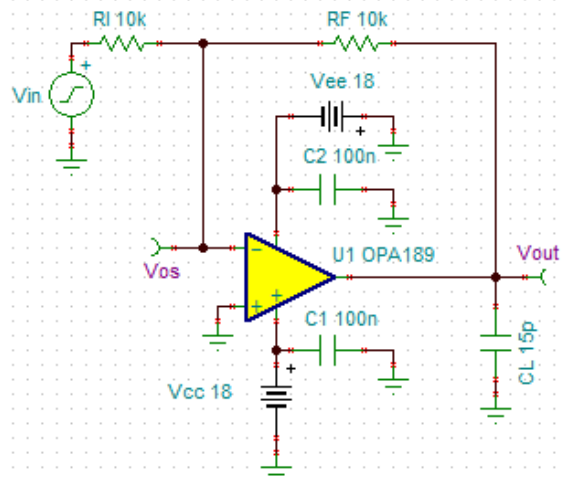
# Performing Analysis with TINA-TI

Case Study: OPA189 Circuit from TINA Reference Design

- Running DC Analysis
- Running AC Analysis
- Running Transient Analysis

# Simulate OPA189 with a 1 uF load

OPA189 TINA-TI Reference Design based on Green-Williams-Lis Pspice simulation model

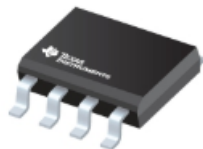


# TINA Model 模擬參數

OPA189(ACTIVE)

14MHz, MUX-friendly, low-noise, zero-drift, RRO, CMOS precision operational amplifier

In English



DATASHEET

OPAx189 Precision, Lowest-Noise 36-V, Zero-Drift, 14-MHz MUX-Friendly, Rail-to-Rail Output, Operational Amplifiers datasheet (Rev. E)

Description & parametrics | Technical documents | **Design & development** |  | Quality & packaging | Support

Models | Design kits & evaluation modules | TI Designs & reference designs | Software | Development tools | TI design

## Models (3)

Title	Category	Type	Date
OPA189 PSpice Model (Rev. C)	PSpice Model	ZIP	27 Feb 2019
OPA189 TINA-TI Reference Design (Rev. C)	TINA-TI Reference Design	TSC	27 Feb 2019
OPA189 TINA-TI Spice Model (Rev. D)	TINA-TI Spice Model	ZIP	27 Feb 2019

```
*****
*
** Released by: Online Design Tools, Texas Instruments Inc.
* Part: OPA189
* Date: 04FEB2019
* Model Type: Generic (suitable for all analysis types)
* EVM Order Number: N/A
* EVM Users Guide: N/A
* Datasheet: SBOS830D SEPTEMBER 2017REVISED DECEMBER 2018
* Created with Green-Williams-Lis Op Amp Macro-model Architecture
*
* Model Version: Final 1.0
*****
OPEN-LOOP GAIN AND PHASE VS. FREQUENCY WITH RL, CL EFFECTS (Aol)
UNITY GAIN BANDWIDTH (GBW)
INPUT COMMON-MODE REJECTION RATIO VS. FREQUENCY (CMRR)
POWER SUPPLY REJECTION RATIO VS. FREQUENCY (PSRR)
DIFFERENTIAL INPUT IMPEDANCE (Zid)
COMMON-MODE INPUT IMPEDANCE (Zic)
OPEN-LOOP OUTPUT IMPEDANCE VS. FREQUENCY (Zo)
OUTPUT CURRENT THROUGH THE SUPPLY (Iout)
INPUT VOLTAGE NOISE DENSITY VS. FREQUENCY (en)
INPUT CURRENT NOISE DENSITY VS. FREQUENCY (in)
OUTPUT VOLTAGE SWING vs. OUTPUT CURRENT (Vo)
SHORT-CIRCUIT OUTPUT CURRENT (Isc)
QUIESCENT CURRENT (Iq)
SETTLING TIME VS. CAPACITIVE LOAD (ts)
SLEW RATE (SR)
SMALL SIGNAL OVERSHOOT VS. CAPACITIVE LOAD
LARGE SIGNAL RESPONSE
OVERLOAD RECOVERY TIME (tor)
INPUT BIAS CURRENT (Ib)
INPUT OFFSET CURRENT (Ios)
INPUT OFFSET VOLTAGE (Vos)
INPUT OFFSET VOLTAGE VS. TEMPERATURE (Vos Drift)
INPUT COMMON-MODE VOLTAGE RANGE (Vcm)
INPUT OFFSET VOLTAGE VS. INPUT COMMON-MODE VOLTAGE (Vos vs. Vcm)
INPUT/OUTPUT ESD CELLS (ESDin, ESDout)
*****
```

# TINA-TI Schematic Editor Tour

The screenshot displays the TINA-TI Schematic Editor interface. The 'Analysis' menu is open, showing the following options:

- ERC...
- Mode...
- Select Control Object
- Set Analysis Parameters...
- DC Analysis
- AC Analysis
- Transient...
- Steady State Solver...
- Fourier Analysis
- Noise Analysis...
- Options...

