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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Field Application Engineer

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 - Vout_swing Limitation

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

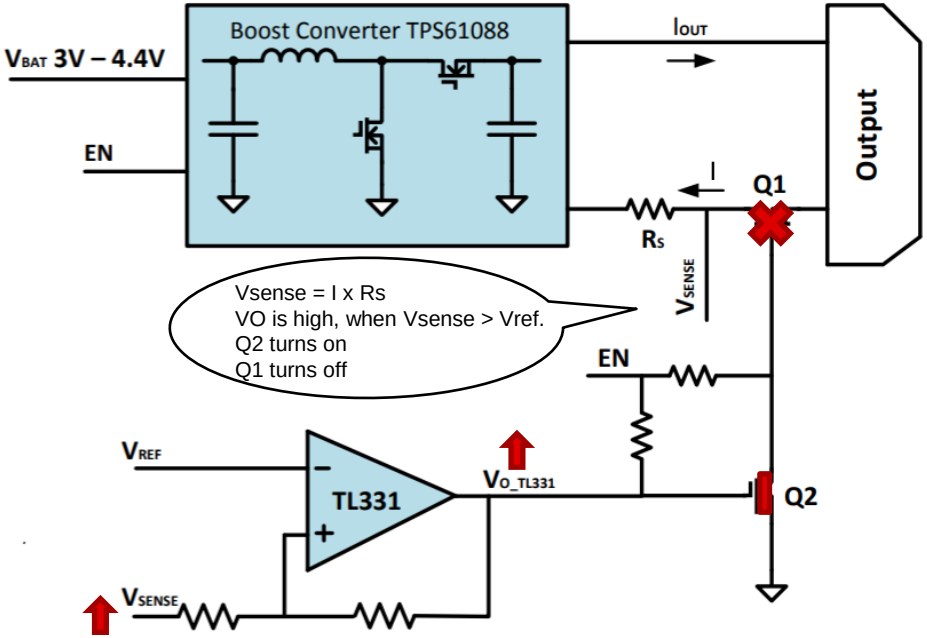


Figure 1. Block Diagram of PMP9779

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

Problems and Why

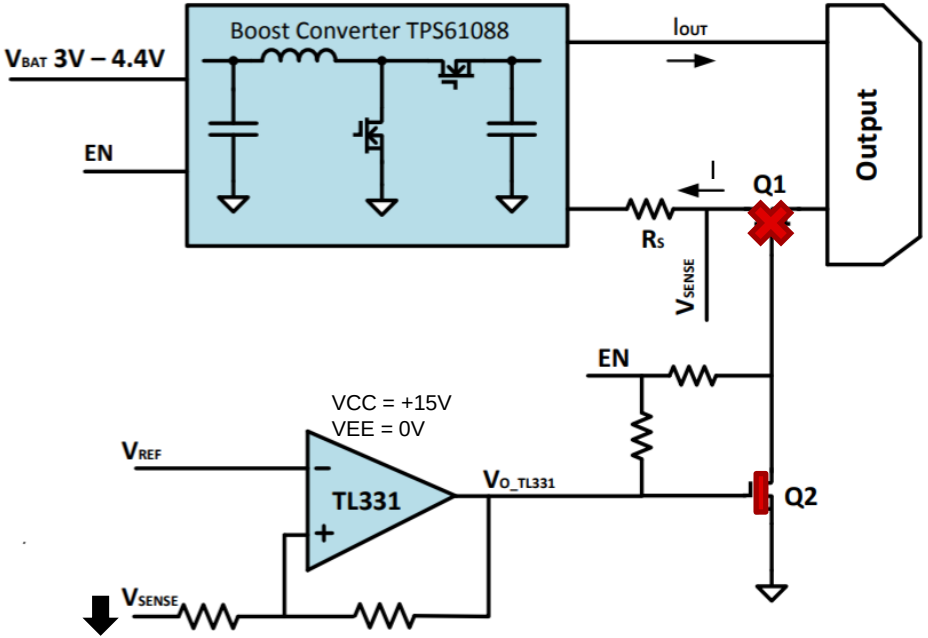


Figure 1. Block Diagram of PMP9779

- 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

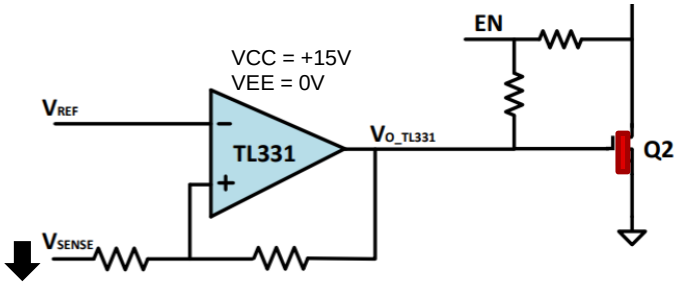


Figure 1. Block Diagram of PMP9779

6.10 Electrical Characteristics: TL071C, TL072C, TL074C

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

PARAMETER		TEST CONDITIONS (1) (2)		MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	V_O = 0, R_S = 50 Ω	T_A = 25°C		3	10	mV
			T_A = Full range			13	
α	Temperature coefficient of input offset voltage	V_O = 0, R_S = 50 Ω	T_A = Full range		18		μV/°C
I_{IO}	Input offset current	V_O = 0	T_A = 25°C		5	100	pA
			T_A = Full range			10	nA
I_{IB}	Input bias current (3)	V_O = 0	T_A = 25°C		65	200	pA
			T_A = Full range			7	nA
V_{ICR}	Common-mode input voltage range	T_A = 25°C		±11	–12 to 15		V
V_{OM}	Maximum peak output voltage swing	R_L = 10 kΩ	T_A = 25°C	±12	±13.5		V
		R_L ≥ 10 kΩ	T_A = Full range	±12			
		R_L ≥ 2 kΩ		±10			

- Root cause:

A. Op Amp output swing limitation. Output swing range from -40C to +85C with Rload >= 2k-ohm is VEE + 5V and VCC -5V.

B. Output swing shrinks with load current increase. In Figure 6, with 2k-ohm load at TA 25C, output swing is +/-11.75V. 0.6k-ohm load shows VOM of +/-10V.

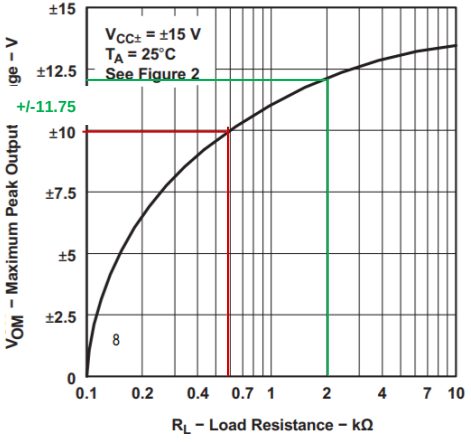
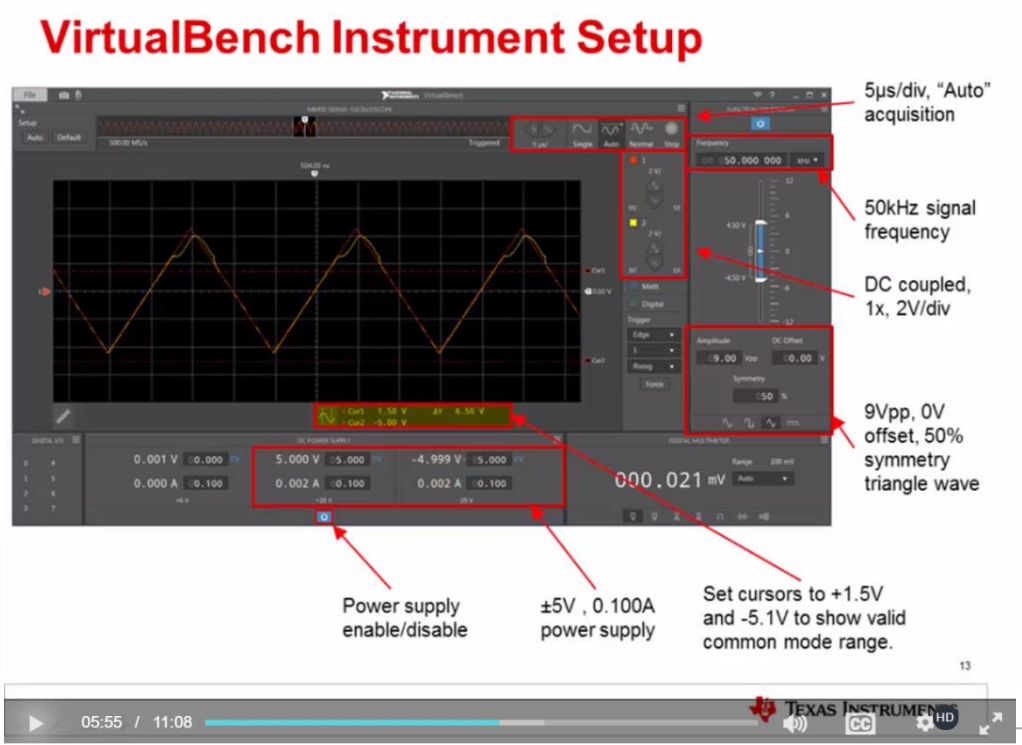


Figure 6. Maximum Peak Output Voltage vs Load Resistance

TI Precision Labs – Op Amps: Input and Output Limitations

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



Op Amp for OCP– Input Clamping Diode

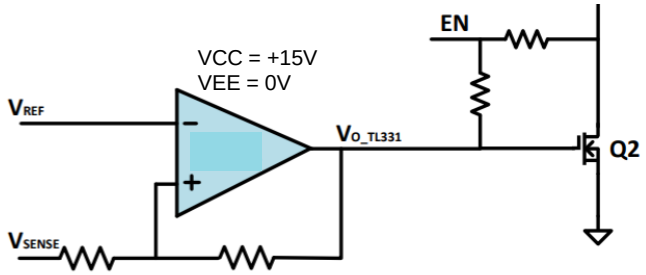


Figure 1. Block Diagram of PMP9779

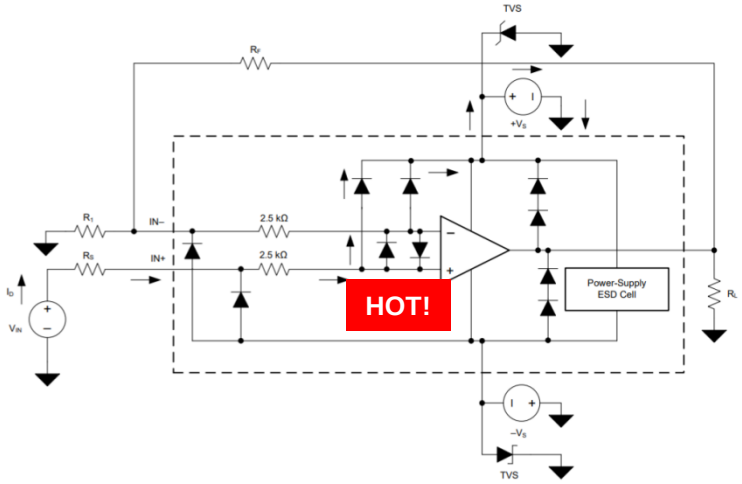


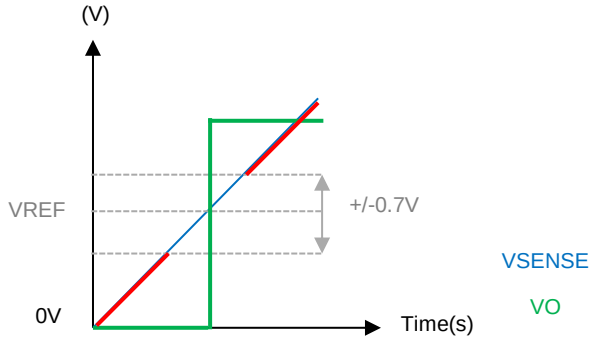
Figure 38. Equivalent Internal ESD Circuitry Relative to a Typical Circuit Application

- Problems:

Op Amp IC has high failure rate and is damaged after turning on power for a while.

