New Product Update:
General Purpose Op amps and PSpice® for TI

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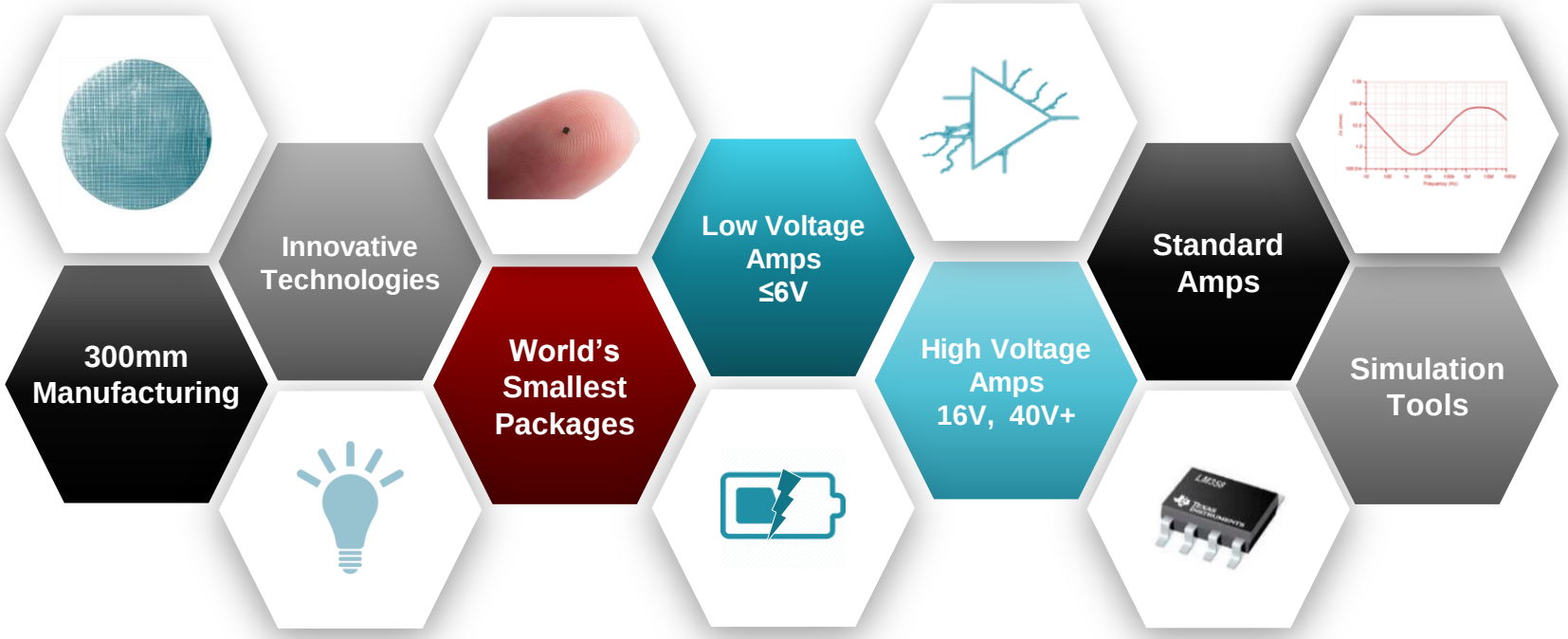
9/17/20

General Purpose Amplifier Agenda

Industry's largest portfolio of amplifiers that are **cost-optimized** and **simple to use** for any application



TI Amplifiers Investment Areas

Linear Amplifiers

RF - Amps

Products
- RF Amps
- RF Power Detectors
- RF TIAs

Focus Markets
- Communications
- Wireless Infrastructure
- Radar
  - Military and Aerospace
- Industrial
  - Test & Measurement

High Speed

Products
- >50 MHz GBW Op Amps
- Fully Differential Amplifiers
- Transimpedance Amplifiers
- Line Drivers

Focus Markets
- Industrial
  - Grid Infrastructure
  - Test & Measurement
  - Aerospace and Defense
  - FA&C
- Automotive
  - ADAS
  - HEV/EV

Comparators

Products
- Low Power Comparators
- High Speed Comparators
- Low Voltage Comparators
- High Voltage Comparators

Focus Markets
- IoT
- Building Automation
- Factory Automation
- Consumer Electronics
- Automotive

Precision

Products
- <1mV V_{OS}
- Class A/B Audio Amps
- Instrumentation Amps
- Power Amps
- XTRs | DIFF Amps | LOGs

Focus Markets
- Industrial
  - Factory Automation
  - Test & Measurement
  - Medical
- Professional Audio
- Automotive

General Purpose

Products
- >1mV V_{OS} Amps
  - Low Voltage Gen Purpose
  - High Voltage Gen Purpose
  - Industry Standard Amps
    - HV & LV
  - AEC Q100 Amps

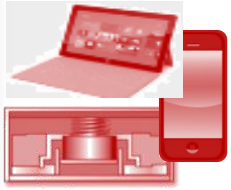
Focus Markets
- Industrial
  - Building Automation
  - Factory Automation
  - Appliances
  - Grid Infrastructure
- Automotive
- Consumer Electronics
- Communications

Switching Amplifiers

Low Power Audio and Actuator

Products
- Low Power Audio
- Low Power Haptics
- Industrial Piezo Drivers

Focus Markets
- Personal Electronics:
  - Smartphones
  - Tablets
  - Wearables
  - Portable Speakers
- Automotive Haptics



Mid Power Audio Amplifiers

Products
- Mid Power Audio Amps
- Automotive Audio Amps
- Mid Power Haptics
- High Power Amps
- Automotive High Power

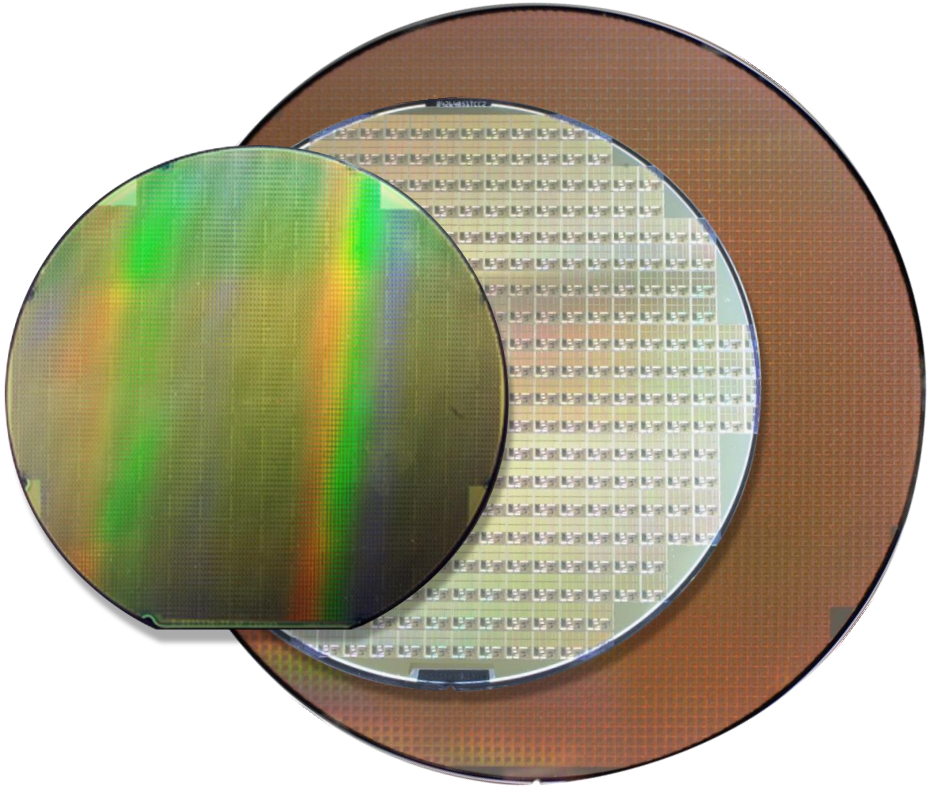
Focus Markets
- Automotive:
  - Telematics
  - Digital Cockpit
  - External Amplifier
- TV & Soundbars
- Smart Speakers
- Building Automation
- Multimedia Devices

Texas Instruments

Wafer Sizes – 300mm Manufacturing

150mm, 200mm, 300mm

- Increased chips per wafer to expand TI's high volume analog production
  - 125% more area than 200mm
  - 300% more area than 150mm
- Multi-fab support to maintain supply continuity
- Assembly sites with 300mm wafer capability



Roughly 6", 8", and 12" in diameter

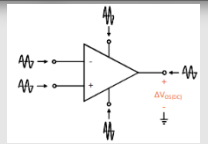
EMI Filter Overview

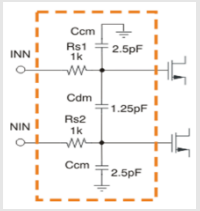
TLV90xx | OPAx990 | LM358B

Overview

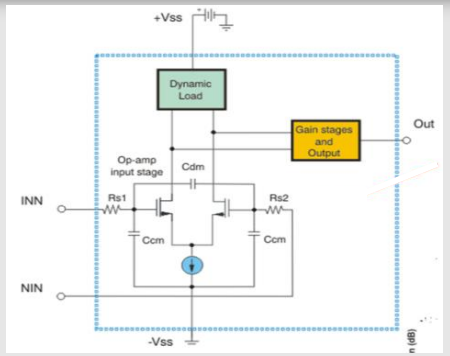
- Today's applications are using denser component spacing, placing mixed-signal analog and digital devices even closer together. EMI can have detrimental effects in these systems.
- TI's amplifiers with EMI Filter inside incorporates an internal input low-pass filter that reduces the amplifiers response to EMI. Both common-mode and differential mode filtering are provided by this filter. The filter is designed for a cutoff frequency outside the bandwidth of the op amp with a roll-off of 20dB per decade.
- Op amps with integrated EMI Filter have better EMI immunity and are more robust to noise-sensitive application, such as motors and switching power supplies.