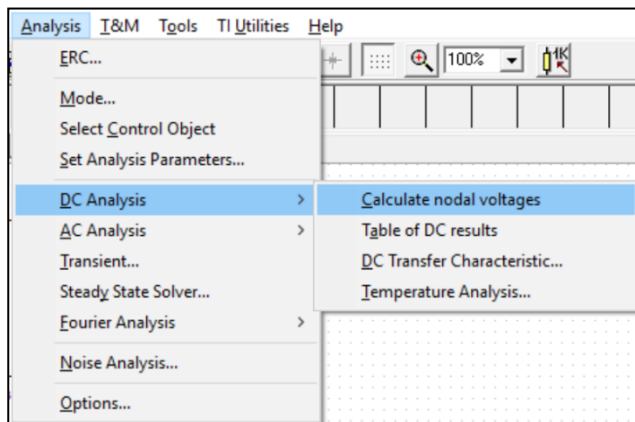
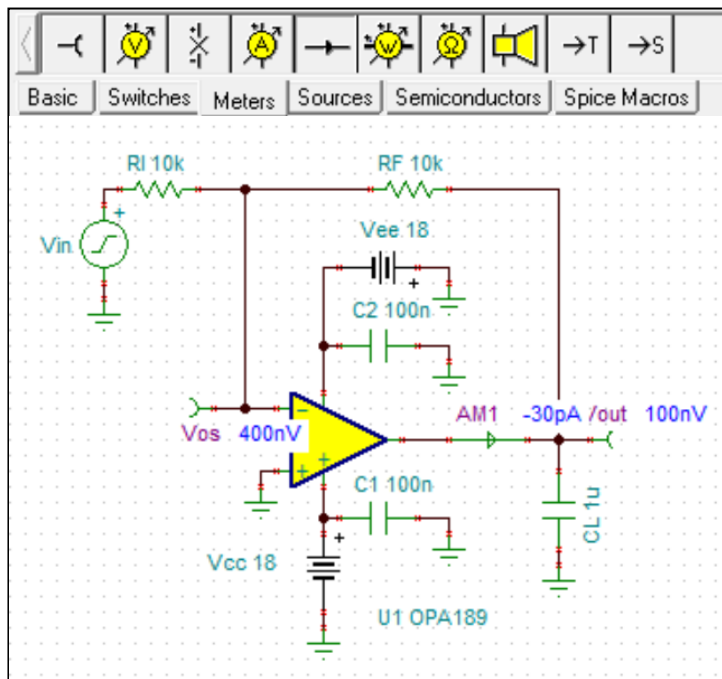
Red arrows point from the menu items to callout boxes:

- From 'DC Analysis' to a box containing: Calculate nodal voltages, Table of DC results, DC Transfer Characteristic..., Temperature Analysis...
- From 'AC Analysis' to a box containing: Calculate nodal voltages, Table of AC results, AC Transfer Characteristic...
- From 'Fourier Analysis' to a box containing: Fourier Series...