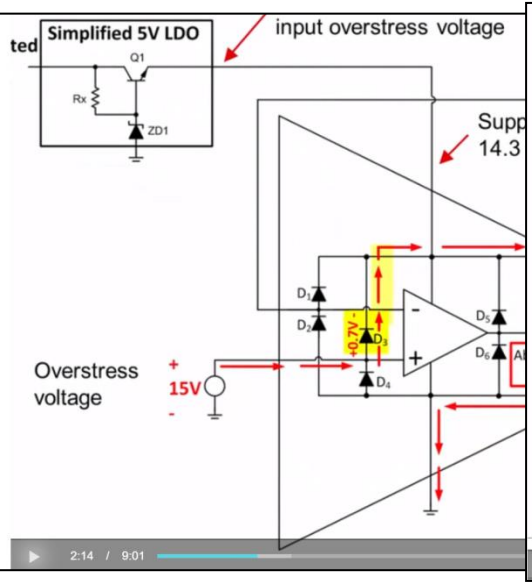
- Root cause:

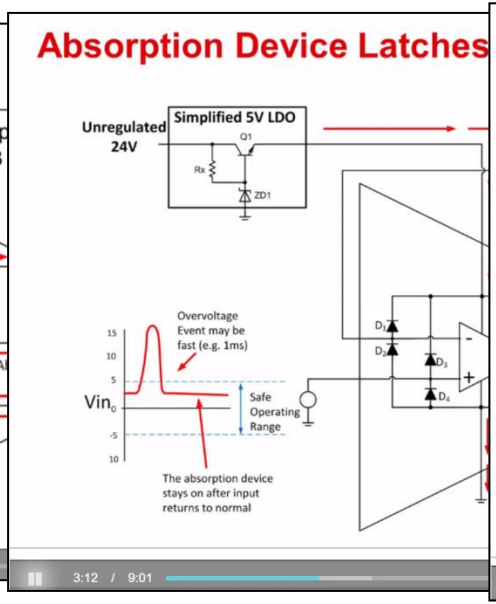
Input clamping diode is conducting and could be damaged without external current limiting resistor.

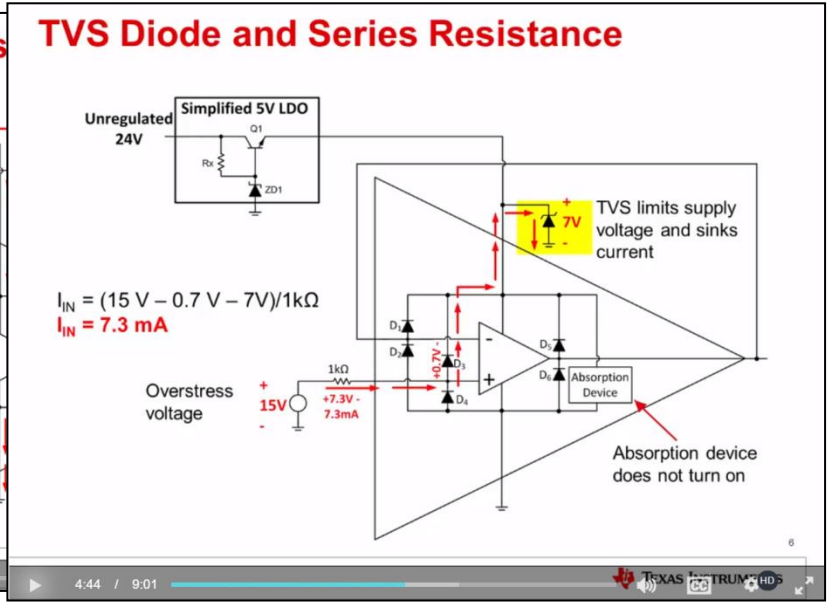


TI Precision Labs – Op Amps: Electrical Overstress (EOS)

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

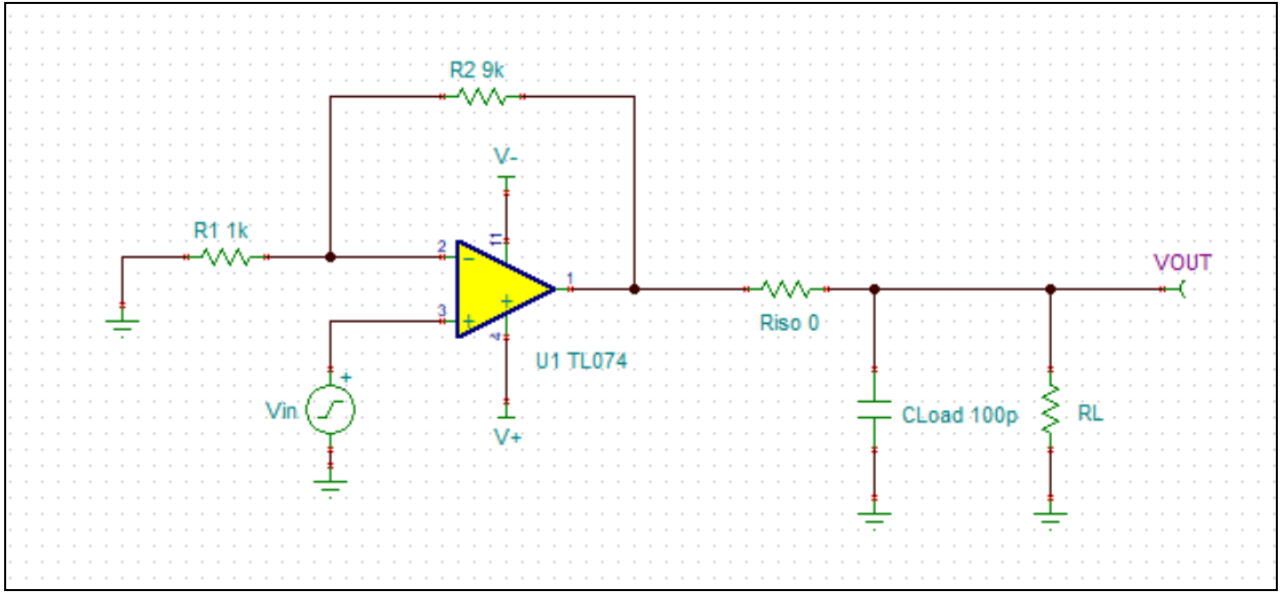






Improve Thermal Performance of Wide Voltage/ Dual Supply Op Amp

+/-15V Op Amp Gain of 10 Circuit



Power Dissipation Calculation

Power dissipation calculation

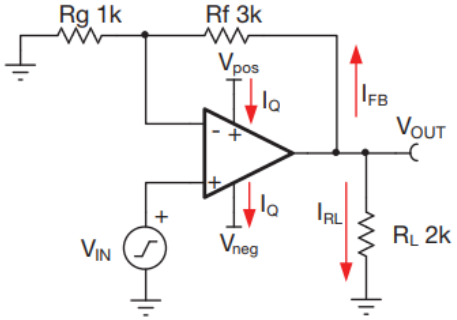


Figure 52: Current and power dissipation for non-inverting amplifier

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

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

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

$$P_L = \left(|I_{RL}| + |I_{FB}|\right)\left(|V_{sup}| - |V_{OUT}|\right)$$ (136) 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.

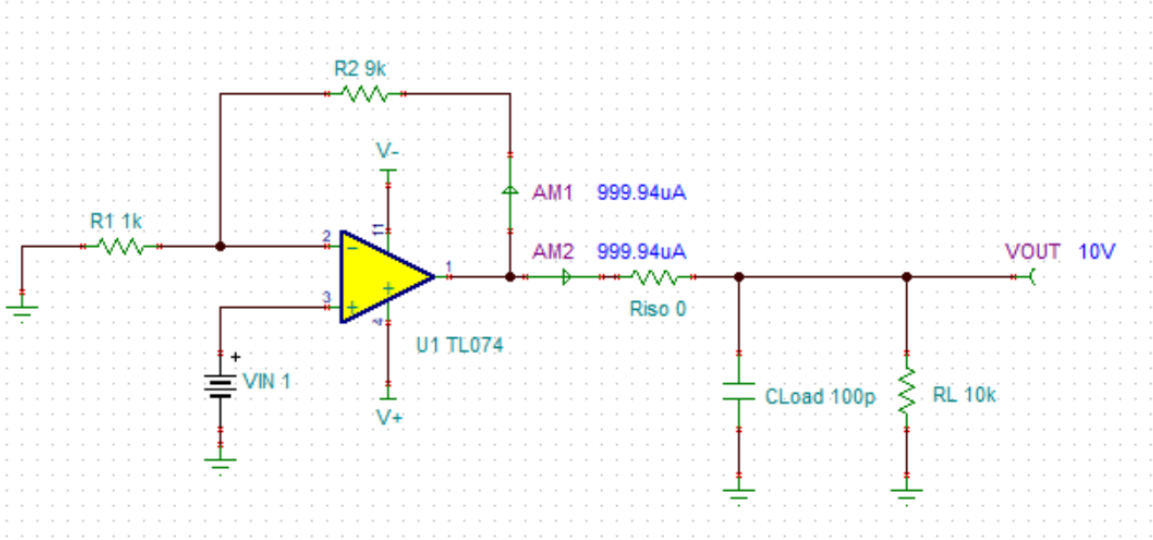
$$P_Q = \left(V_{pos} - V_{neg}\right) \cdot I_Q$$ (137) Total power from quiescent current

$$P_T = P_L + P_Q$$ (138) 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

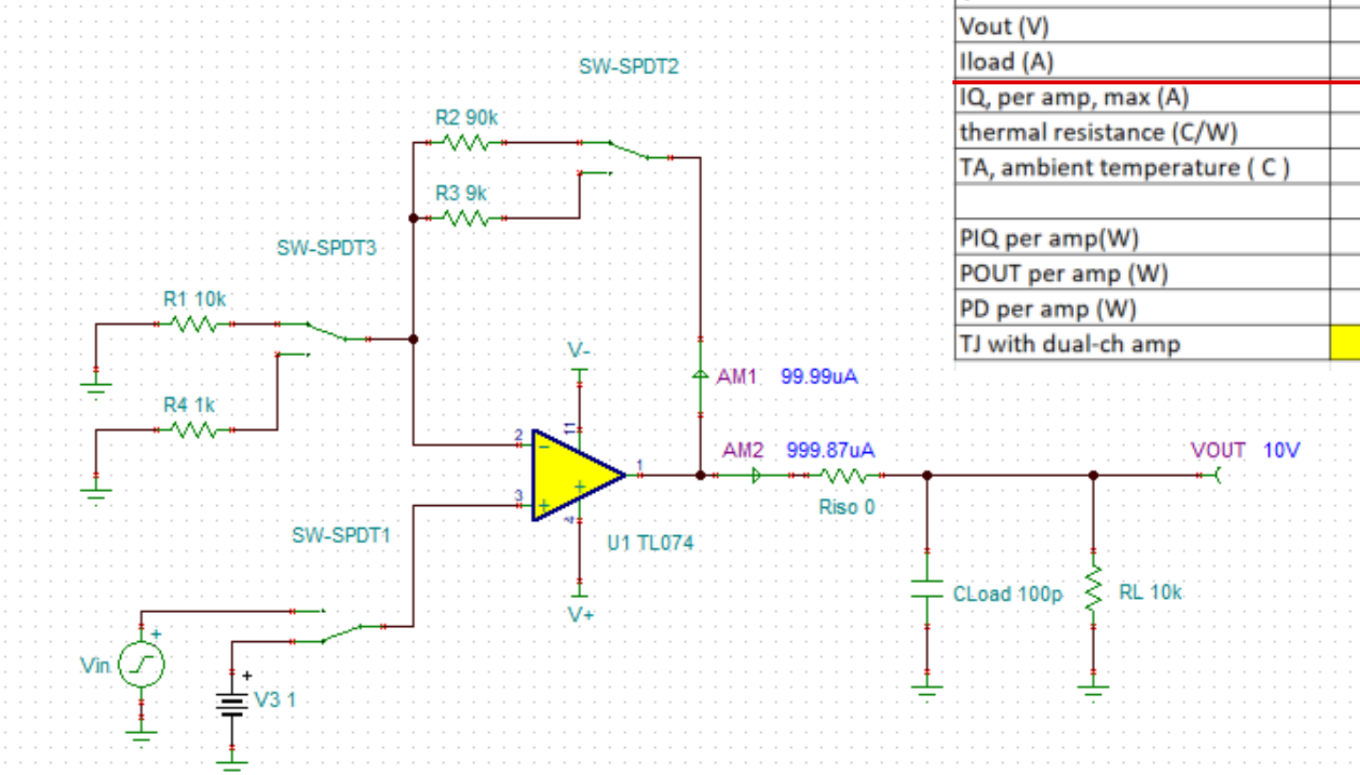


PARAMETER		TEST CONDITIONS (1) (2)		MIN	TYP	MAX	UNIT
I_{CC}	Supply current (each amplifier)	V_O = 0; no load	T_A = 25°C		1.4	2.5	mA