Implementation



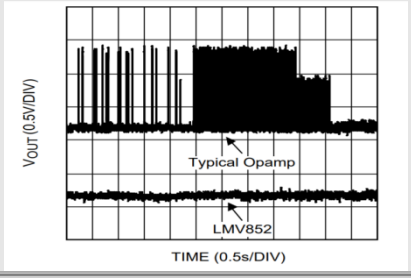


Integrated



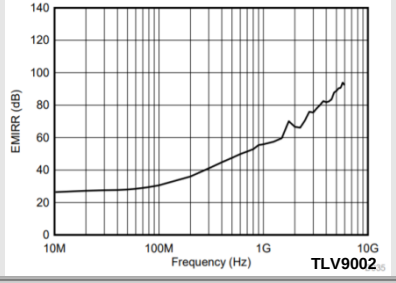
Problems solved

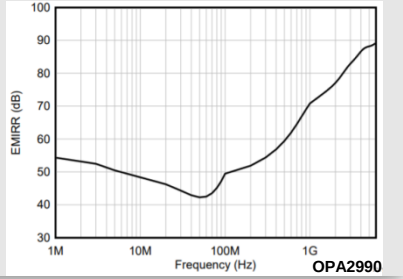
Comparing EMI Robustness



- ✓ **Improved** EMI immunity of an operational amplifier over a broad frequency spectrum extending from 10 MHz to 6 GHz.
- ✓ **Reduce** the effects of EMI from sources such as wireless communications and densely-populated boards with a mix of analog signal chain and digital components.

Device Example: EMIRR vs Frequency





Industry Leading in Tiny Amps

Options for Industrial & Auto

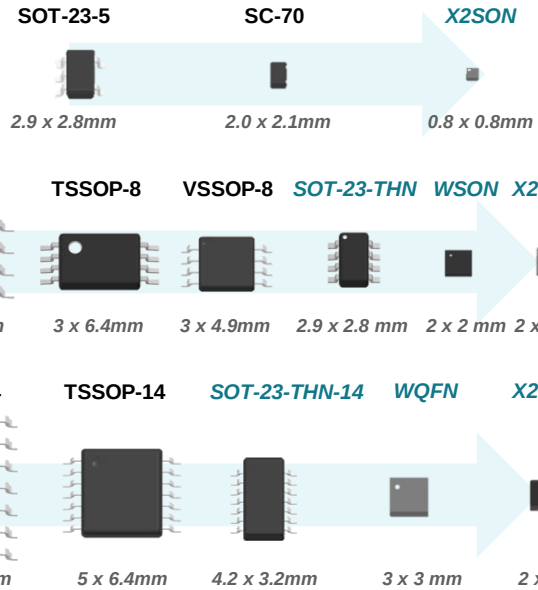
Easy manufacturing for customers

Broad product portfolio

Evolution in size – more functions in smaller spaces

Competitive Edge in Small Packages

- **World's smallest amplifiers** — *Down to 0.8 x 0.8mm (1ch), 1.5 x 2mm (2ch), 2 x 2mm (4ch)*
- **Smallest leaded packages** — *Meets needs of space-constrained and manufacturing-constrained industrial & automotive designs*
- **Layout compatible options with industry standard packages** — *Satisfies second-source requirements for commodity devices*



Package dimensions include leads

DDF Package

leaded SOT23 package | 8 pins | 0.65mm lead pitch

Available Now!

Features

- Body Size — ***1.6 mm x 2.9 mm***
- Body + Leads Size — 2.8 mm x 2.9 mm
- Lead Pitch — 0.65 mm
- Package Height — 1.1 mm
- Identical lead pitch as TSSOP, VSSOP

TLV9002	LMV358A	OPA2991	TLV9162
TLV9052	LM358B	OPA2992	TLV9302
TLV9062	LM2904B	TLV9102	TLV9352
LM358LV	OPA2990	TLV9152	TLV9362

Applications

- Electronic Point of Sale (EPOS)
- Building Automation
- Factory Automation & Control
- Motor Drives
- Digital Camera and Lenses
- Portable Speakers

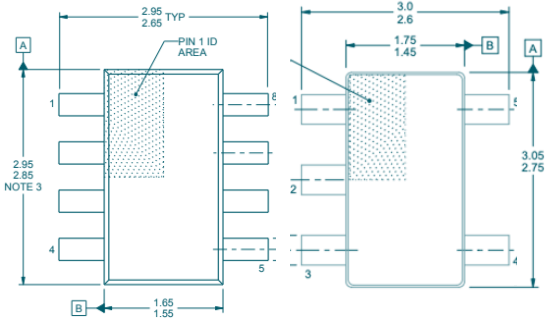
Benefits

- Smallest *leaded* dual package in Amoeba family enables a reduced PCB area without requiring QFN manufacturing techniques
- 0.65mm pin pitch allows for dual-layout techniques with industry standard SOIC, TSSOP, and VSSOP packages

www.ti.com/smallamp-designguide

www.ti.com/smallamps

Same Size as DBV (SOT23-5)



DGK to DDF
VSSOP to SOT23-8

PW to DDF
TSSOP to SOT23-8

Texas Instruments

New Devices Package Options

Channel	Package Name	Designator (pins)		Body Size (mm)	Package Size (mm)	Shutdown	Industry Standard	Small Package
1	X2SON	DPW	5	0.8 x 0.8	Same			✓
	SOT553	DRL	5	1.6 x 1.2	1.6 x 1.6			✓
	SC70	DCK	5	2.0 x 1.25	2.0 x 2.1		✓	
	SOT23	DBV	5/6	2.9 x 1.6	2.9 x 2.8	✓	✓	
2	X2QFN	RUG	10	2.0 x 1.5	Same	✓		✓
	WSON	DSG	8	2.0 x 2.0	Same			✓
	SOT23-THIN	DDF	8	2.9 x 1.6	2.9 x 2.8		✓	✓
	VSSOP	DGK DGS	8/10	3.0 x 3.0	3.0 x 4.9	✓	✓	
	TSSOP	PW	8	3.0 x 4.4	3.0 x 6.4		✓	
	SOIC	D	8	4.9 x 3.91	4.9 x 6.0		✓	
4	X2QFN	RUC	14	2.0 x 2.0	Same			✓
	WQFN	RTE	16	3.0 x 3.0	Same	✓		✓
	SOT23-THIN	DYY	14	5.8 x 1.6	5.8 x 2.8		✓	✓
	TSSOP	PW	14	5.0 x 4.4	5.0 x 6.4		✓	
	SOIC	D	14	8.65 x 3.91	8.65 x 6.0		✓	

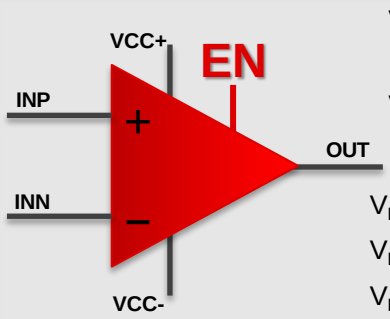
Shutdown Overview

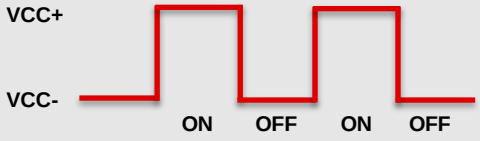
TLV900xS | TLV905xS | TLV906xS | OPAx990S | OPAx991S

Overview

- As products require longer battery life, the need for lower power solutions is increasing. Typically, low I_Q amplifiers have high noise specs and low GBP. If these are key specs for your system, using a shutdown amplifier is a solution.
- By using a logic signal to turn the amplifier off between readings, the system level IQ is reduced significantly. Therefore one could utilize a higher GBW, lower noise amplifier to obtain the required info. It's important to consider SHDN enable and disable times. Typically they are proportional to GBW of the device.
- Aside from the obvious power savings, putting the amplifier into shutdown also provides a know output state of high-Z. This can be useful in applications where safety is key, such as medical products or mission-critical applications.