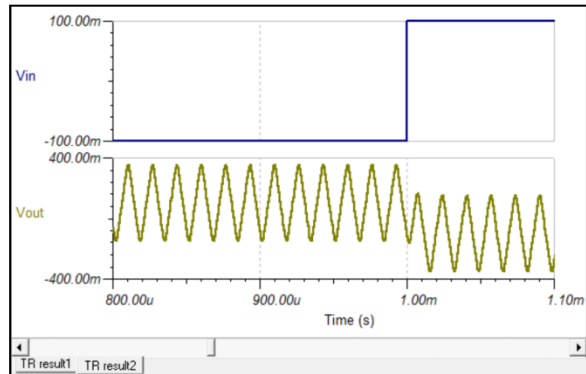
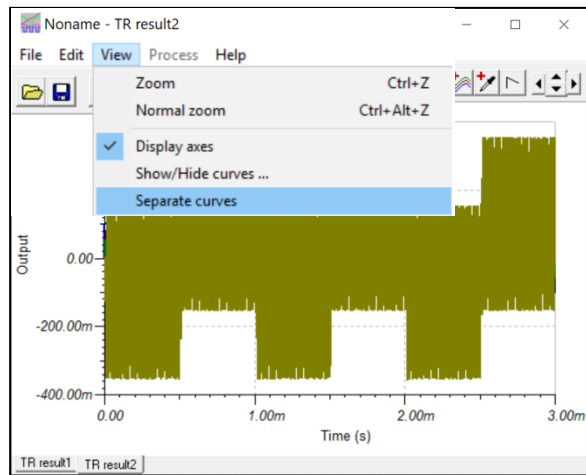
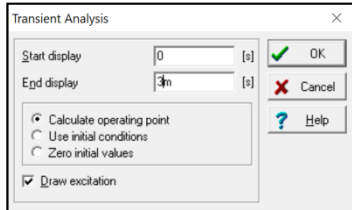
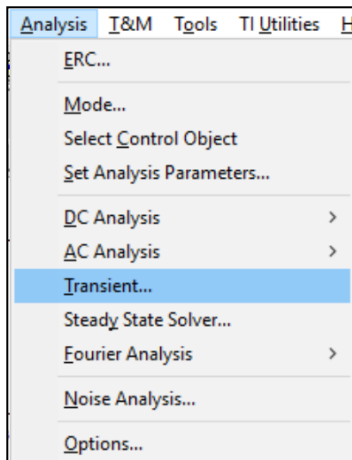
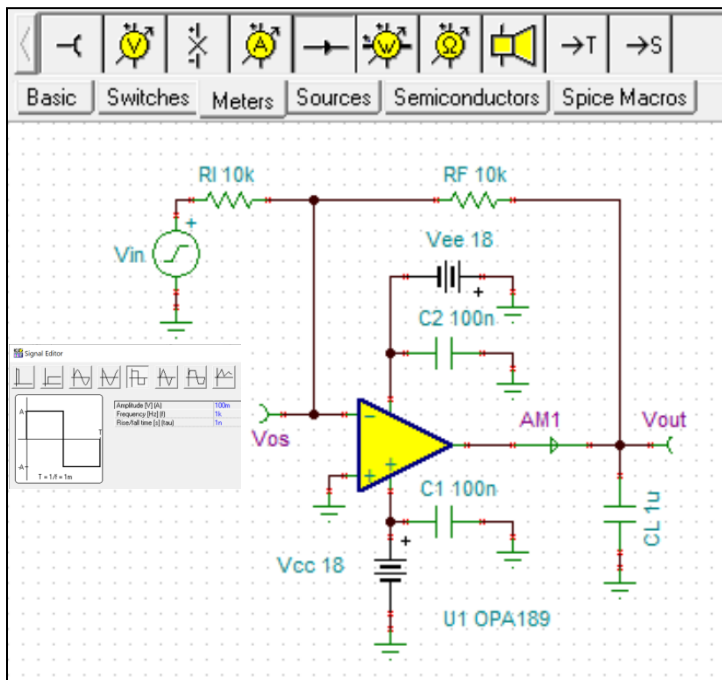
A red box on the right contains the text: 建議電路完成後先 Run DC節點分析.

At the bottom of the window, the status bar shows 'Noname' and 'Exit' buttons, with coordinates 'X: 996 Y: 306'.

# DC Nodal Analysis



# Transient Analysis



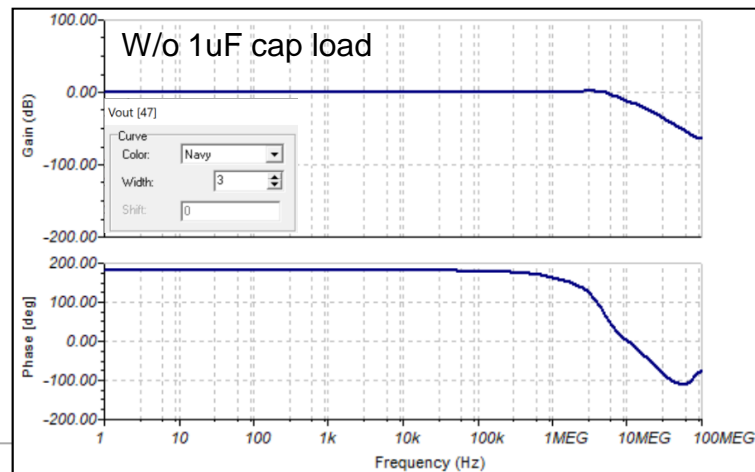
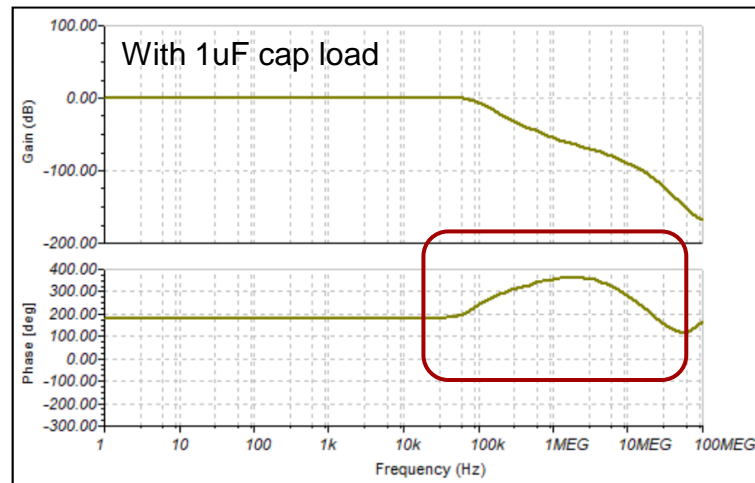