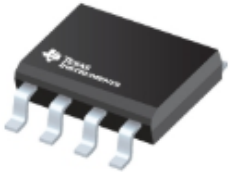
SPICE-based Sumulator
http://www.ti.com/tool/TINA-TI

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	55.617



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 V to 40 V (±2.25 V to ±20 V) at T_A = 25°C, R_L = 10 kΩ 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
OUTPUT							
	Voltage output swing from rail	Positive rail headroom	V_S = 40 V, R_L = no load		3		mV
			V_S = 40 V, R_L = 10 kΩ		50	75	
			V_S = 40 V, R_L = 2 kΩ		250	350	
		Negative rail headroom	V_S = 4.5 V, R_L = no load		1		
			V_S = 4.5 V, R_L = 10 kΩ		20	30	
			V_S = 4.5 V, R_L = 2 kΩ		40	75	
I_{SC}	Short-circuit current				±60		mA
C_{LOAD}	Capacitive load drive				See *Typical Characteristics*		
Z_O	Open-loop output impedance	f = 1 MHz, I_O = 0 A			600		Ω
POWER SUPPLY							
I_Q	Quiescent current per amplifier	I_O = 0 A			150	175	µA
			T_A = –40°C to 125°C			175	

	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			
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

TL07x 13V/us
TLV930x 3V/us

Op Amp Selection Tips

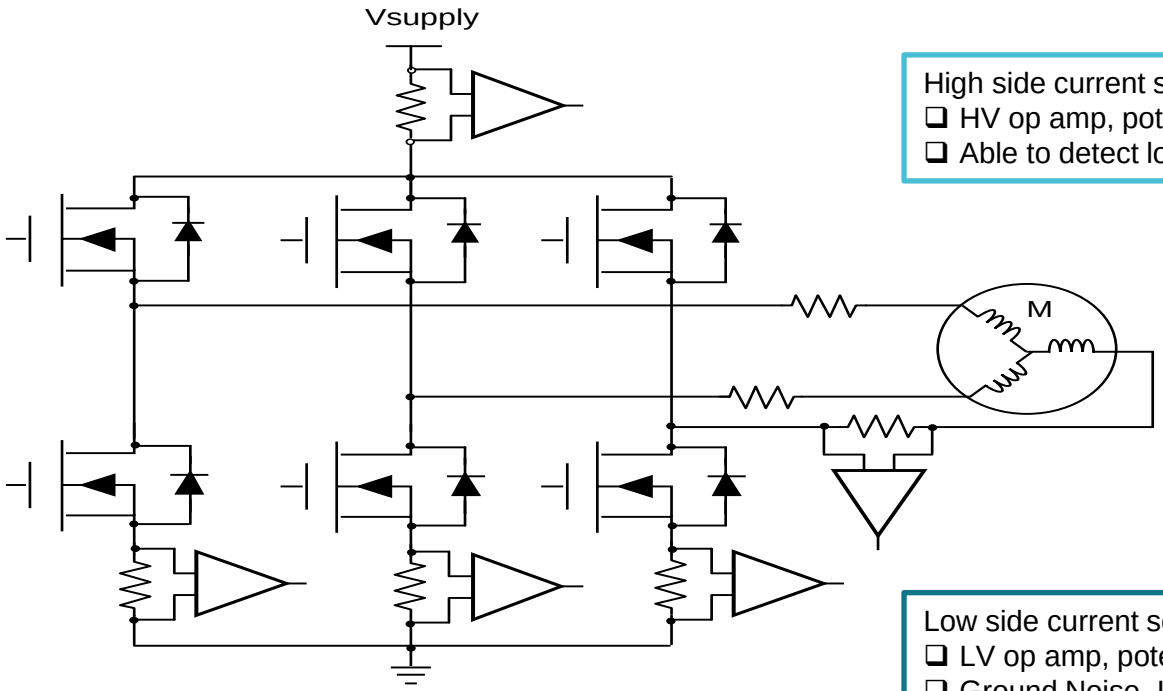
- Considering circuit function and important specs of it:
- Process sine wave/ care synchronization => Small signal latency => GBW
- Use as OCP/ OVP protection function => Large signal response time => Slew Rate
- Light load current monitoring/precision current sensing

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

■工業應用技術專題: 精密電流量測
https://www.ti.com/seclit/ml/sszp076/sszp076.pdf

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

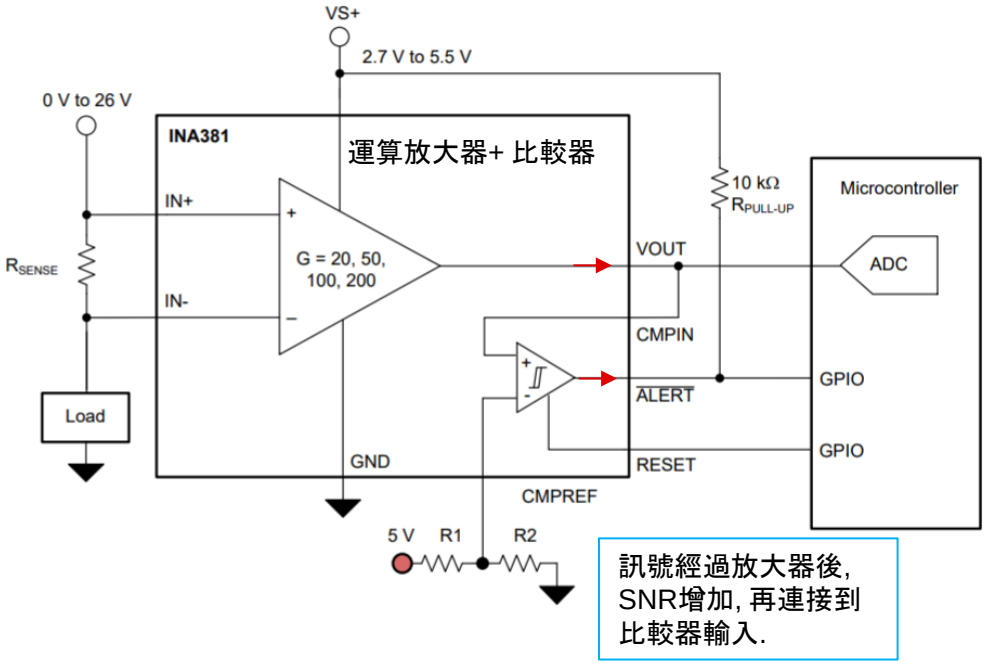
Light Load Accuracy @1.5A +/-10%

OCP response time 10us

Input signal max frequency sine 10kHz

Analog Engineer's Circuit: Amplifiers
High Side Current Sensing and OCP
https://www.ti.com/seclit/sl/slyy137a/slyy137a.pdf

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 µV (Maximum)
  - Offset Voltage, V_{CM} = 0 V: 150 µV (Maximum)
  - Offset Voltage Drift: 1 µV/°C (Maximum)
  - Gain Error: 1% (Maximum)
  - Gain Error Drift: 20 ppm/°C (Maximum)
- Available Amplifier Gains:
  - INA381A1: 20 V/V
  - INA381A2: 50 V/V
  - INA381A3: 100 V/V
  - INA381A4: 200 V/V

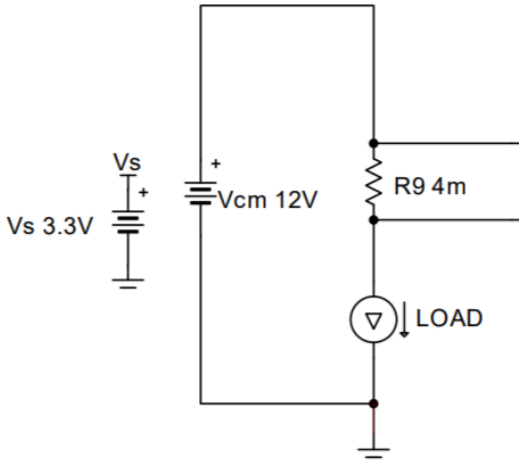
350	kHz
210	kHz
150	kHz
105	kHz

- 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)

Analog Engineer's Circuit: Amplifiers
High Side Current Sensing and OCP
https://www.ti.com/seclit/sl/slyy137a/slyy137a.pdf

System Specs and INA381 Parameter Rshunt Calculation

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



Rshunt Calculation: Highest SNR

Vout_max = Imax x Rshunt x Gain

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

$$R_{standard\ \ shunt} = 4m\Omega \text{ (standard 1\% value)}$$

Considering power loss:

12V x 40A = 480W

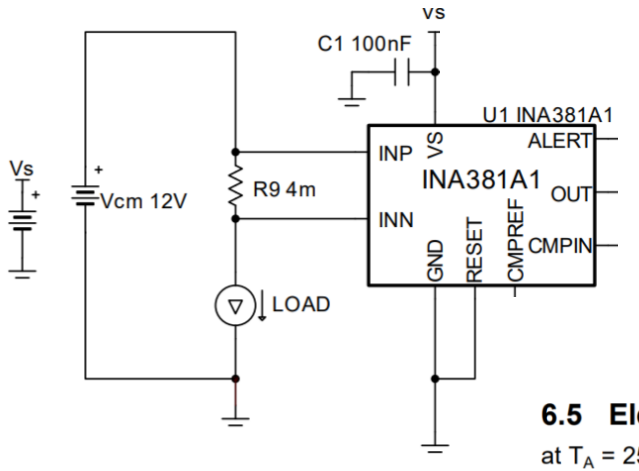
480W x 0.1% = 0.48W

0.48W = I^2R

R = 0.48/1600 = 0.3m-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%:

Vsense = Imin x Rsense
Vsense = 1.5A x 4m-ohm
Vsense = 6mV
Allowable Error = 6m-ohm x +/-10%
= +/-600uV

Drift calculation
Max ambient temperature 45C
Vos_Drift
= 1uV/C x (delta T)
= 1uV/C x (45-25)
= 20uV

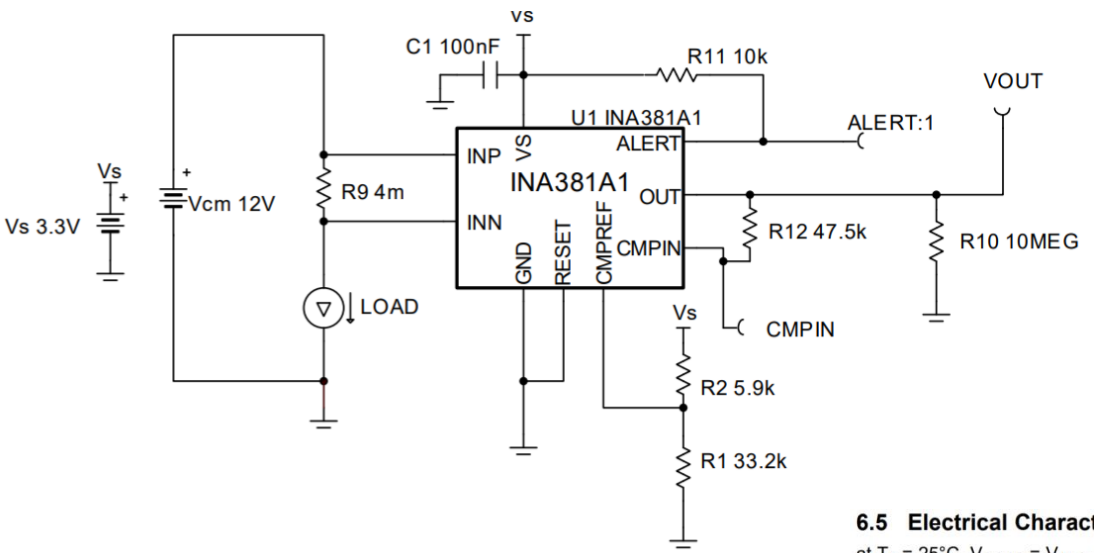
6.5 Electrical Characteristics

at T_A = 25°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
INPUT						
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°C to +125°C	84	100		dB
V_{OS}	Offset voltage, RTI(1)	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(1)	T_A= –40°C to +125°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
= Vout_max/ time
= 2.8V/ 10us
= 0.28V/us