Implementation



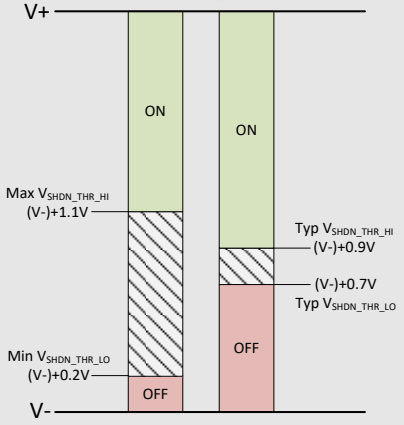


Enable Pin Power Cycling

V_{EN} = NC ➡ Amplifier Enabled

V_{EN} > (Vcc-)+0.9V ➡ Amplifier Enabled

V_{EN} < (Vcc-)+0.7V ➡ Amplifier Disabled



Problems solved

Pin out difference

One Extra pin for Single

Two Extra pins for Dual, Quad

Advantage

- ✓ Saves Power
- ✓ CMOS logic compatible
- ✓ Default Power ON - NC Acceptable

Device Example

Specifications	TLV900xS w/ Shutdown	TLV313 w/o Shutdown
$\overline{SHDN}$ pins Enable	I_Q=0.5uA	I_Q=65uA
$\overline{SHDN}$ pins Disable	I_Q=60uA	I_Q=65uA
Total IQ with 10% Duty Cycle	I_Q=6.45uA	I_Q=65uA

General Purpose Amps | Roadmap Overview

Production Sampling

Low voltage
(VDD < 7V)

- TLV900x 1MHz — *1 MHz*
- TLV906x 10MHz — *10MHz*
- TLV904x 350kHz, 10uA — *350 kHz – Low Iq*
- TLV905x 5MHz, 15V/us — *5MHz– High Slew Rate*
- OPAx375 10MHz 3.1nV/√Hz — *10 MHz - Low noise*

High voltage
(VDD > 7V)

40V	16V
OPAx990 40V, 1MHz, 1.5mV, RRIO TLV930x 40V, 1MHz, 2.5mV, RRO	TLV910x 16V, 1MHz, 1.5mV, RRIO
1 MHz	*1 MHz*
OPAx991 40V, 4.5MHz, 0.675mV, RRIO TLV935x 40V, 3.5MHz, 1.8mV RRO	TLV915x 16V, 4.5MHz, 0.675mV, RRIO
3-5 MHz	*3-5 MHz*

Standard amps
(5V and 36V)

5V standard amplifiers

LM321LV Single
LM358LV Dual
LM324LV Quad

Optimized for 5V systems

36V standard amplifiers

LM358B 1MHz, Dual -40 – 85C	LM2904B 1MHz, Dual -40 – 125C	TL06xH TL07xH TL08xH 3MHz, -40–125C
Industry Standard Bipolar		*JFET/CMOS*

Catalog LV Roadmap (1.8V-5.5V)

Production | Sampling

General

OPAx313
TLVx313/TLV600x → TLV900x/S | 1MHz
RRIO, 1.5mV, 60µA

OPAx316
TLVx316 → TLV906x/S | 10MHz
RRIO, 1.5mV, 0.75mA

Differentiated

OPAx347
OPAx348 → TLV904x/S | 350kHz
1.2V Opp. RRIO, 2.2mV, 10uA
Lower I_Q

OPAx314
TLVx314 → TLV905x/S | 5MHz
RRIO, 15V/µs, 0.33mA
Higher Slew Rate

OPAx375 | 10MHz
RRO, 0.5mV, 3.1nV/√Hz

TLV674x | 10MHz
RRO, 1.5mV, 3.1nV/√Hz
Lower Noise

TLV906x: TLV9061 / TLV9062 / TLV9064

10MHz | 300µV typ| 1.8V - 5.5V | World's Smallest Amplifier

Features

- ***0.8mm x 0.8mm package***
- Rail-to-Rail Input and Output
- Wide Bandwidth — 10 MHz
- Quiescent Current — 538 µA (typ)
- Low Offset — ***1.6 mV (max)***
- Very Low Noise — ***10 nV/√Hz***
- Supply Voltage — 1.8 V to 5.5 V
- Extended Temp Range — -40C to 125C
- EMI Input Filtered

Benefits

- ***World's smallest amplifier package enables robust performance in tight places***
- Rail-to-rail and wide voltage supply capabilities allow for a versatile range of low voltage applications
- High performance features such as high GBW, low offset, low noise, and a varying supply voltage operation ease the burden of selection of finding an all-around op amp suitable for a variety of applications.
- Low noise enables use in high dynamic range applications
- EMI filtering results in high EMIRR

Applications

- E-bike Battery management unit
- Currency counters
- Sensors and Signal Conditioning
- ADC Input Driver amplifier
- Medical Instrumentation

- Low Side Current Sensing
- PCB Layout Guidelines
- Design and Manufacture with TI's X2SON Packages

TLV900x: TLV9001 / TLV9002 / TLV9004

RRIO | 1 MHz | 1.8V - 5.5V CMOS Amplifier for Cost-Sensitive Applications

Features

- Rail-to-Rail Input and Output
- Wide Bandwidth — ***1 MHz***
- High Cap-load Drive — 100 pF
- Low Offset — ***1.5 mV (max)***
- Very Low Noise — 26 nV/√Hz @ 1kHz
- Quiescent Current — 60 µA (typ)
- Supply Voltage — 1.8 V to 5.5 V
- Unity Gain Stable
- EMI Input Filtered

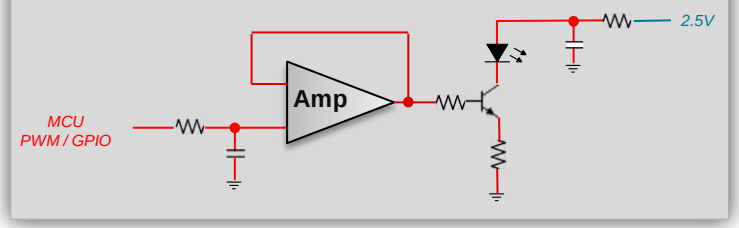
Benefits

- Rail-to-rail and wide voltage supply capabilities allow for a versatile range of low voltage applications
- High bandwidth-1 MHz supports high-speed signal processing
- Higher cap load drive results in robust solutions w.r.t stability
- Low noise enables use in high dynamic range applications
- EMI filtering results in high EMIRR

Applications

- E-bike Battery management unit
- Currency counters
- Sensors and Signal Conditioning
- ADC Input Driver amplifier
- Medical Instrumentation

Linear IR LED Drive with Temperature Compensation



TLV904x: TLV9041 / TLV9042 / TLV9044

RRIO | 350 kHz | 1.2 V – 5.5 V Low Iq, CMOS Amplifier

Features

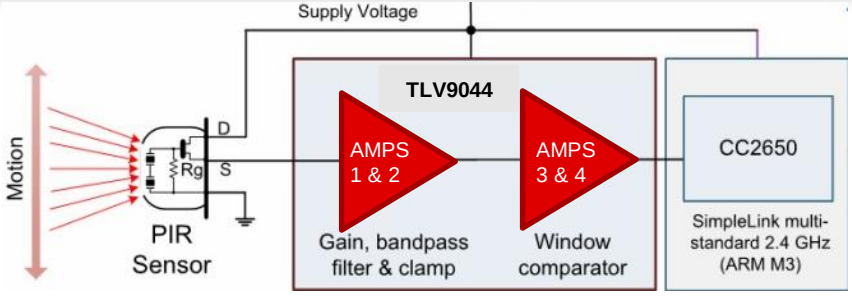
- Rail-to-Rail Input and Output
- Quiescent Current ***10 µA (typ)***
- Wide Bandwidth ***350 kHz***
- High Cap-load Drive 75 pF
- Low Offset ***3 mV max*** *375 uV typ*
- Low Noise 82 nV/√Hz @ 1kHz
- Supply Voltage ***1.2 V to 5.5 V***
- Unity Gain Stable
- EMI Input Filtered

Benefits

- High bandwidth 350kHz @ Low Quiescent current
- Rail-to-rail and 1.2V minimum voltage supply capabilities allow for a versatile range of low voltage applications
- Utilizes innovative output stage to provide high cap-load drive improves stability across design parameters
- Low noise for low power amplifiers enables use in high dynamic range applications
- EMI filtering results in high EMIRR

Applications

- Smoke Detectors
- Motion Detectors
- Wearables
- Sensor Signal Conditioning
- Personal Electronics



TLV905x: TLV9051 / TLV9052 / TLV9054

RRIO | 5 MHz | 1.8V - 5.5V CMOS Amplifier for Cost-Sensitive Applications

Features

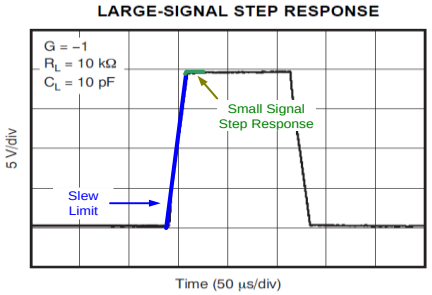
- Rail-to-Rail Input and Output
- Wide Bandwidth ***5 MHz***
- Low Offset +/- 0.35mV (typ)
- Very Low Noise 16 nV/√Hz @ 1kHz
- Quiescent Current ***330 µA (typ)***
- Fast Slew Rate ***15 V/µS***
- Supply Voltage 1.8 V to 5.5 V
- Internal RFI & EMI Filter on supply rails
- Extended Temp Range -40ºC to 125ºC

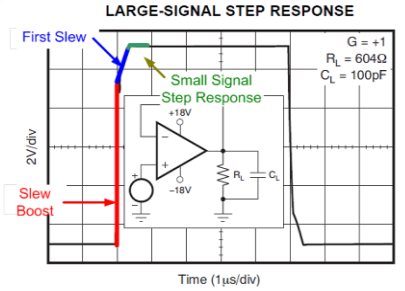
Applications

- HVAC: Heating, Ventilating, and AC
- Photodiode Amplifier
- Current Shunt Monitoring for DC Motor Control
- White Goods (Fridges, Washer/Dryer, Large Appliances)
- Low-Side Current Sensing

Benefits

- RRI allows operation down to 1.8V providing ability to function slightly below the rail
- High bandwidth-5MHz supports faster settling time compared to lower GBW amplifiers
- Slew boost technology provides better transient performance rapid changing inputs
- Low noise enables lower SNR in high-gain sensor signal conditioning applications
- RC Filtering supply improves EMIRR