# AC Analysis

The screenshot shows the software's menu system. The 'Analysis' menu is open, and 'AC Analysis' is selected. A sub-menu is visible with options: 'Calculate nodal voltages', 'Table of AC results', and 'AC Transfer Characteristic...'. The 'AC Transfer Characteristic...' option is highlighted. Below this, the 'AC Transfer Characteristic' dialog box is open, showing the following settings:

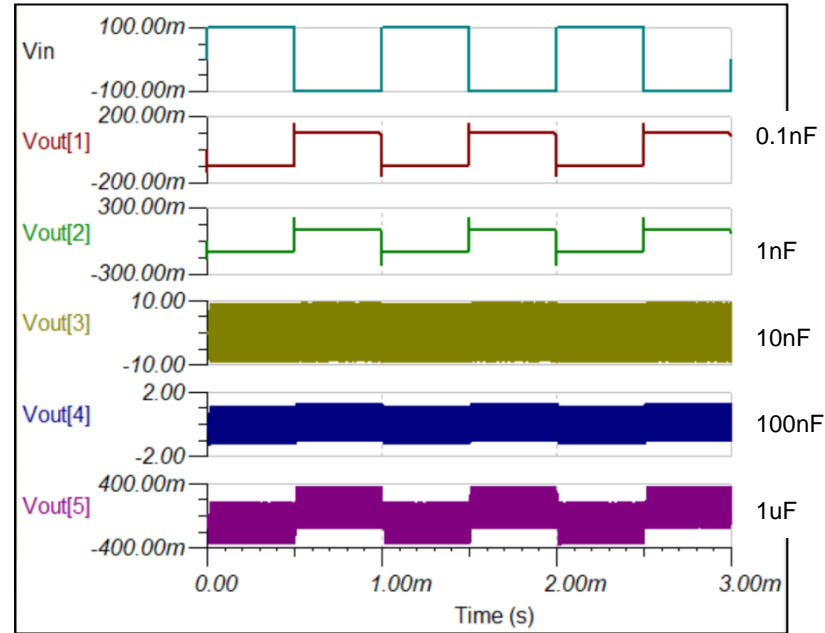
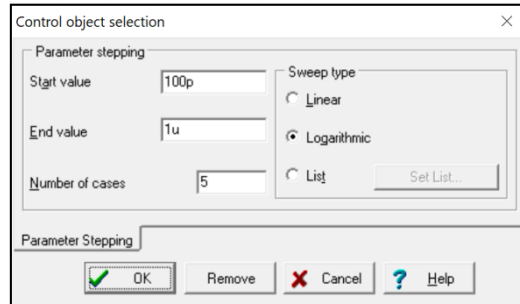
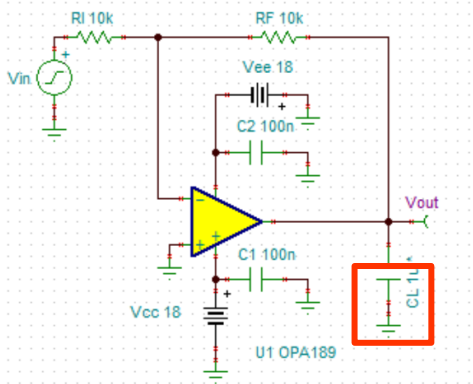
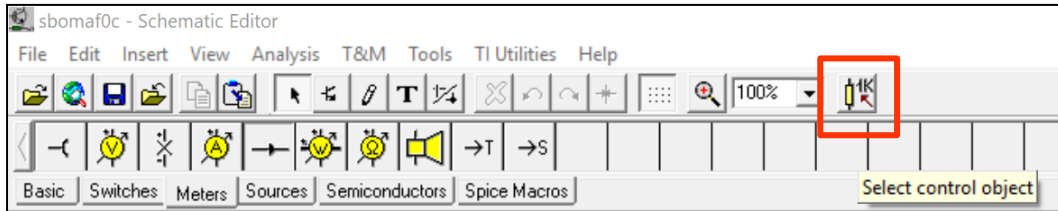
- Start frequency: 1 [Hz]
- End frequency: 100MEG [Hz]
- Number of points: 100
- Sweep type:  Logarithmic
- Diagram:  Amplitude & Phase

Buttons for 'OK', 'Cancel', and 'Help' are also visible.