Fin max
10kHz

6.5 Electrical Characteristics

at T_A = 25°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
FREQUENCY RESPONSE						
BW	Bandwidth	INA381A1		350		kHz
		INA381A2		210		kHz
		INA381A3		150		kHz
		INA381A4		105		kHz
SR	Slew rate			2		V/µs

Analog Engineer's Circuit: Amplifiers
High Side Current Sensing and OCP
https://www.ti.com/seclit/sl/slyy137a/slyy137a.pdf

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

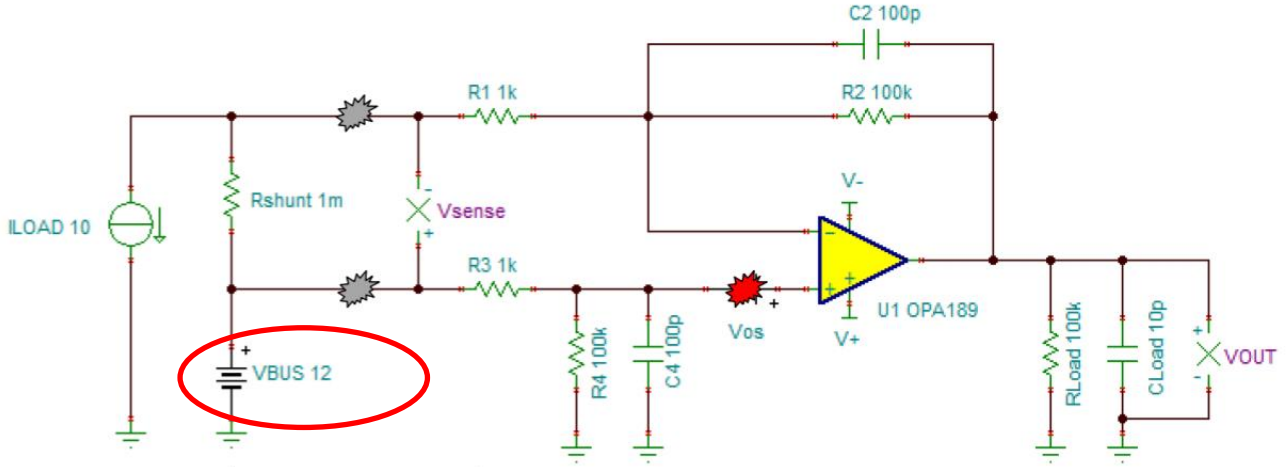
OCP response time
10us

Slew Rate
= Vout_max/ time
= 2.8V/ 10us
= 0.28V/us

Input Signal max frequency sine
10kHz

Slew Rate (SR)
Full power Bandwidth
SR = 2 x pi x F x Vpp
SR = 2 x 3.14 x 10kHz x 2.8
SR = 0.176V/us

Current Sensing Error Sources



Shunt Resistor Tolerance

Trace Resistance

Op Amp Input Offset Voltage(Vos) Correlated:

- ❑ Vos at Room Temperature 25C
- ❑ Vos_Drift
- ❑ Vos_CMRR_DC
- ❑ Vos_CMRR_AC
- ❑ Vos_PSRR_DC
- ❑ Vos_PSRR_AC
- ❑ Bias Current

Noise

- ❑ Extrinsic Noise
- ❑ Intrinsic Noise

24

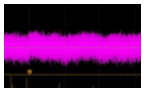
■工業應用技術專題: 精密電流量測
https://www.ti.com/seclit/ml/sszp076/sszp076.pdf

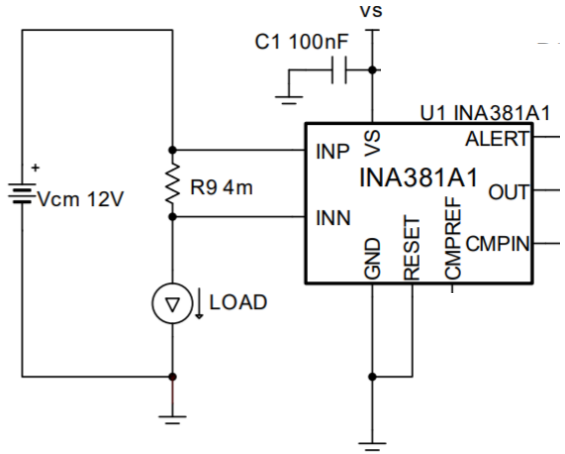
VCM 12V Ripple and FFT

12V supply
AC coupling
mode

~7.3mV 50kHz
~4.1mV 100kHz
~4.1mV 280kHz
~4.1mV 460kHz
~0.13mV 570kHz
~4.1mV 520kHz
~0.13mV 860kHz
~4.1mV 920kHz
~13mV 970kHz

System Specs and INA381 Parameter CMRR AC

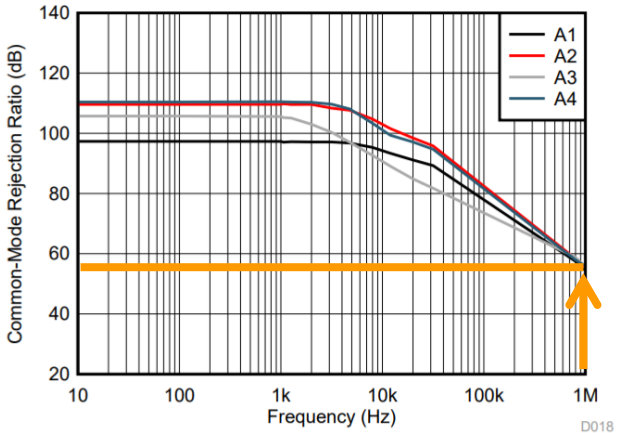




6.5 Electrical Characteristics

at T_A = 25°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
INPUT						
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°C to +125°C	84	100		dB



- A1 CMRR is ~55dB@1MHz at 25-C.
- It has 1.78mV/V attenuation capability to the common mode noise.
- VOS_CMRR_AC
= 13mV x 1.78mV = 23.14uV

To see more circuit detail analysis:

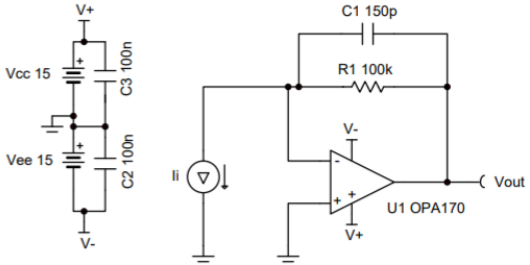
Transimpedance amplifier circuit

Design Goals

Input		Output		BW	Supply	
I_{iMin}	I_{iMax}	V_{oMin}	V_{oMax}	f_p	V_{cc}	V_{ee}
0A	50µA	0V	5V	10kHz	15V	–15V

Design Description

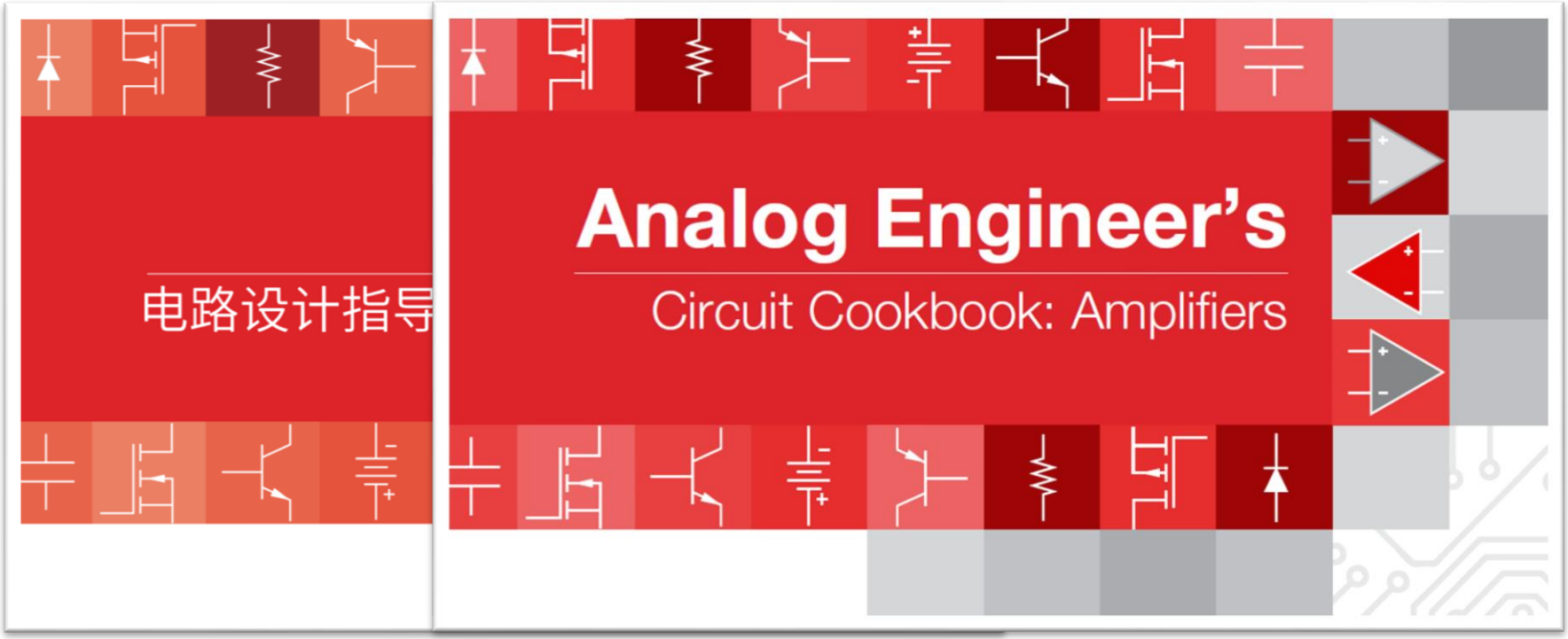
The transimpedance op amp circuit configuration converts an input current source into an output voltage. The current to voltage gain is based on the feedback resistance. The circuit is able to maintain a constant voltage bias across the input source as the input current changes which benefits many sensors.



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_{ol} specification) to minimize non-linearity errors.