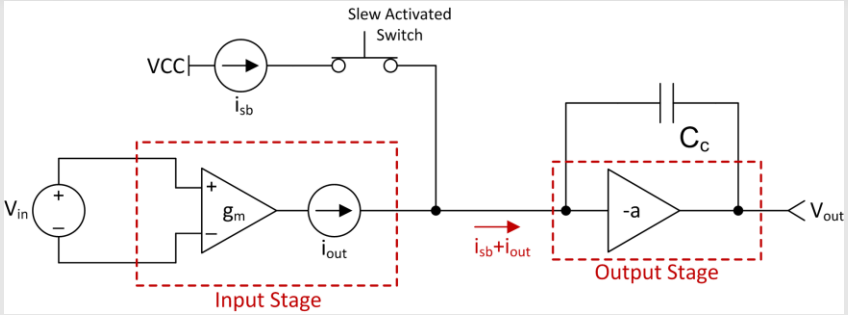
Slew Boost Overview

TLV905x | OPAx991 | TLV915x | TLV935x

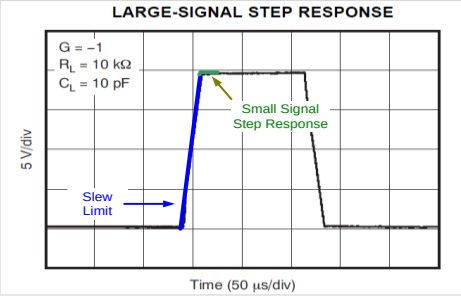
Overview

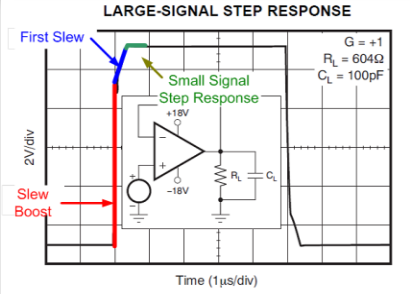
- A typical amplifier has an input stage and an output stage with a compensation capacitor (C_c). Its slew rate is determined by the maximum current (i_{out}) available to charge C_c.
- TI's Slew Boost topology senses large signal inputs and switches in another current source (i_{sb}) to increase the amount of current available for charging C_c.
- Slew boosted op amps have better transient performance in applications with rapidly changing inputs or discontinuous signals such as motor control and current sensing.

Implementation



Problems solved





- **Improved** slew rate performance for a given device bandwidth and current consumption.
- **Decreased** settling time for large signal inputs

Device Example:

Specifications	Slew Boosted TLV905x	Non-Slew Boosted OPAx377
Slew Rate (V/µs)	15	2
GBW	5 MHz	5.5 MHz
Supply Current (I_q)	330 µA	1050 µA

OPAx375: OPA375 / OPA2375 / OPA4375

RRO | 10MHz | 1.8V – 6.0V | Low Noise, CMOS Amplifier

Features

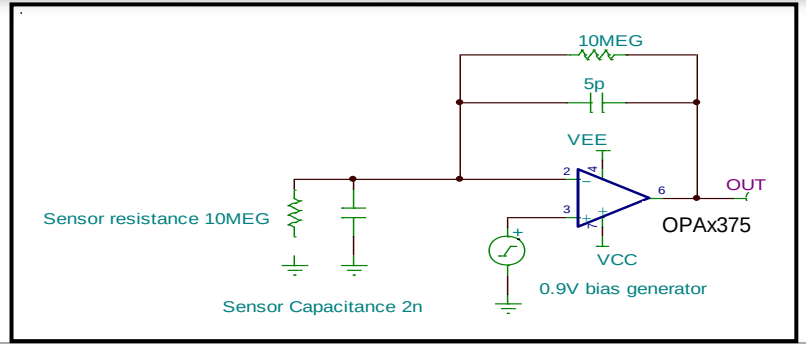
- Very Low Noise — ***3.7 nV/√Hz @ 10k***
- Wide Bandwidth — ***10 MHz***
- High Cap-load Drive — 50 pF
- Low Offset — ***500 µV(max)***
- Quiescent Current — 980 µA (typ)
- Supply Voltage — 1.8 V to 6.0 V
- Max Vos Drift — 2.0 µV / °C
- Rail-to-Rail Output
- Unity Gain Stable

Benefits

- Low Noise enables high gain configurations to amplify weak sensor signals
- High bandwidth-10MHz supports high-speed signal processing
- Higher cap load drive results in robust solutions w.r.t stability
- Low noise enables lower SNR in high-gain sensor signal conditioning applications
- EMI filtering results in high EMIRR

Applications

- Smoke Detectors
- Infotainment Audio applications
- Sensors and Signal Conditioning
- ADC Input Driver amplifier
- Medical Instrumentation



TLV674x: TLV6741 / TLV6742 / TLV6744

RRO | 10MHz | 1.8V - 5.5V Low Noise, CMOS Amplifier

Features

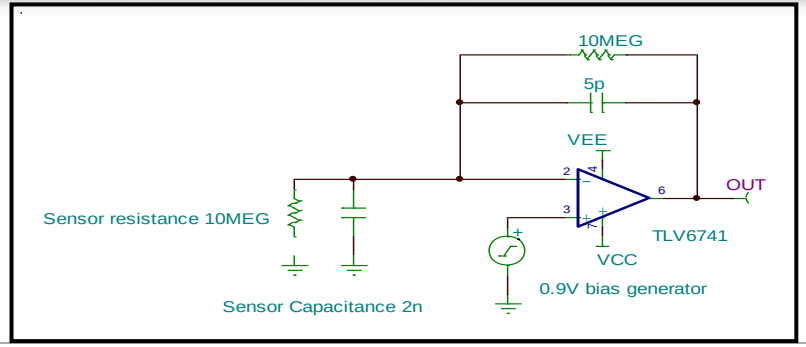
- Very Low Noise — ***3.7 nV/√Hz***
- Wide Bandwidth — ***10 MHz***
- High Cap-load Drive — 50 pF
- Low Offset — ***1 mV (max)***
- Quiescent Current — 960 µA (typ)
- Supply Voltage — 1.8 V to 5.5 V
- Rail-to-Rail Output
- Unity Gain Stable
- EMI Input Filtered

Benefits

- Low Noise enables high gain configurations to amplify weak sensor signals
- High bandwidth-10MHz supports high-speed signal processing
- Higher cap load drive results in robust solutions w.r.t stability
- Low noise enables use in high dynamic range applications
- EMI filtering results in high EMIRR

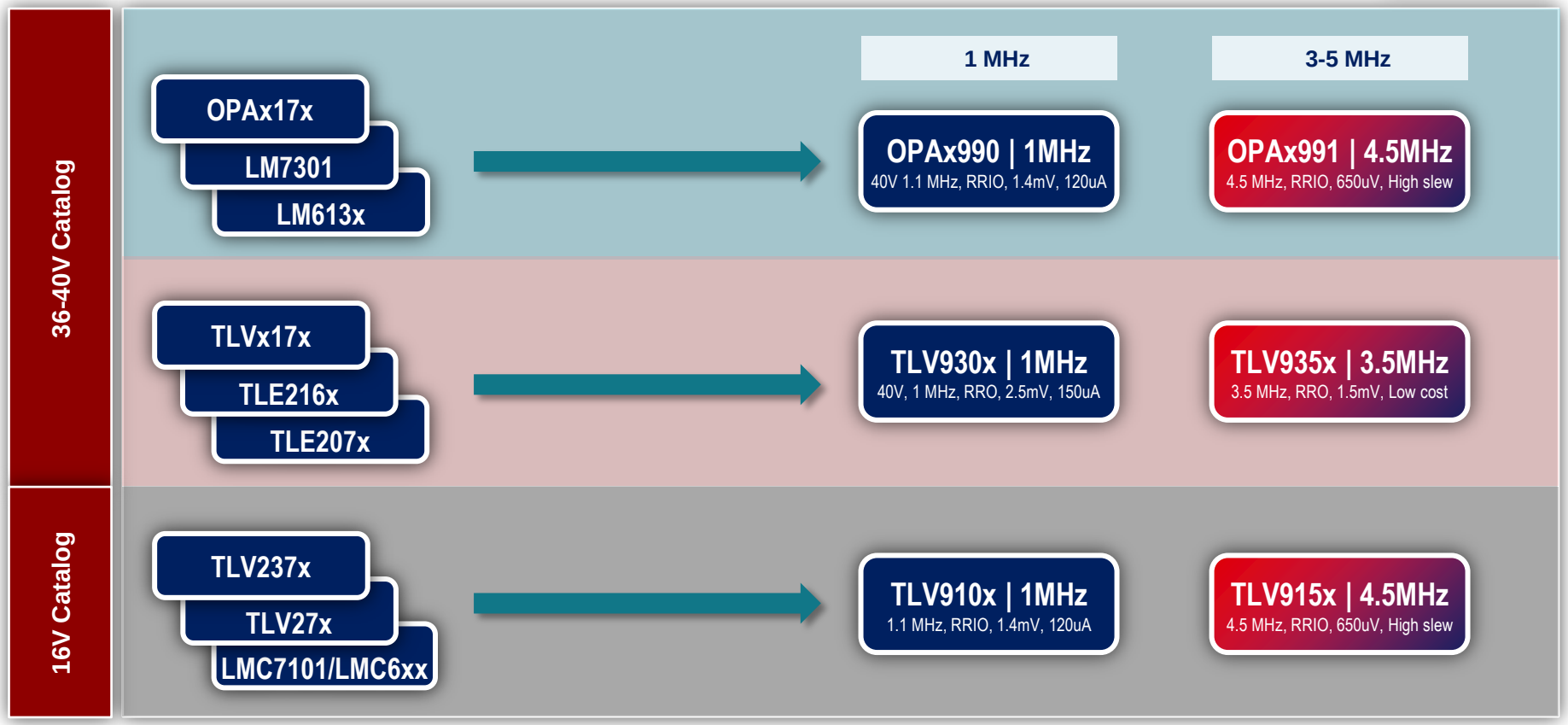
Applications

- Medical Sensor Signal Conditionings
- Microphone pre amplifiers
- Infotainment Systems
- ADC Input Driver amplifier
- Currency counters