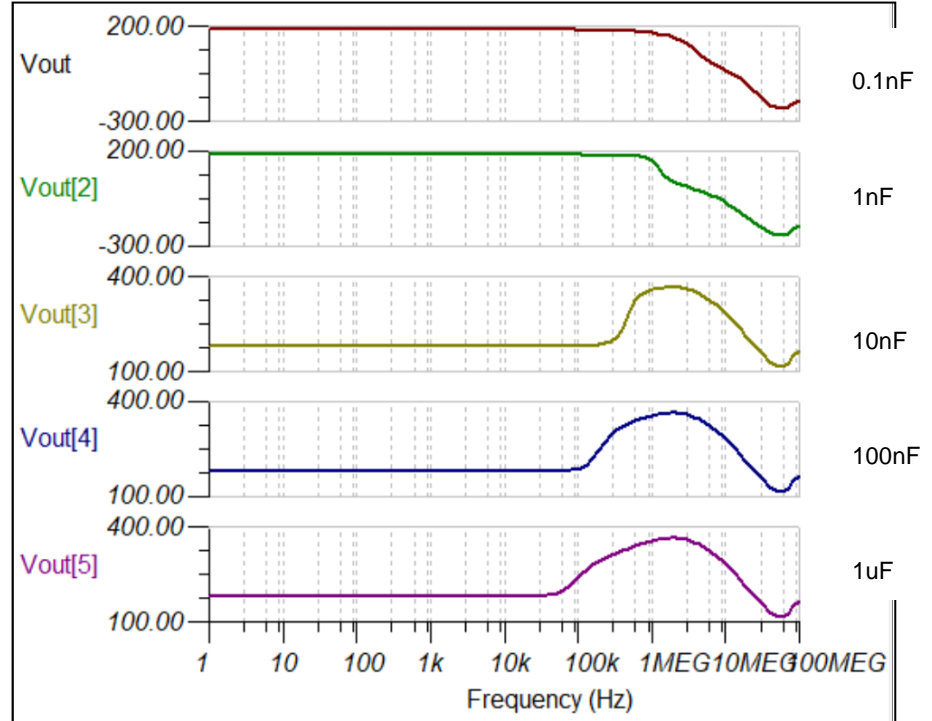
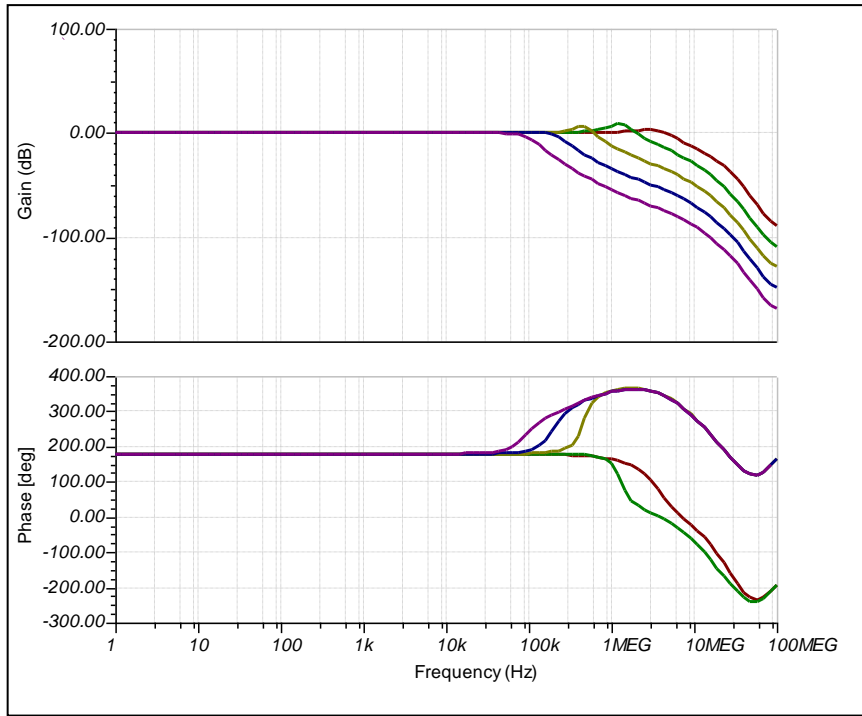