類比工程師 電路設計指導手冊

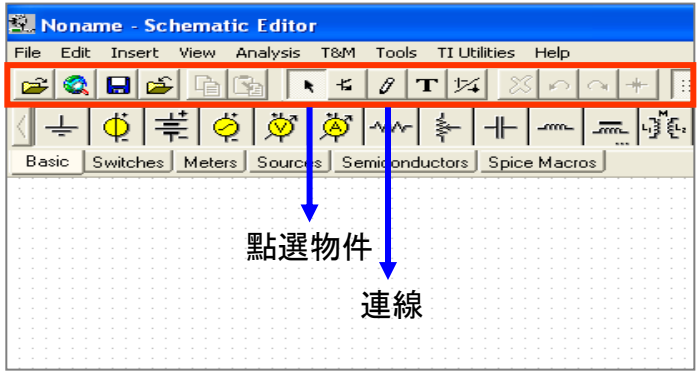


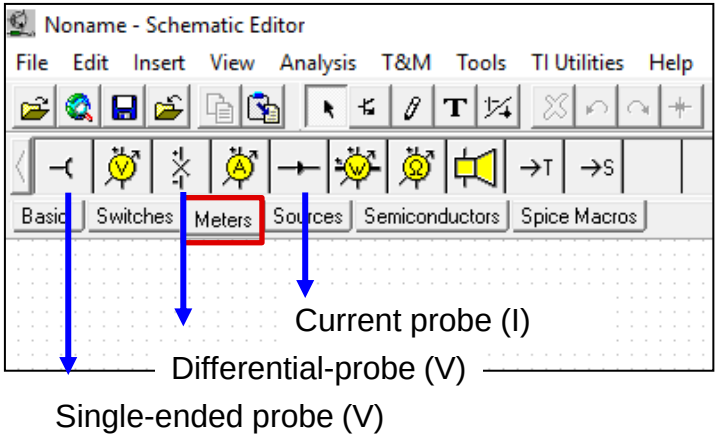
https://www.ti.com/seclit/sl/zhcy082a/zhcy082a.pdf
https://www.ti.com/seclit/sl/slyy137a/slyy137a.pdf

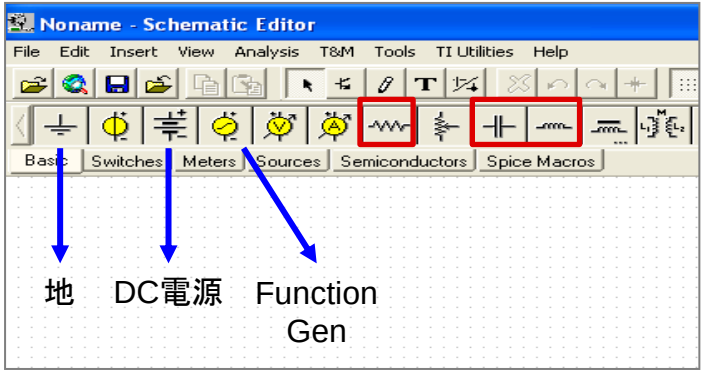
Introduction to TINA-TI Simulations

OPA189 Circuit

TINA-TI Editor/Tool Bar







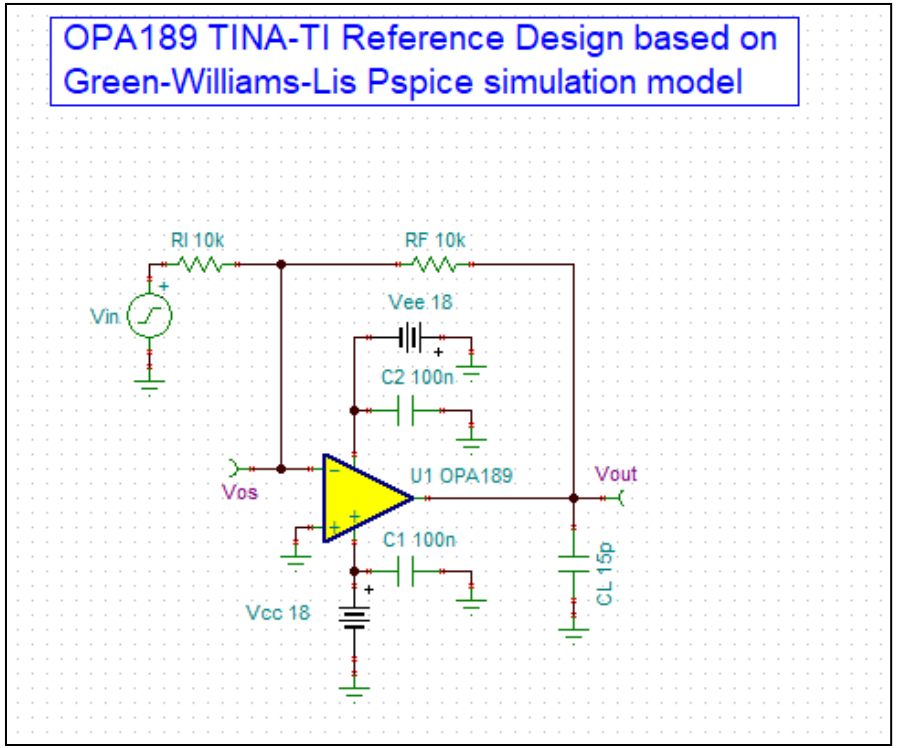
DC, Transient, and AC Simulation

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

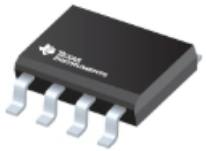


TINA Model 模擬參數

OPA189(ACTIVE)

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

In English ▾ | Alert me



DATASHEET

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

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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 □EPTEMBER 2017□EVISED 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)
*****************************************
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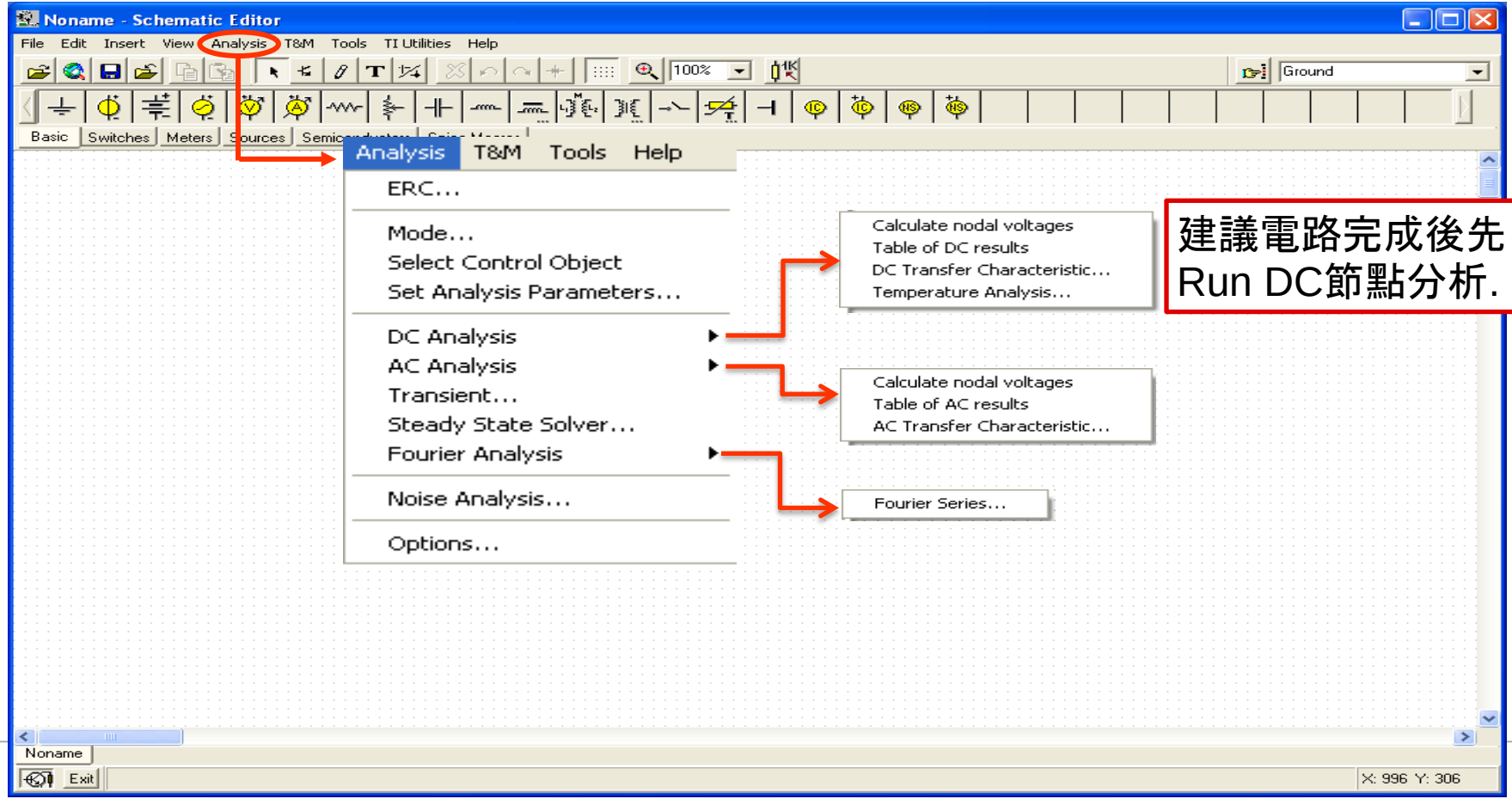
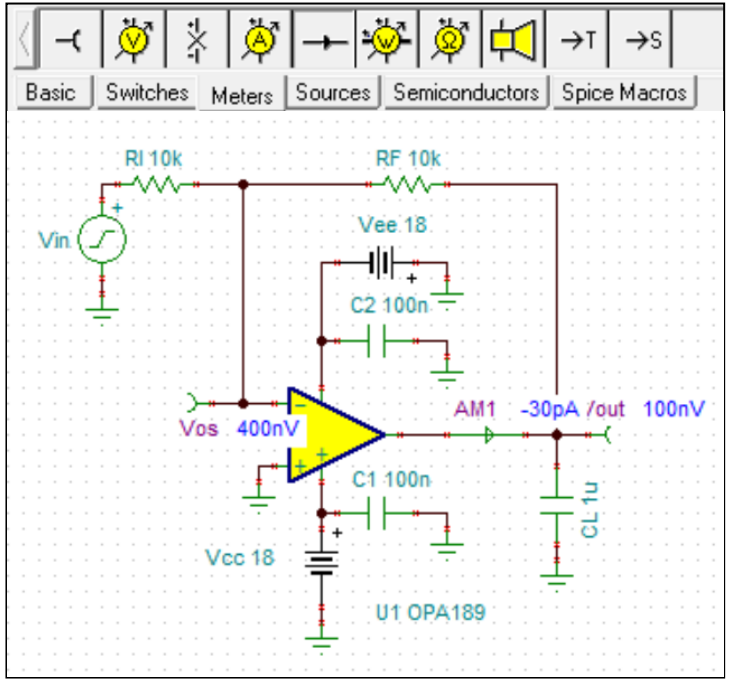
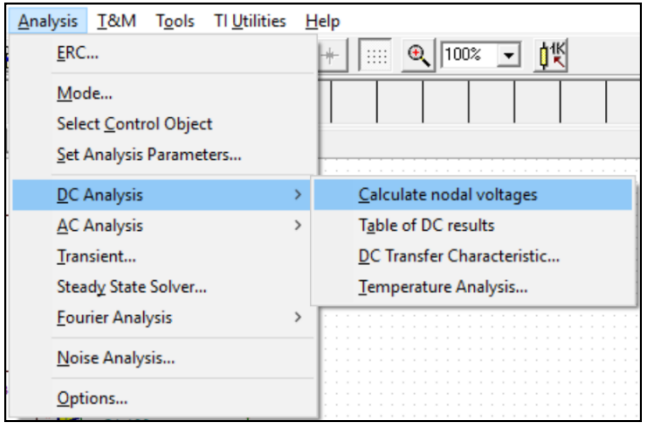
TINA-TI Schematic Editor Tour