Catalog HV Roadmap

Production | Sampling



OPAx990: OPA990 / OPA2990 / OPA4990

RRIO | 1.1MHz | 1.5mV | MUX-friendly | 2.7V - 40V CMOS amplifier

Features

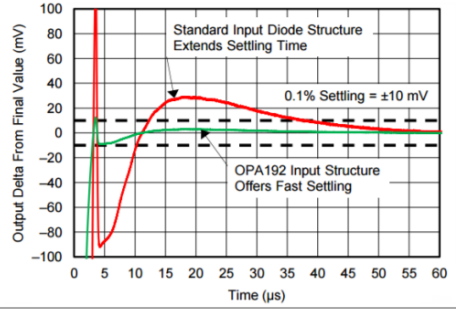
- ***Rail to rail input and output***
- Wide bandwidth — 1.1 MHz
- Low offset — ***0.3mV/1.5mV(typ/max)***
- Low offset drift — ***0.6µV/°C***
- Very low noise, THD+N — ***28 nV/√Hz, 0.00162%***
- Quiescent current — 120 µA (typ)
- High output current — ***80mA (typ)***
- High slew rate — ***4.5V/µs***
- Cap load drive — ***100pF***
- MUX-friendly inputs — ***No back-to-back diodes***
- Excellent EMIRR — ***72dB***

Benefits

- Full common-mode input range over a wide supply gives consistent performance for many configurations
- ***Strong output current and cap load drive*** with low settling time ideal for ADC-driving applications
- Low noise and ***THD+N*** improves dynamic range
- ***Industry-leading slew rate for I_Q*** enables applications with fast transients and step responses.
- EMI filtering for robust performance in noisy environments

Applications

- Optical modules and networking
- Test & measurement
- Grid infrastructure
- Industrial automation
- Industrial, telecom, and server power delivery



MUX-friendly inputs give **much faster settling time** when interfaced with MUX

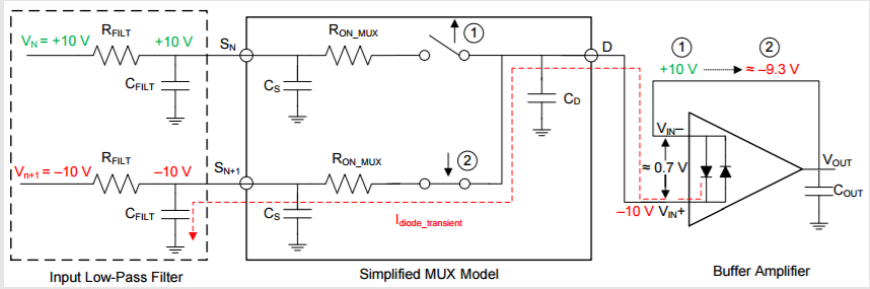
MUX-Friendly Input Overview

OPAx99x | TLV93xx | TLV91xx| OPA189 | OPA19x

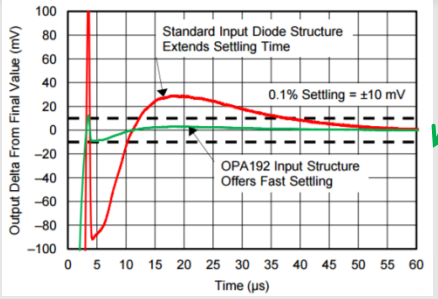
Overview

- Most high voltage amplifiers have back-to-back diodes connected between the inputs of the amplifier for front-end protection. These protection diodes introduce a significant settling time delay in multiplexed applications.
- When switching between input channels, the MUX observes a full-scale step change. This forces the input protection diodes to turn ON and draw large currents.

Settling Issues in Multiplexed Signal Chain



Problems solved



Much faster settling time when interfaced with MUX

- 16-bit, differential four-channel multiplexed DAQ system
- 400-kSPS throughput
- Differential input of ±20V
- Integral nonlinearity (INL) **< ±0.9 LSB**
- Channel-to-channel settling**< ±1.2 LSB**

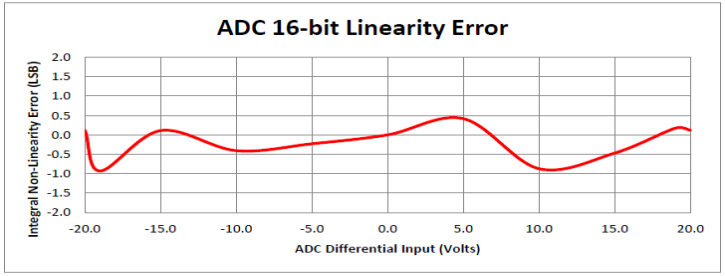


Figure 30: Measurement Data – ADC INL Plot (11 Points)

TLV910x: TLV9101 / TLV9102 / TLV9104

RRIO | 1.1MHz | 1.5mV | MUX-friendly | 2.7V - 16V CMOS Amplifier

Features

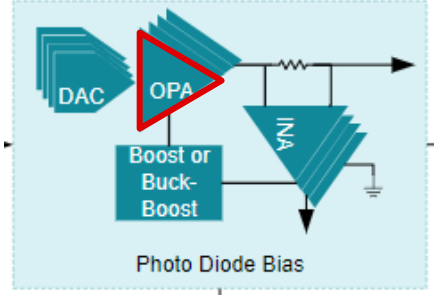
- ***Rail to Rail Input and Output***
- Wide Bandwidth — 1.1 MHz
- Low Offset — ***0.3mV (typ),1.5 mV (max)***
- Very Low Noise, THD+N — ***28 nV/√Hz, 0.0028%***
- Quiescent Current — 120 µA (typ)
- High Output Current — ***80mA (typ)***
- Cap Load Drive — ***100pF***
- High Slew Rate — ***4.5V/µs***
- MUX-Friendly Inputs — ***No back-to-back diodes***
- EMI Input Filtered

Benefits

- Full common-mode input range over a wide supply gives consistent performance for many configurations
- ***Strong output current*** and ***cap load drive*** with low settling time ideal for ADC-driving applications
- Low noise and ***THD+N*** improves dynamic range
- ***Industry-leading slew rate for I_Q*** enables applications with fast transients and step responses.
- EMI filtering for robust performance in noisy environments

Applications

- Optical modules
- Battery-powered test & measurement
- Portable and low power industrial automation
- Telecom RRU/BBU and power
- Appliances



High current output drive for photo diode or laser bias application.

TLV930x: TLV9301 / TLV9302 / TLV9304

RRO | 1MHz | 2.5mV | MUX-friendly | 4.5V - 40V CMOS amplifier

Features

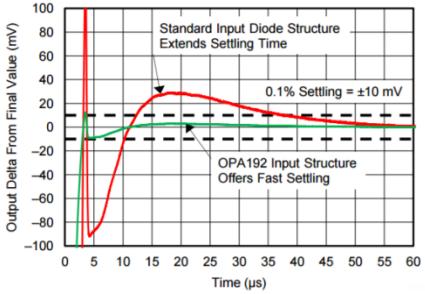
- Rail to rail output
- Wide bandwidth — 1 MHz
- Low offset — ***0.5mV(typ), 2.5 mV(max)***
- Very low noise, THD+N — ***30 nV/√Hz, 0.003%***
- Quiescent current — 150 µA (typ)
- High output current — ***60mA (typ)***
- Cap load drive — ***100pF***
- High slew rate — ***3V/µs***
- MUX-friendly inputs — ***No back-to-back diodes***
- EMI input filtered

Applications

- PSU: merchant and server power
- Power delivery: AC-DC/DC-DC
- Motor drive and closed loop control
- Low-side current sense

Benefits

- ***Strong output current*** and ***cap load*** drive with low settling time ideal for ADC-driving applications
- Low noise and ***THD+N*** improves dynamic range
- ***Industry-leading slew rate for I_Q enables*** applications with fast transients and step responses.
- EMI filtering for robust performance in noisy environments



MUX-friendly inputs give **much faster settling time** when interfaced with MUX

OPAx991: OPA991 / OPA2991 / OPA4991

RRIO | 4.5MHz | 125µV | MUX-friendly | 2.7V - 40V low noise CMOS amplifier

Features

- ***Rail to rail input and output***
- Wide bandwidth 4.5 MHz
- Low offset ***125µV (typ), 750µV (max)***
- Low offset drift ***0.3 µV/°C***
- Very low noise, THD+N ***10 nV/√Hz, 0.0002%***
- Quiescent current 575 µA (typ)
- High output current ***75 mA (typ)***
- High slew rate ***22V/µs***
- Cap load drive ***1nF***
- Excellent EMIRR ***85dB @ 1GHz***