# Parameter-stepping

# Parameter-stepping – Transient Analysis

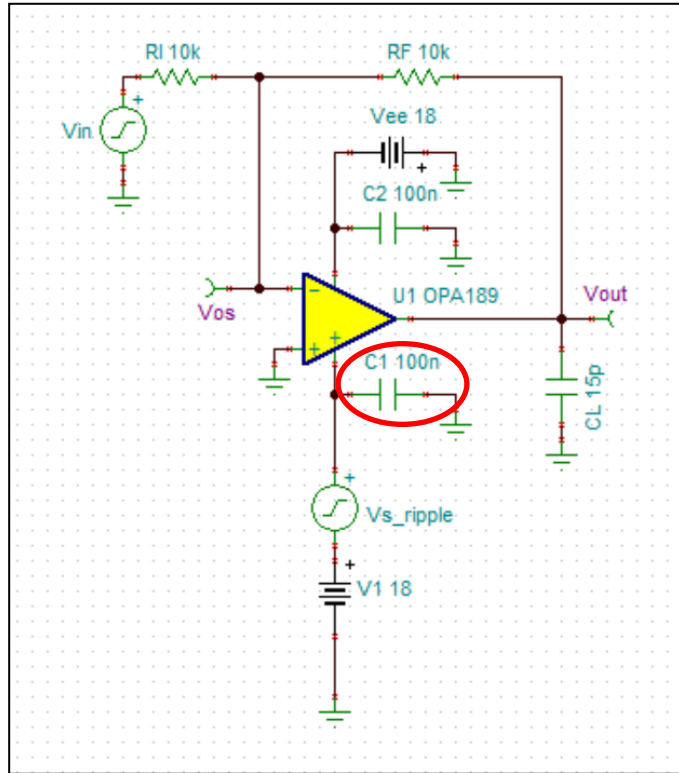


# Parameter-stepping – AC Analysis



# TINA Tips

# Supply Noise and Decoupling Cap



PSRR at high frequency:  
assume 10mVpp ripple:  
40dB  $\Rightarrow$  10mV/V  $\Rightarrow$  0.1mV ( $V_{os\_PSRR}$ )  
20dB  $\Rightarrow$  100mV/V = 1mV  
10dB  $\Rightarrow$  316mV/V  $\Rightarrow$  3.16mV

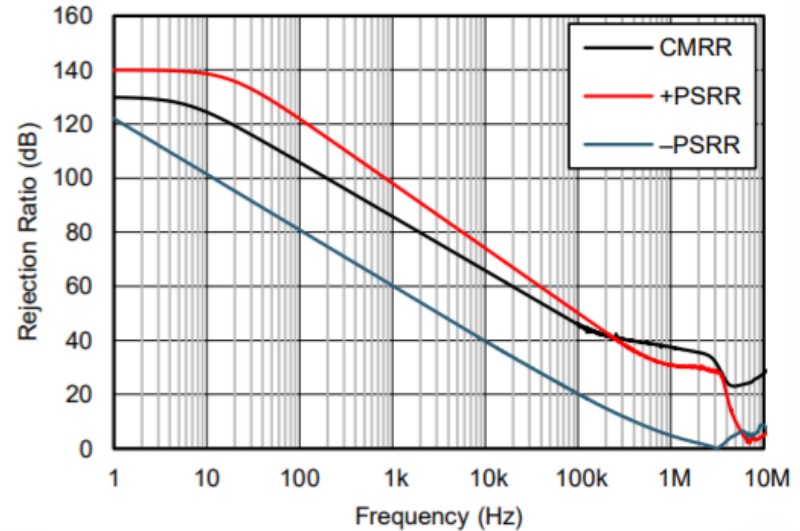
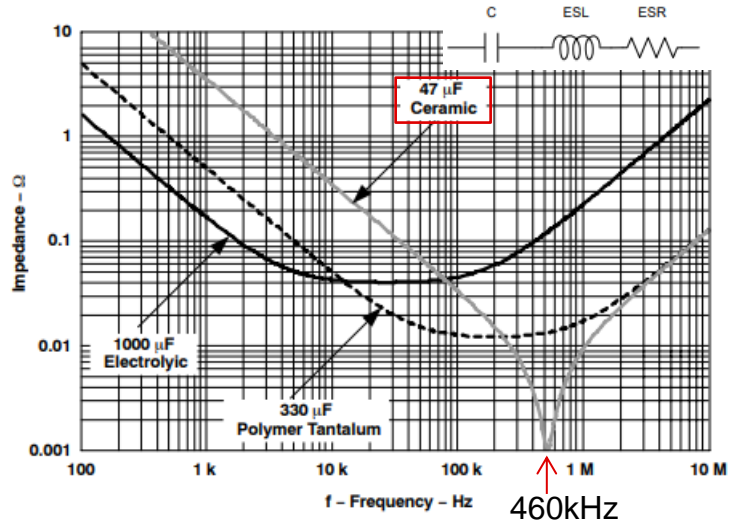
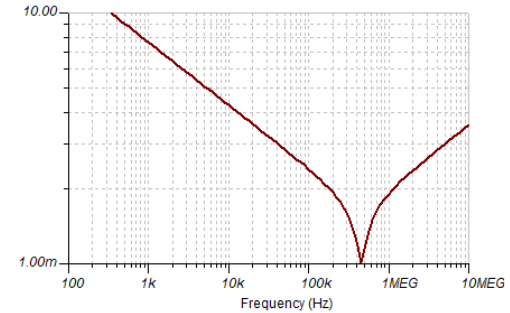
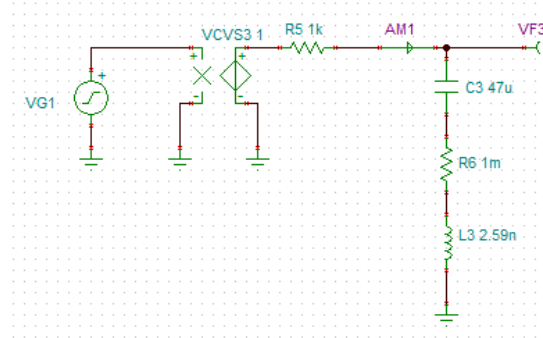