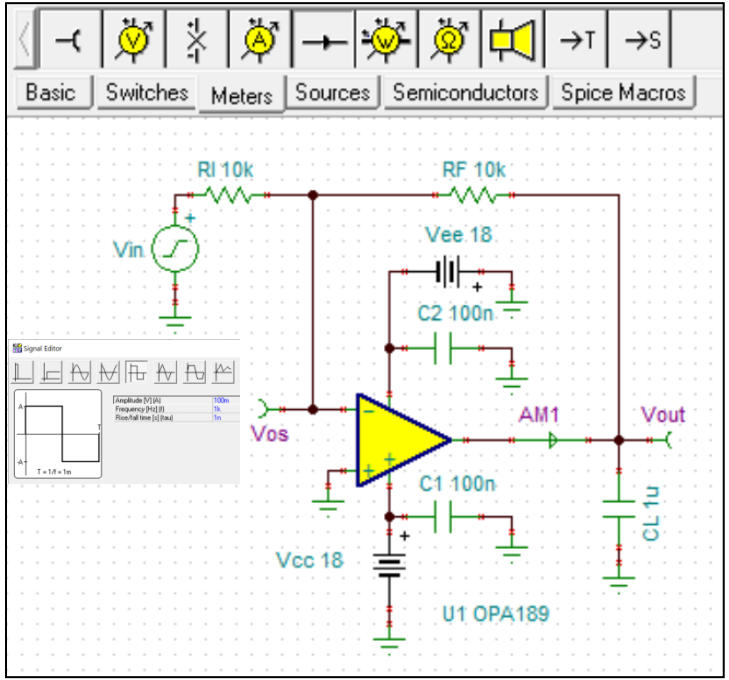


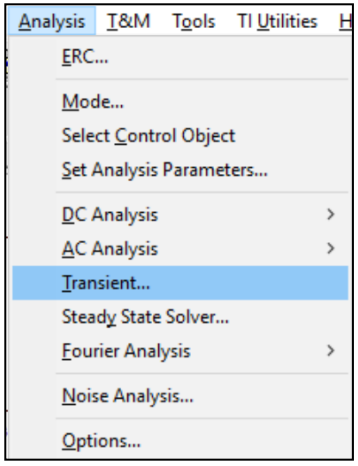
DC Nodal Analysis

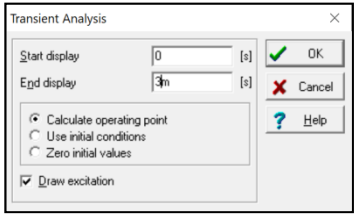


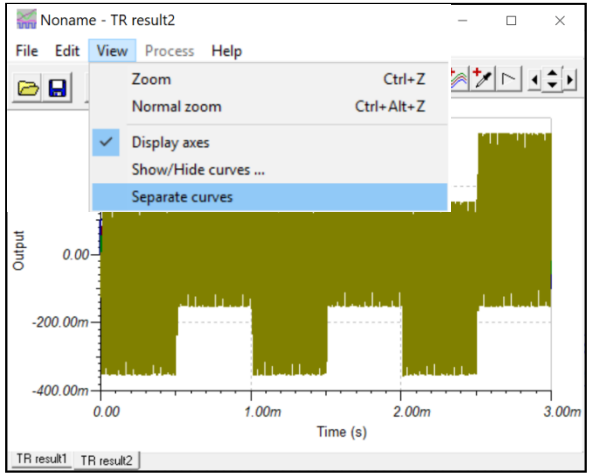


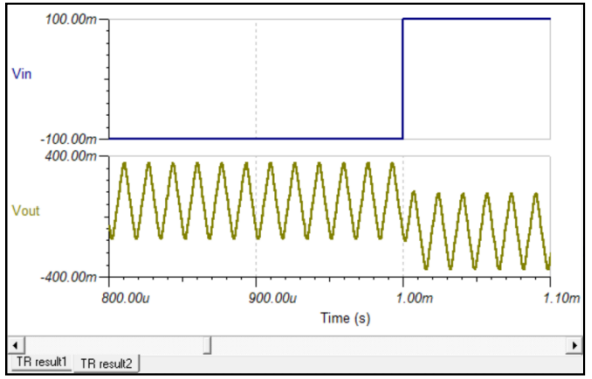
Transient Analysis



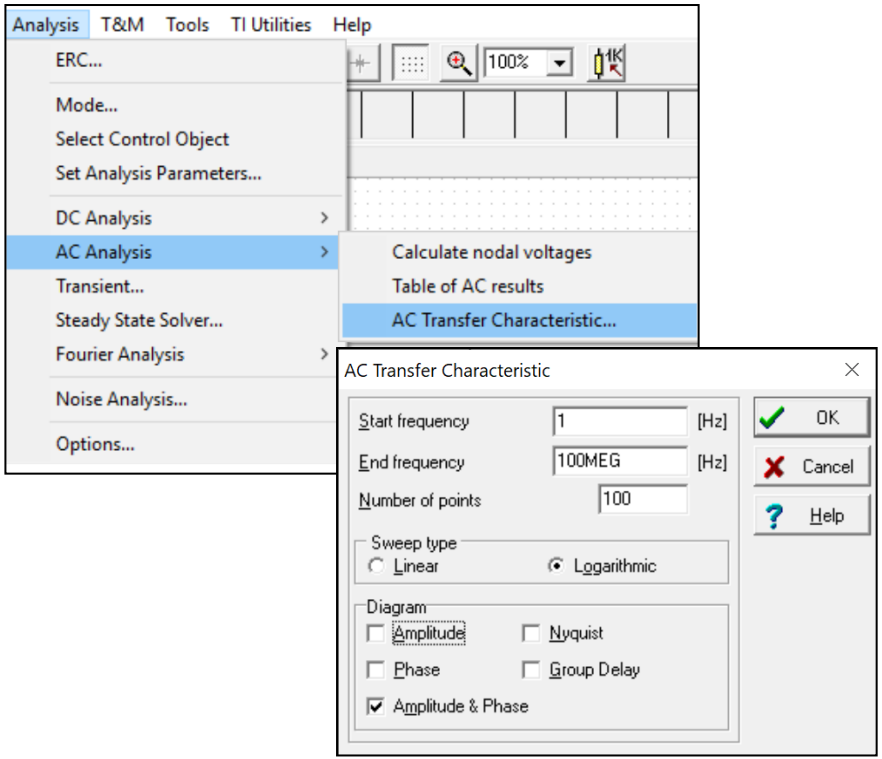


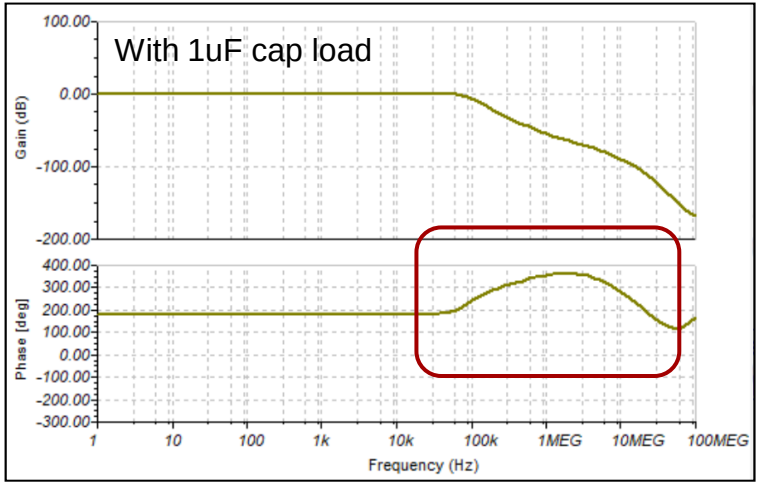






AC Analysis


Analysis
T&M
Tools
TI Utilities
Help
ERC...
Mode...
Select Control Object
Set Analysis Parameters...
DC Analysis
AC Analysis
Transient...
Steady State Solver...
Fourier Analysis
Noise Analysis...
Options...
100%
Calculate nodal voltages
Table of AC results
AC Transfer Characteristic...
AC Transfer Characteristic
Start frequency
1
[Hz]
End frequency
100MEG
[Hz]
Number of points
100
Sweep type
Linear
Logarithmic
Diagram
Amplitude
Nyquist
Phase
Group Delay
Amplitude & Phase
OK
Cancel
Help


With 1uF cap load
Gain (dB)
Phase [deg]
Frequency (Hz)
100.00
0.00
-100.00
-200.00
400.00
300.00
200.00
100.00
-300.00
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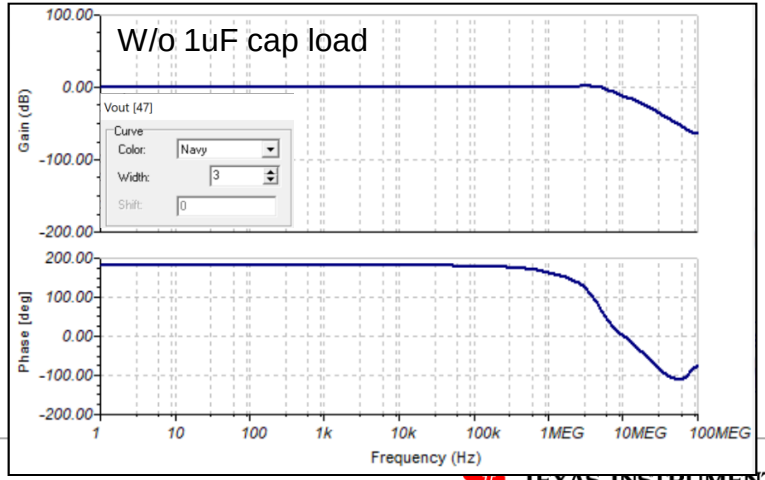
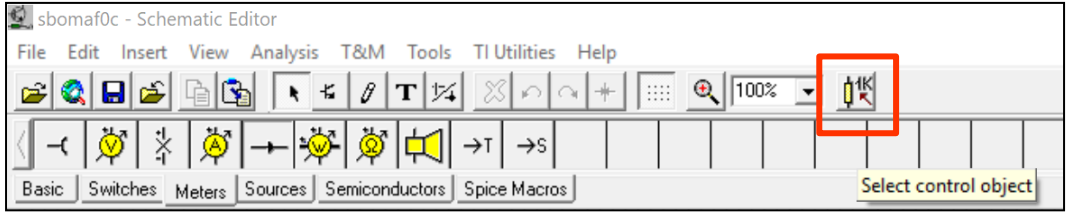
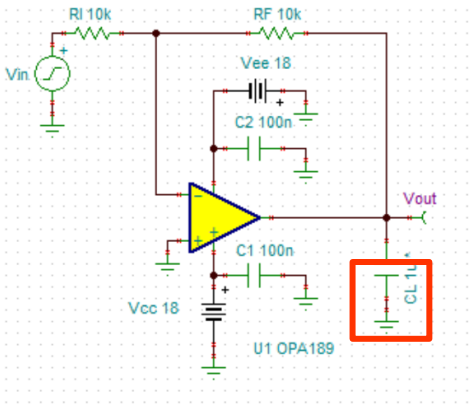
10
100
1k
10k
100k
1MEG
10MEG
100MEG

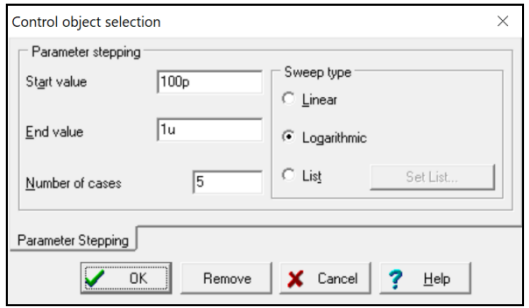

W/o 1uF cap load
Gain (dB)
Phase [deg]
Frequency (Hz)
Vout [47]
Curve
Color:
Navy
Width:
3
Shift:
0
100.00
0.00
-100.00
-200.00
200.00
1
10
100
1k
10k
100k
1MEG
10MEG
100MEG