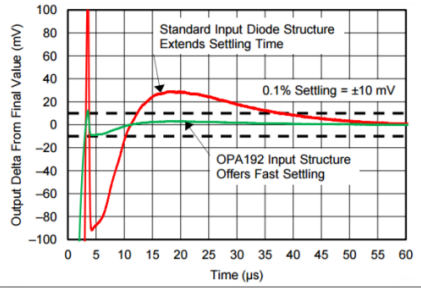
Applications

- Test & measurement
- Medical
- Grid and solar infrastructure
- Motor drive and closed loop control
- Industrial, telecom, and server power delivery

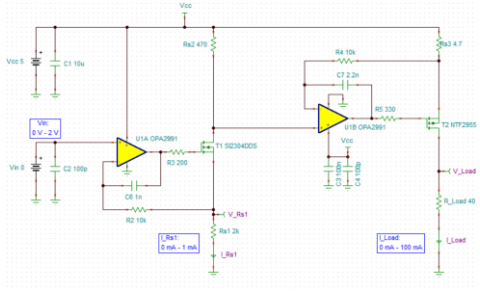
Benefits

- ***Broadest supply voltage in the industry***, rail-to-rail support offers exceptional flexibility in a range of applications
- Low offset voltage and offset voltage drift parameters allow for accurate measurements across temperature
- Low noise and THD+N enables audio/high-gain configurations
- Excellent I_Q to BW/noise ratio; suitable for portable applications
- Strong output current and cap load drive with low settling time ideal for ADC applications
- EMI filtering for robust performance in noisy environments

MUX-friendly inputs give **much faster settling time** when interfaced with MUX



Low-error **V-I converter**



TLV915x: TLV9151 / TLV9152 / TLV9154

RRIO | 4.5 MHz | 125µV | 560µA/channel | 2.7V - 16V Low Power CMOS Amplifier

Features

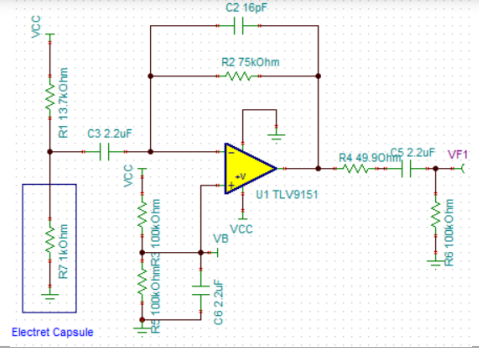
- ***Rail to rail input and output***
- Wide bandwidth — 4.5 MHz
- Low offset — ***150µV (typ), 750µV (max)***
- Very low noise, THD+N — ***11 nV/√Hz, 0.0002%***
- Quiescent current — 550 µA (typ)
- High output current — ***70 mA (typ)***
- Cap load drive — ***800pF***
- Excellent EMIRR — ***83dB @ 1GHz***

Applications

- Portable test & measurement
- Battery-powered medical
- Motor drive and closed loop control
- Industrial, telecom, and server power delivery
- Low noise, low power audio

Benefits

- Broad supply voltage, rail-to-rail support offers exceptional flexibility in a range of applications
- Low offset voltage and offset voltage drift parameters allow for accurate measurements across temperature
- Low noise and THD+N enables audio/high-gain configurations
- Excellent I_Q to BW/noise ratio; suitable for portable applications
- Strong output current and cap load drive with low settling time ideal for ADC applications
- EMI filtering for robust performance in noisy environments



Electret mic **pre-amplifier**

TLV935x: TLV9351 / TLV9352 / TLV9354

RRO | 3.5 MHz | 1.5mV | MUX-friendly | 4.5V - 40V Low Noise CMOS Amplifier

Features

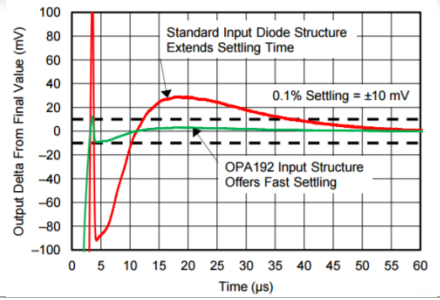
- ***Rail to rail output***
- Wide bandwidth — 3.5 MHz
- Low offset — ***0.3mV (typ), 1.8mV (max)***
- Very low noise,THD+N — ***14 nV/√Hz, 0.001%***
- Quiescent current — 800 µA (typ)
- High output current — ***60 mA (typ)***
- High slew rate — ***20V/µs***
- Cap load drive — ***1nF***
- MUX-friendly inputs — ***No back-to-back diodes***
- EMI input filtered

Benefits

- High voltage, rail-to-rail support offers exceptional flexibility in a range of applications
- Strong output current and cap load drive with low settling time ideal for ADC applications
- New ESD protection implementation removes the need for back-to-back diodes and provides faster settling.
- Low noise and THD+N enables audio applications
- EMI filtering for robust performance in noisy environments

Applications

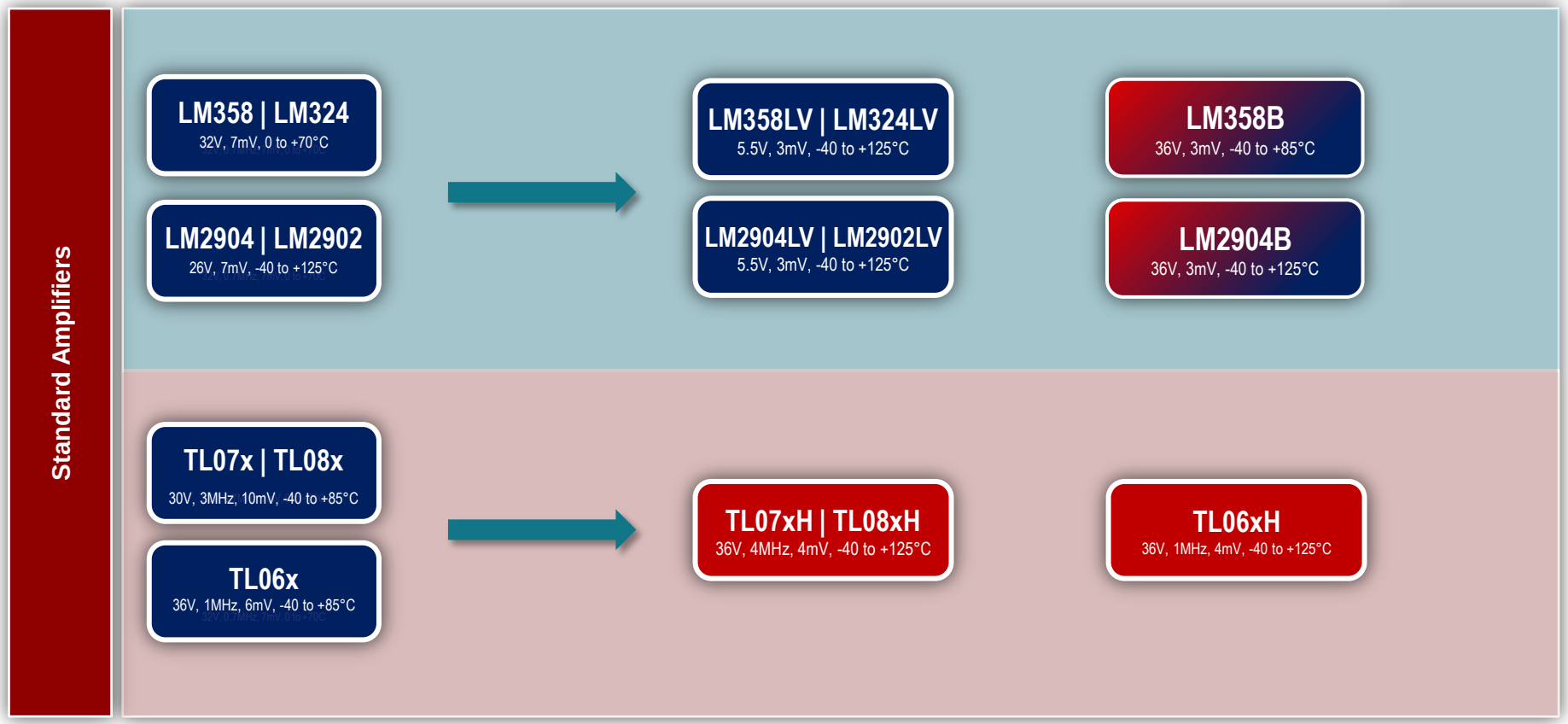
- Industrial, telecom, and server power delivery
- Industrial automation and PLC
- Motor drive and closed loop control
- Audio preamplifier
- Low-side current sense



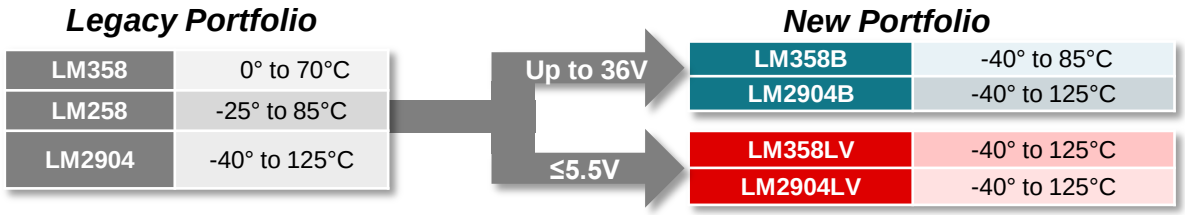
MUX-friendly inputs give **much faster settling time** when interfaced with MUX