Figure 14. CMRR and PSRR vs Frequency

# Put Real Capacitor in TINA



$f = 1/(2 \times \pi \times r t(LC))$	
$L = 1/(\text{sqrt}(2 \times \pi \times f) \times C)$	
f	4.60E+05 Hz
C	4.70E-05 F
L	2.549571 nH



C Simulation 2.TSC

# Function Generator

Vin - Voltage Generator

Label	Vin
Parameters	(Parameters)
DC Level [V]	0 <input type="checkbox"/>
Signal	Sine wave ...
Internal resistance [Ohm]	0 <input type="checkbox"/>
ID state	Input
Fault	None

OK Cancel Help

Signal Editor 產生自訂波形

Max: 1  
Min: 0 Max: 4m

Repeat Forever	.....
0	0
1m	1 → 時間1ms時, 電壓為1V
2m	1
3m	0
4m	0
Endrepeat	.....

Press the Test button to see the signal.

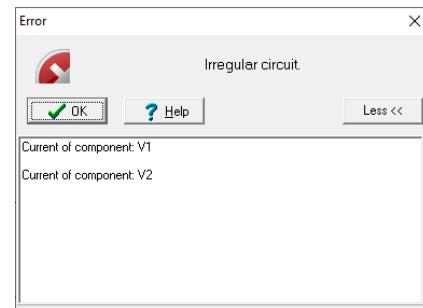
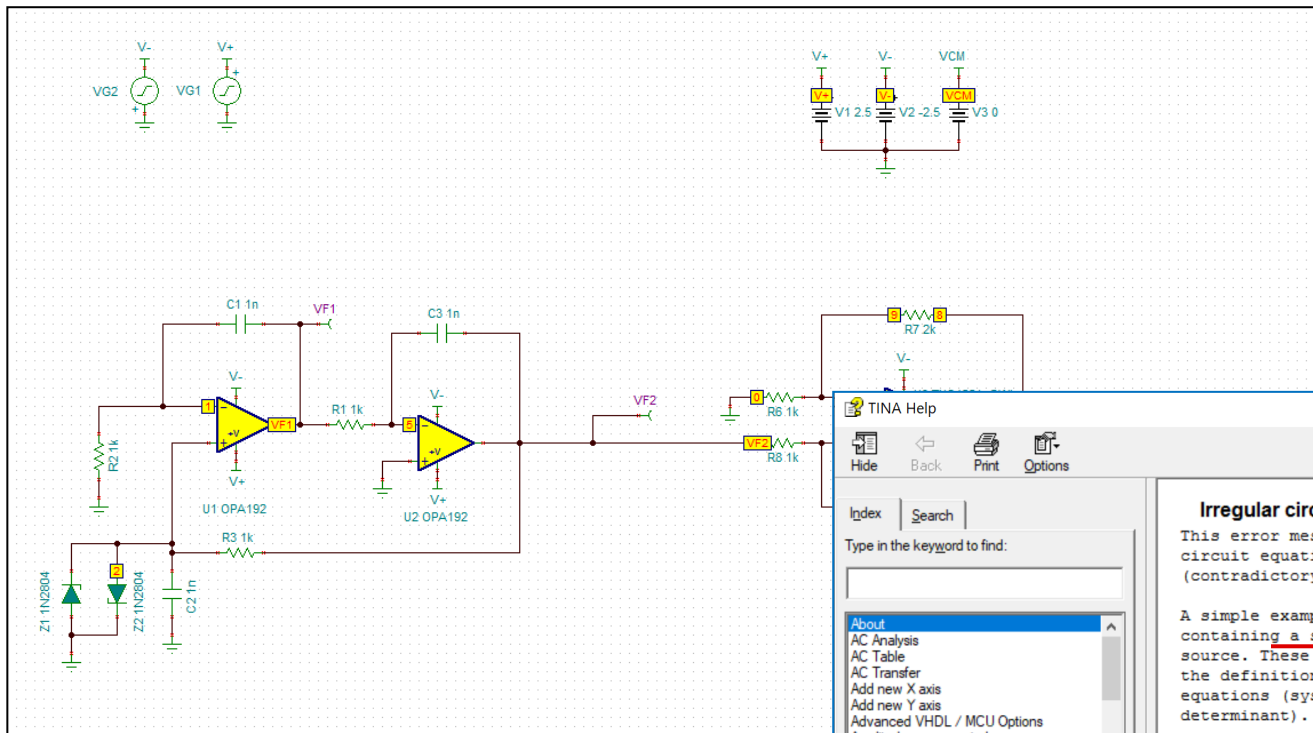
Line: 1 Col: 9  Menu

OK Cancel Help

→ 重複波形



# Error – Irregular Circuit



TINA Help window showing the "Irregular circuit" error message. The window includes a search bar and a list of help topics.