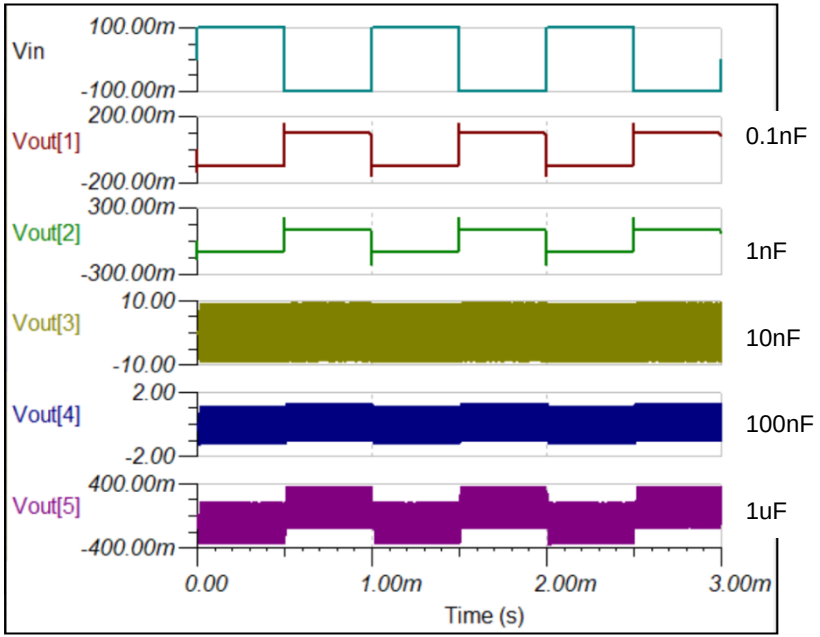
Parameter-stepping

Parameter-stepping – Transient Analysis

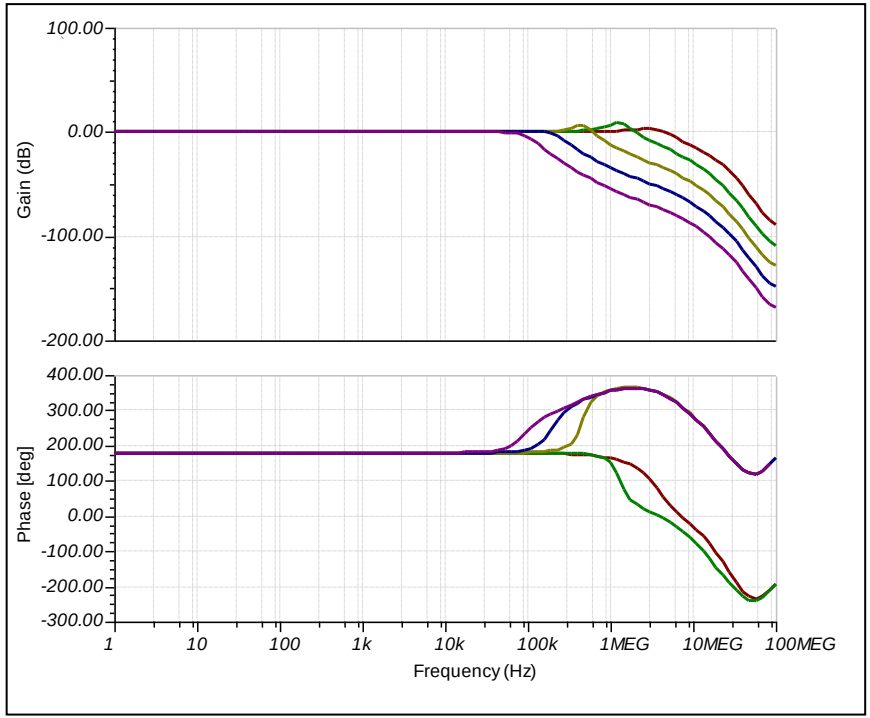


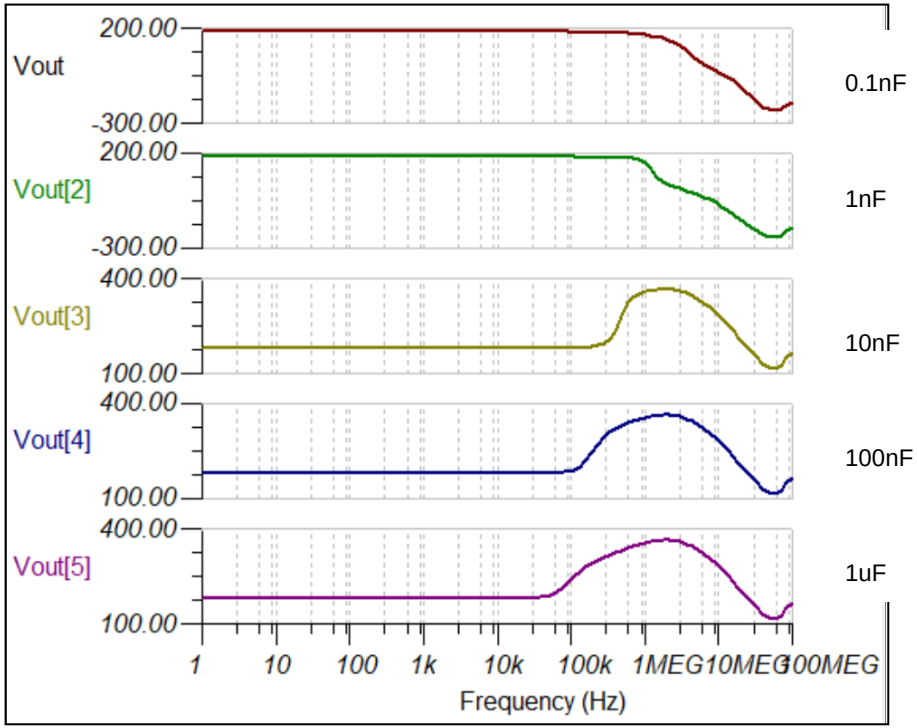






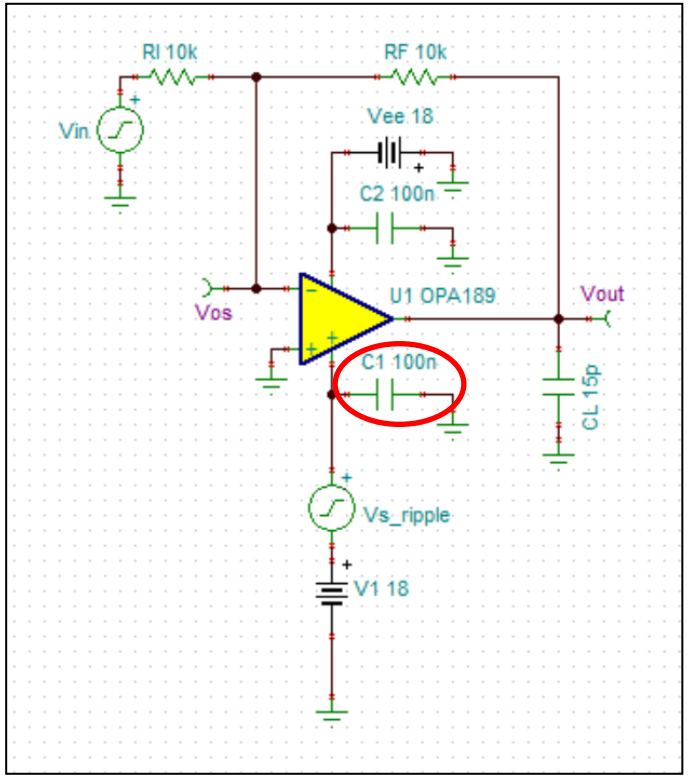
Parameter-stepping – AC Analysis





TINA Tips

Supply Noise and Decoupling Cap



PSRR at high frequency:
assume 10mVpp ripple:
40dB=> 10mV/V => 0.1mV (Vos_PSRR)
20dB => 100mV/V = 1mV
10dB=> 316mV/V => 3.16mV

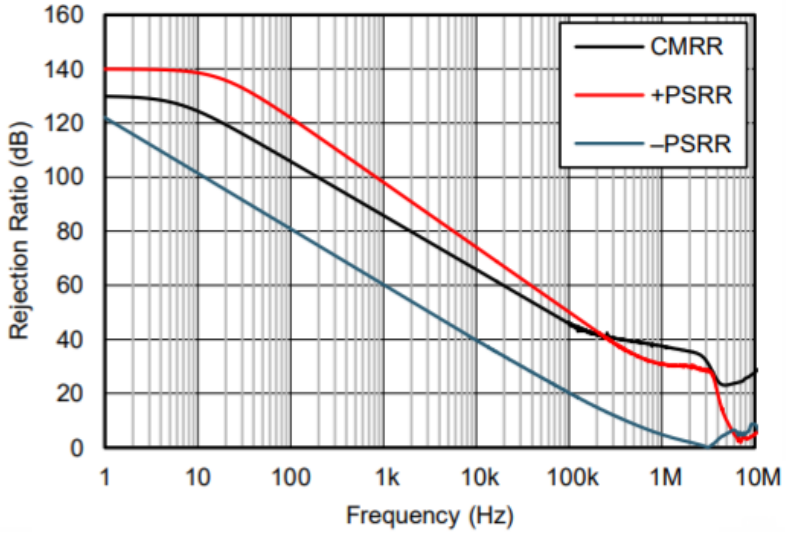


Figure 14. CMRR and PSRR vs Frequency

Put Real Capacitor in TINA

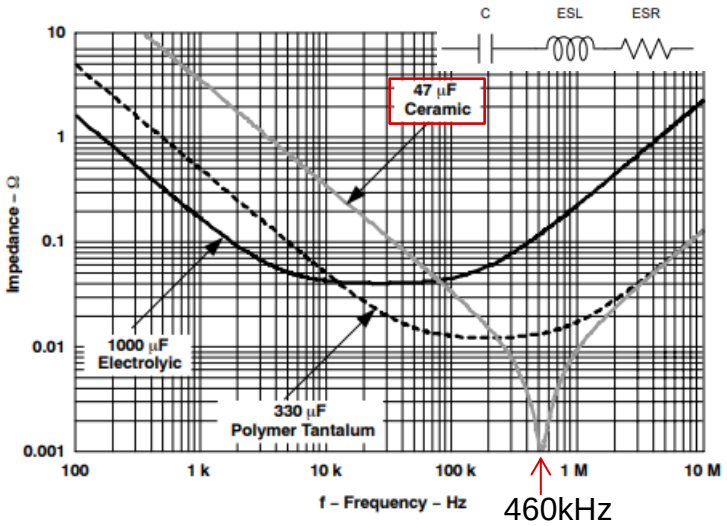
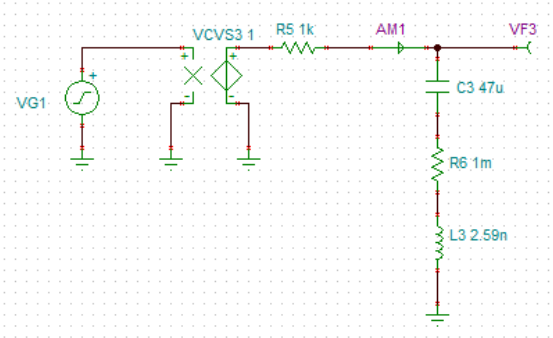
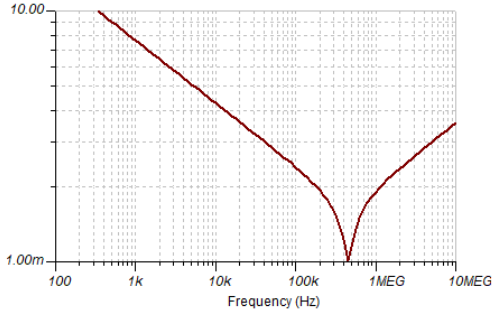


Figure 4. Capacitor Impedance Characteristics

f = 1/(2 x pi x rt(LC))		
L = 1/(sqrt(2 x pi x f) x C)		
f	4.60E+05	Hz
C	4.70E-05	F
L	2.549571	nH



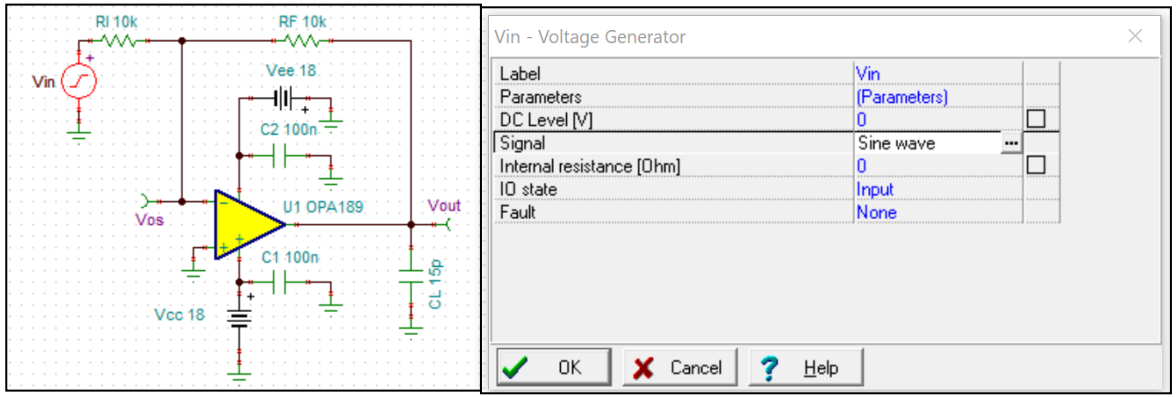


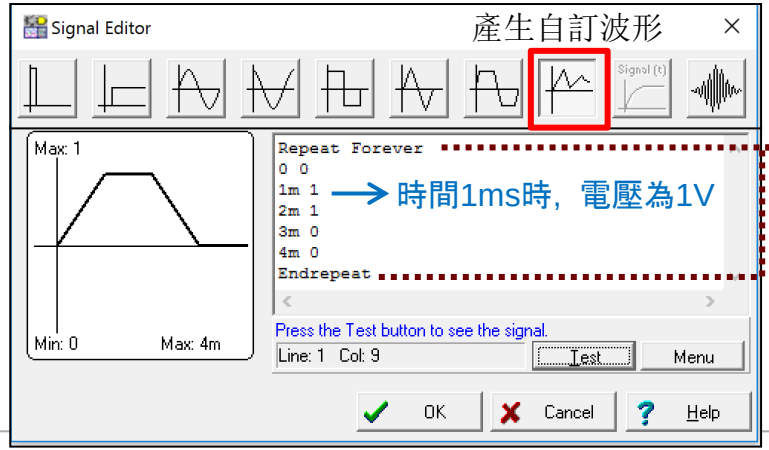
C Simulation 2.TSC

How to Choose a TPS7B67xx-Q1 Output Capacitor
http://www.ti.com/lit/an/slva759/slva759.pdf