Standard Amplifier Roadmap

Production | Sampling



New Standard Amplifiers | LM358 & LM2904 refresh



Specs	LM358	LM358A	LM2904	LM358B	LM2904B	LM358LV LM2904LV
Supply Voltage	3V to 32V	3V to 32V	3V to 26V	*3V to 36V*	*3V to 36V*	2.7V to 5.5V
Temp. Range	0° to 70°C	0° to 70°C	-40° to 125°C	*-40° to 85°C*	*-40° to 125°C*	*-40° to 125°C*
V_{OS} (max)	7 mV	3 mV	7 mV	*3 mV*	*3 mV*	*3 mV*
I_B (typ)	20 nA	15 nA	20 nA	10 nA	10 nA	*15 pA*
GBW	0.7 MHz	0.7 MHz	0.7 MHz	*1.2 MHz*	*1.2 MHz*	*1 MHz*
Slew Rate	0.3 V/µs	0.3 V/µs	0.3 V/µs	0.5 V/µs	0.5 V/µs	*1.5 V/µs*
I_Q (typ)	350 µA	350 µA	350 µA	300 µA	300 µA	*90 µA*
ESD Rating (HBM)	500V	500V	500V	*2kV*	*2kV*	*2kV*
Other Features	–	–	–	*EMI Hardened*	*EMI Hardened*	*EMI Hardened*
Packages	SOIC, TSSOP, VSSOP, PDIP	SOIC, TSSOP, VSSOP, PDIP	SOIC, TSSOP, VSSOP, PDIP	SOIC, TSSOP, VSSOP, SOT-23-8, WSON	SOIC, TSSOP, VSSOP, SOT-23-8, WSON	SOIC, TSSOP, VSSOP, SOT-23-8, WSON

LM358B | LM2904B

1.2MHz | low offset | Extended Temp Range | 36V Bipolar Amplifier

Features

- Supply voltage 3.0V to 36 V
- Input offset voltage ***3.0 mV (Max@ 25°C)***
- Bandwidth ***1.2 MHz***
- Input fail-safe ***Up to 36 V***
- Quiescent current 0.3 mA (typ)
- Robust ESD ***2kV (HBM)***
- Circuit topology Bipolar
- Integrated EMI filter
- Available Packages: SOIC, VSSOP, TSSOP, and TSOT

Benefits

- Wide supply voltage allows for a versatile range of low and high voltage applications
- Improved Human Body Model ESD ratings provide more reliability during manufacturing
- Integrated EMI filter offers immunity against EMI/ RFI interference
- Space saving TSOT package helps to miniaturize the existing designs using the popular LM358 functions

Applications

- Power Supply Units
- AC Inverter & VF Drives
- Industrial Motor Control
- LED Current Sensing
- Automotive Powertrain
- Body and Lighting

	LM358	LM358B	LM2904	LM2904B
Supply (V)	3V-32V	**3V-36V**	3V-26V	**3V-36V**
Temp Range	0 to 70C	**-40 to +85C**	-40 to +125C	**-40 to +125C**
V_{OS} (max)	7mV	**3mV**	7mV	**3mV**
I_Q / ch (typ)	350µA	**300µA**	350µA	**300µA**
EMI Filters		✔		✔
ESD (HBM)	500V	**2kV**	500V	**2kV**

LM358BA | LM2904BA

1.2MHz | Low offset | Extended Temp Range | 36V Bipolar Amplifier

Features

- Supply voltage — 3.0V to 36 V
- Input offset voltage — ***1.75 mV (Max@ 25ºC)***
- Bandwidth — ***1.2 MHz***
- Input fail-safe — ***Up to 36 V***
- Quiescent current — 0.3 mA (typ)
- Robust ESD — ***2kV (HBM)***
- Circuit topology — Bipolar
- Integrated EMI filter
- Available Packages: SOIC, VSSOP, TSSOP, and TSOT

Benefits

- Wide supply voltage allows for a versatile range of low and high voltage applications
- Improved Human Body Model ESD ratings provide more reliability during manufacturing
- Integrated EMI filter offers immunity against EMI/ RFI interference
- Space saving TSOT package helps to miniaturize the existing designs using the popular LM358 functions

Applications

- Power Supply Units
- AC Inverter & VF Drives
- Industrial Motor Control
- LED Current Sensing
- Automotive Powertrain
- Body and Lighting

	LM358A	LM358BA	LM2904A	LM2904BA
Supply (V)	3V-32V	**3V-36V**	3V-26V	**3V-36V**
Temp Range	0 to 70C	**-40 to +85C**	-40 to +125C	**-40 to +125C**
V_{OS} (max)	3mV	**1.75mV**	3mV	**1.75mV**
I_Q / ch (typ)	350µA	**300µA**	350µA	**300µA**
EMI Filters		✔		✔
ESD (HBM)	500V	**2kV**	500V	**2kV**

Texas Instruments

LM3xxLV | LM290xLV: LM321LV / LM358LV / LM324LV / LM2904LV / LM2902LV

1 MHz | Low Power | Extended Temp Range | 5V Low Cost Amplifier

Features

- Supply voltage — 2.7V to 5.5 V
- Improved offset voltage — ***3.0 mV (Max@ 25ºC)***
- Improved slew rate — ***1.5 V/µs***
- Bandwidth — ***1 MHz***
- Lower noise — ***40 nV/Hz***
- Quiescent current — 0.09 mA (typ)
- Robust ESD — ***2kV (HBM)***
- Integrated EMI filter
- In to V-

Benefits

- Single channel, dual channel, and quad channel options
- 5.5V supply improves performance in low voltage systems
- Low supply current offers extended battery life and lower power consumption compared to existing generation
- Integrated EMI filter offers immunity against EMI/ RFI interference
- Enhanced ESD performance improves ruggedness during manufacturing and operation

Applications

- Power Supply Units
- AC Inverter & VF Drives
- Industrial Motor Control
- LED Current Sensing
- Automotive Powertrain
- Body and Lighting

	LM358	LM358LV	LM2902	LM2902LV
Supply (V)	3V-32V	**2.7V-5.5V**	3V-26V	**2.7V-5.5V**
Temp Range	0 to 70C	**-40 to +125C**	-40 to +125C	**-40 to +125C**
V_{OS} (max)	7mV	**3mV**	7mV	**3mV**
I_Q / ch (typ)	350µA	**90µA**	350µA	**90µA**
EMI Filters		✔		✔
ESD (HBM)	500V	**2kV**	500V	**2kV**

New Standard Amplifiers | TL06x, TL07x, TL08x refresh

Legacy Portfolio

Part	GBW
TL06x	1 MHz
TL07x	3 MHz
TL08x	3 MHz

New Portfolio

Part	GBW
TL06xH	1 MHz
TL07xH	4 MHz
TL08xH	4 MHz

Specs	TL06x	TL06xH	TL07x	TL07xH	TL08x	TL08xH
RTM	Existing	**2Q20**	Existing	**2Q20**	Existing	**2Q20**
Supply Voltage	7V – 36V	***4.5V - 36V***	7V – 36V	***4.5V - 36V***	10V – 30V	***4.5V - 36V***
V_{OS} (max)	15mV	***4mV***	6 mV	***4mV***	15mV (C grade) 6mV (I grade)	***4mV***
I_B (typ)	30 pA	***5 pA***	65 pA	30 pA	30 pA	30 pA
GBW	1 MHz	1MHz	3 MHz	***4 MHz***	3 MHz	***4 MHz***
Slew Rate	3.5 V/us	3.5 V/us	13 V/us	***20 V/us***	13 V/us	***20 V/us***
I_Q (typ)	0.2 mA/ch	***0.1 mA/ch***	1.4 mA/ch	***0.8 mA/ch***	1.4 mA/ch	***0.8 mA/ch***
ESD	2kV ESD	2kV ESD	2kV ESD	2kV ESD	1kV ESD	***2kV ESD***
Temp Grades	0 – 70C (C), -40 to 85C (I)	***-40 – 125C***	0 – 70C (C), -40 to 85C (I)	***-40 – 125C***	0 – 70C (C), -40 to 85C (I)	***-40 – 125C***

X = 1, 2, and 4 (channel count)

TL06xH: TL061H / TL062H / TL064H

RRI to V+ | 1MHz | 4mV | 4.5V – 36V General Purpose Amplifier

Features

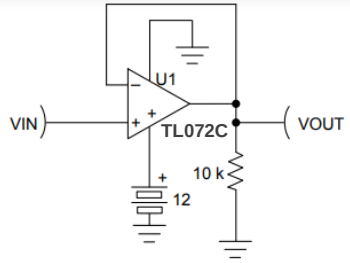
• Wide Supply Range	4.5V – 36V
• Wide Bandwidth	1 MHz
• Low Offset	***2mV/4mV (typ/max)***
• Low offset drift	***3µV/°C***
• Low Noise	37 nV/√Hz
• Quiescent Current	100µA (typ)
• High Slew Rate	***3.5V/µs***
• ESD	***2kV HBM***
• Full industrial temp range	***-40 to 125°C***
• Integrated EMI filter	

Benefits

- High voltage support offers robust flexibility in a range of industrial applications
- Low offset and drift offer improved accuracy
- Input common mode range to V+ enables high side current sensing applications
- High slew rate for motor control and closed loop control applications
- EMI filtering for robust performance in noisy environments

Applications

- Industrial automation and PLC
- Motor drive and closed loop control
- Audio preamplifier and DAC buffer
- High-side current sense