**Irregular circuit**

This error message means that TINA could not solve the circuit equations, probably due to an irregular (contradictory) feature of the circuit.

A simple example of an irregular circuit is a circuit containing a shorted voltage source or an open current source. These circuits have a topology that contradicts the definition of the parts, resulting in unsolvable equations (system of linear equations with a zero determinant).

Search index:

- About
- AC Analysis
- AC Table
- AC Transfer
- Add new X axis
- Add new Y axis
- Advanced VHDL / MCU Options

# Error – Convergence Problem

Convergence problem. Check the analysis parameters!

Calculating 67%

Back to Back Zener to prevent clipping and distortion.

Parameter	Value
Operating point with initial conditions (No)	No
TR max. iteration number [-] (20)	40
TR max. abs. voltage incr. [V] (200m)	200m
TR max. abs. current incr. [A] (20m)	20m
TR max. relative increment [%] (1.0E+30)	1.0E+30
TR maximum value relative error [%] (1m)	1m
TR LTE voltage-based/charge-based (Yes)	Yes
TR truncation error factor [-] (7)	7
TR iteration control factor [-] (500m)	500m
TR charge tolerance (10f)	10f
TR maximum time step [s] (10G)	10G
TR minimum time step [s] (1.0E-30)	1.0E-30
TR excitation subdivisions [-] (10)	10
TR time intrv. subdivisions [-] (100)	100
Abs. error of optimization [-] (1n)	1n
Rel. error of optimization [%] (1u)	1u
Semiconductor capacitors enabled (Yes)	Yes
Shunt conductance [S] (0)	0
Shunt capacitance [F] (0)	0
Max. no. of saved TR points [-] (1000000)	1000000
Wave processing quality (1-4) (1)	1
Audio latency [s] (500m)	500m

Description

Default analysis parameters.  
These parameters establish convergence and sufficient accuracy for most circuits. In case of convergence or accuracy problems click on the "hand" button to Open

OK Cancel Help

# TINA-TI Training Videos

Right-Click the desired line and select *Open Hyperlink*.

- [Introduction to TINA-TI](#)
- [Using the TINA-TI simulator – ERC and Analysis types](#)
- [Configuring Sources in TINA-TI simulator](#)
- [TINA-TI Waveform Viewer, Part 1](#)
- [TINA-TI Waveform Viewer, Part 2](#)
- [Sweeping parameters in TINA-TI simulator](#)
- [Noise, Fourier analysis and Signal Chain content in TINA-TI](#)
- [Power product simulation in TINA-TI simulator](#)
- [Importing SPICE models into TINA-TI](#)
- [Tips and Tricks for TINA-TI simulator](#)
- [How to use the Controlled Source Wizard in the TINA-TI simulator](#)
- [Using WEBENCH® simulation export to create files for TINA-TI simulator](#)
- <https://training.ti.com/tina-ti-video-training-series>

# TI Training & Videos

- Tips and Tricks for TINA-TI simulator

## 1.10 Tips and Tricks for TINA-TI(TM) simulator

Email

**TPS54331 Transient Model (TPS54331EVM-232)**

Calculating 81%

Cancel Preview Pause

Notes:

- 1.) To Run, select Analysis-->Transient
- 2.) Plot for  $V_{in}=15V$  and  $I_{out}=3A$  is shown.
- 3.) Zoomed plot of steady state for above conditions also shown.
- 4.) The model has been encrypted.

Note: Soft Start time reduced compared with EVAL board from 4ms to 1.85ms

Title	TPS54331EVM-232 3A, SWIFT Reg
Size	Document No. SLVU247-July 2008
Date	5/8/2009

# Summary

- Op Amp in Over Current Protection Circuit
  - Output swing limitation
  - Input ESD steering diodes
- Improve Thermal Performance Op Amp Circuit
  - Power Dissipation Calculation
  - Thermal Impedance and Junction Temperature
  - Consider Protection Response Time, Signal Latency, Spike Signal Rise Time
- Amplifier Major Parameters in Current Sensing Application
  - High Side Current Sensing Circuit Specifications
  - Rshunt Calculation
  - Offset Voltage and Drift
  - Slew Rate and Bandwidth
  - CMRR AC
- TINA Tutorial

**Thank you.**