Input and Output Capacitor Selection
http://www.ti.com/lit/an/slta055/slta055.pdf

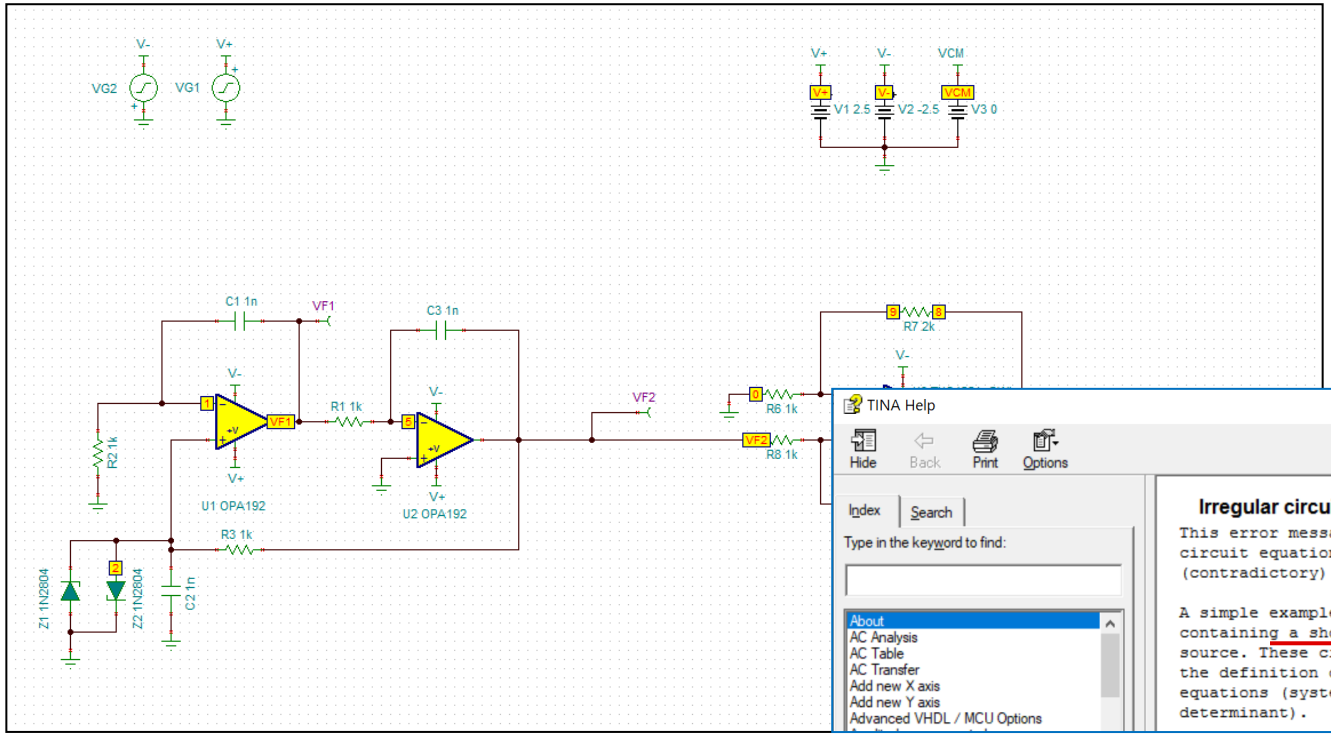
Function Generator

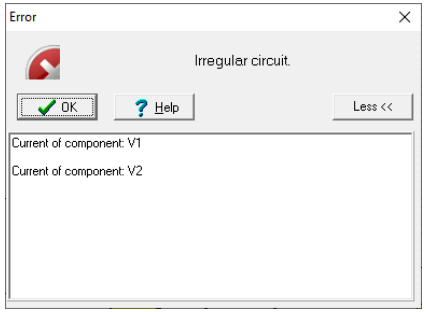




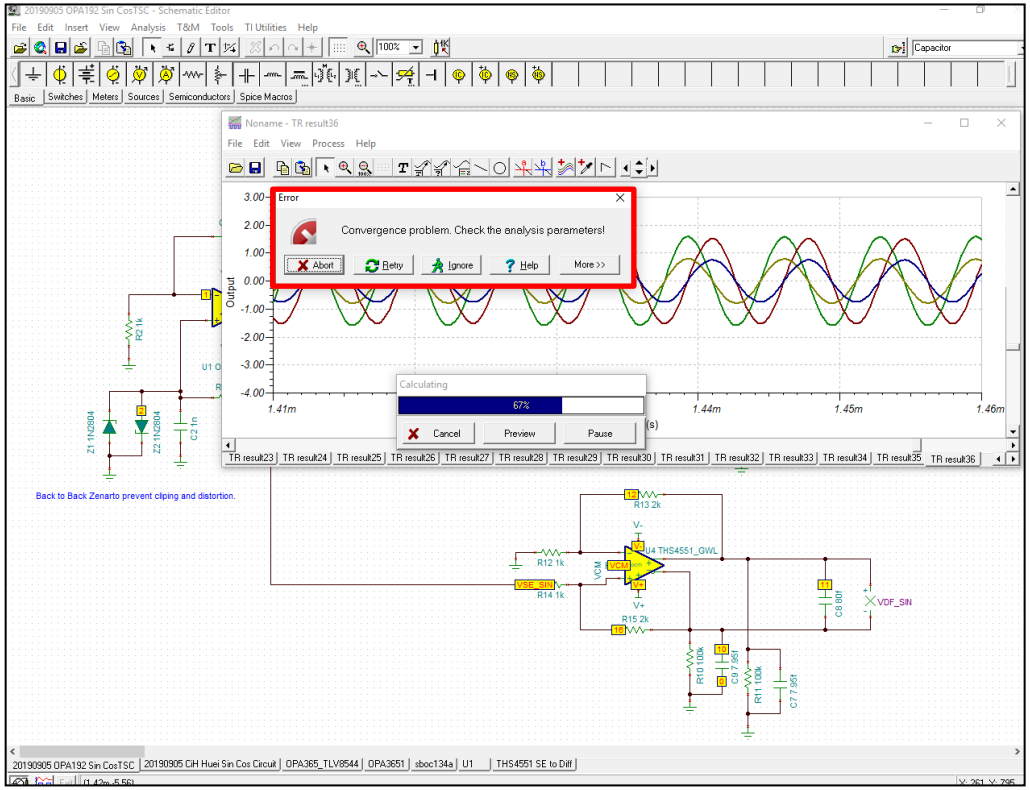
重複波形

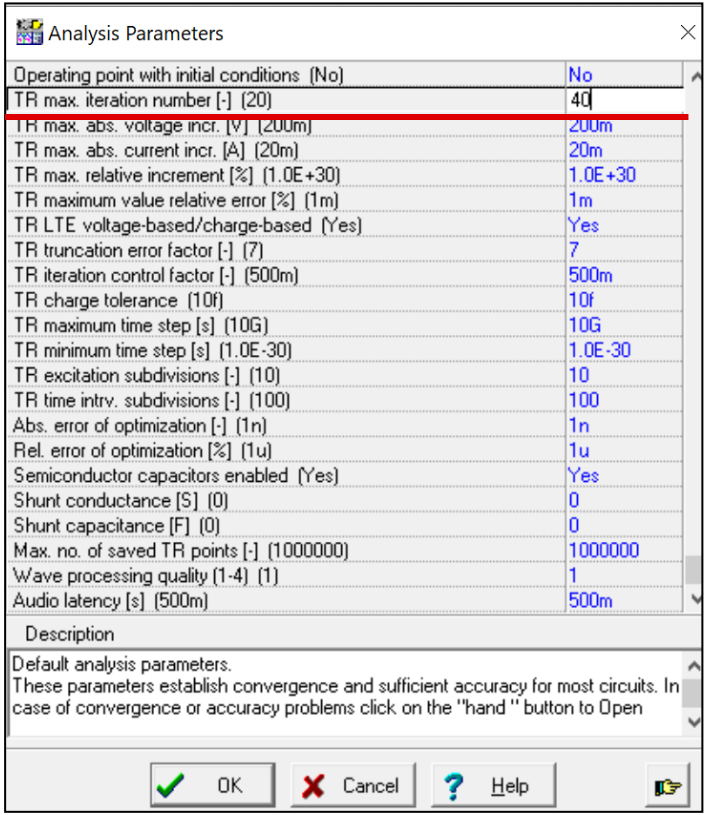
Error – Irregular Circuit





Error – Convergence Problem





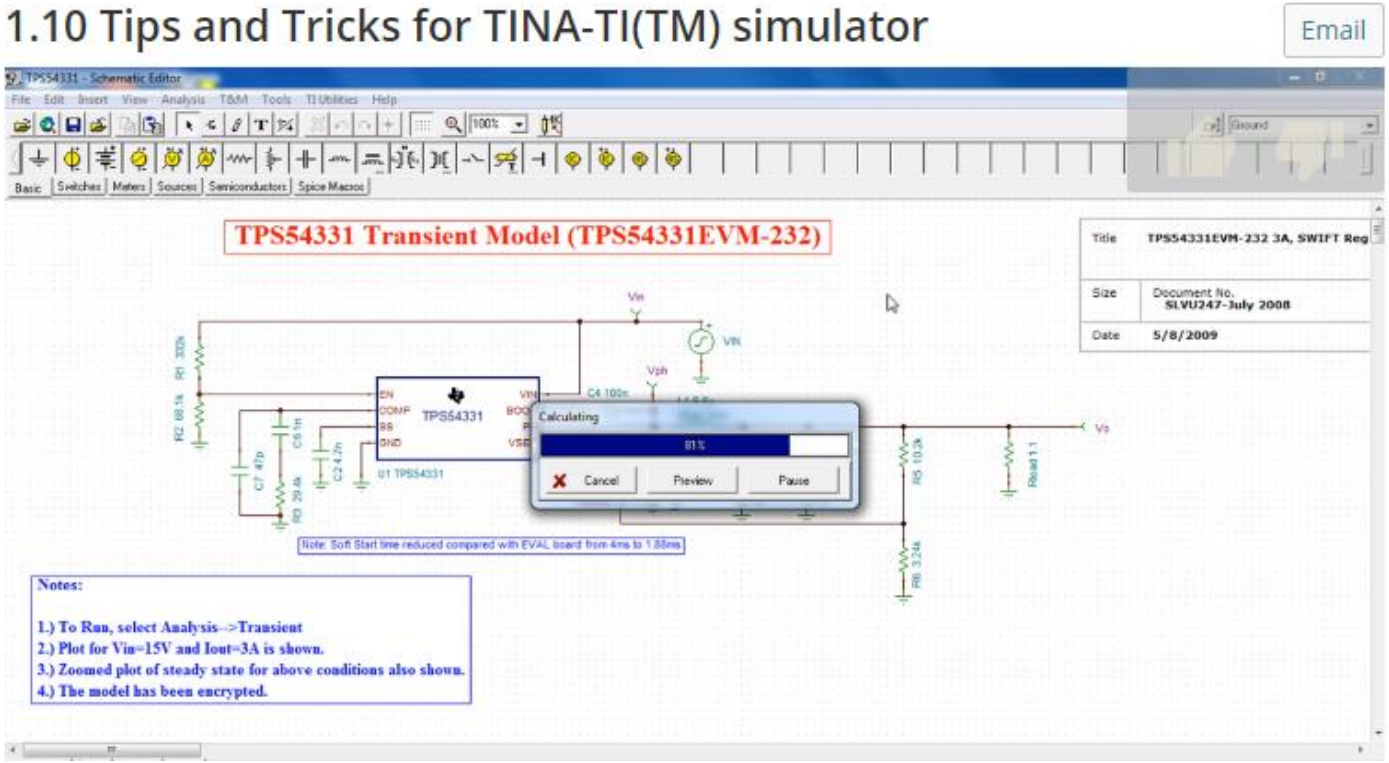
TINA-TI Training Videos

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



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.