TL07xH: TL071H / TL072H / TL074H

RRI to V+ | 4MHz | 2mV | 4.5V – 36V Low Noise General Purpose Amplifier

Features

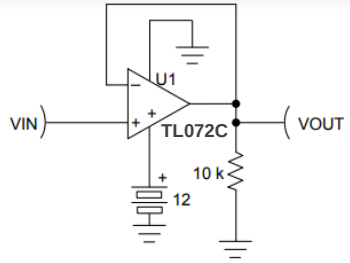
- Wide Supply Range 4.5V – 36V
- Wide Bandwidth 4 MHz
- Low Offset ***2mV/4mV (typ/max)***
- Low offset drift ***3µV/°C***
- Very Low Noise, THD+N 18 nV/√Hz, 0.003%
- Quiescent Current 1mA (typ)
- High Slew Rate ***13V/µs***
- ESD ***2kV HBM***
- Full industrial temp range ***-40 to 125°C***
- Integrated EMI filter

Applications

- Industrial automation and PLC
- Motor drive and closed loop control
- Audio preamplifier and DAC buffer
- High-side current sense

Benefits

- High voltage support offers robust flexibility in a range of industrial applications
- Low offset and drift offer improved accuracy
- Input common mode range to V+ enables high side current sensing applications
- Low noise and THD+N enables audio applications
- High slew rate for motor control and closed loop control applications
- EMI filtering for robust performance in noisy environments



TL08xH: TL081H / TL082H / TL084H

RRI to V+ | 4MHz | 2mV | 4.5V – 36V General Purpose Amplifier

Features

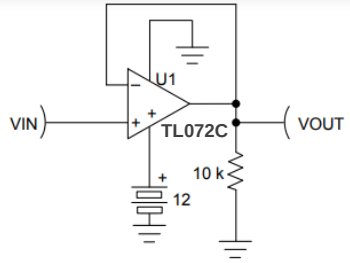
- Wide Supply Range 4.5V – 36V
- Wide Bandwidth 4 MHz
- Low Offset ***2mV/4mV (typ/max)***
- Low offset drift ***3µV/°C***
- Quiescent Current 1mA (typ)
- High Slew Rate ***13V/µs***
- ESD ***2kV HBM***
- Full industrial temp range ***-40 to 125°C***
- Integrated EMI filter

Benefits

- High voltage support offers robust flexibility in a range of industrial applications
- Low offset and drift offer improved accuracy
- Input common mode range to V+ enables high side current sensing applications
- High slew rate for motor control and closed loop control applications
- EMI filtering for robust performance in noisy environments

Applications

- Industrial automation and PLC
- Motor drive and closed loop control
- Audio preamplifier and DAC buffer
- High-side current sense



PSpice for TI Introduction and Demo

New Product Update webinar series

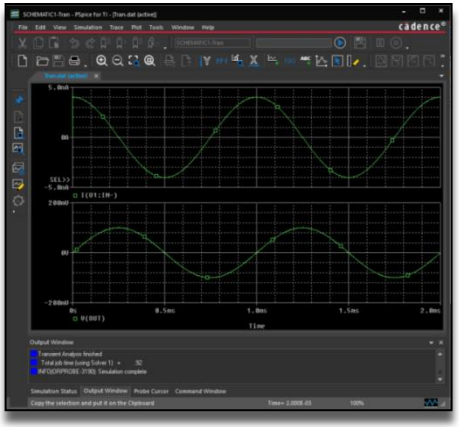
Jerry Madalvanos

Agenda

- Benefits of PSpice for TI
- How to Download
- Creating and running a project
  - Live demo

Benefits of PSpice® for TI – Free Version

- PSpice for TI is a new design and simulation tool that utilizes the industry leading Cadence® PSpice technology
- Familiar Cadence® environment (industry's most widely used schematic capture and simulation environment).
- Full-featured simulator
  - Automatic measurements, post-processing, advanced analyses (Monte Carlo, Worst-case, Thermal)
- Training Videos: Introduction and Advanced
- Integration with TI.com
  - Integrated library with thousands of built-in models that automatically synchronizes with TI.com
  - E2E Forum Support
  - Ability to work off-line
- Simulate with unlimited markers for TI models
  - 3 marker limit for non-TI models, paid upgrade unlocks marker limit

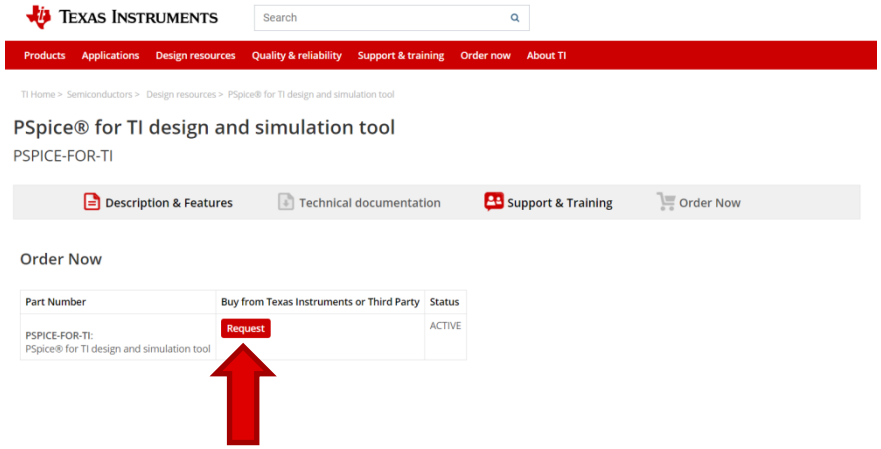


Helpful Resources

- Download Link
  - https://www.ti.com/tool/PSPICE-FOR-TI
- Tutorial Videos
  - https://training.ti.com/pspice-ti-introduction

Downloading PSpice® for TI

- Navigate to https://www.ti.com/tool/PSPICE-FOR-TI
- Click “Request”
- Login to your myTI account and fill out the required information
- Approval can be immediate
  - May take 24-48 hours (excluding weekends)
- Follow the instructions in the email to download PSPICE for TI

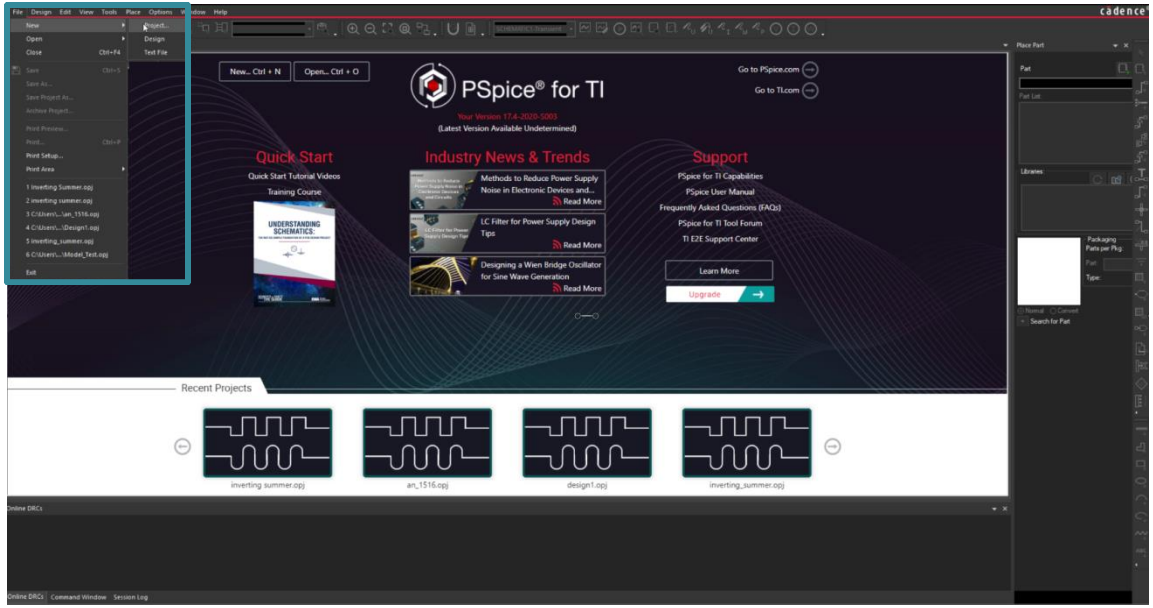


Live Demo

- How to create a project
- How to build a simple circuit (op amp, passives, sources, label nets)
- How to create & run a simulation profile (transient)
- How to view the results
- How to export the design as a *.zip file

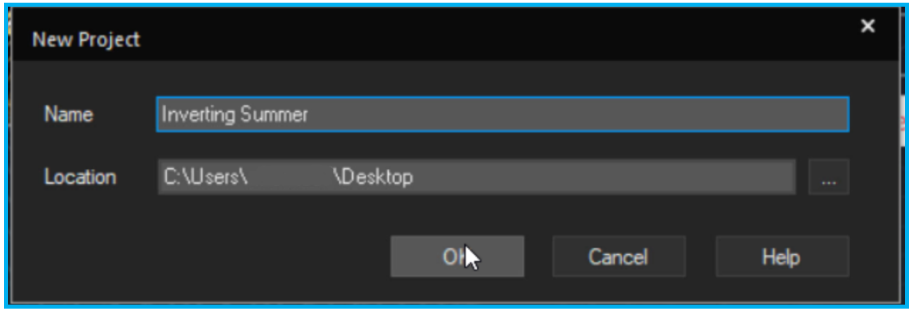
Creating Project

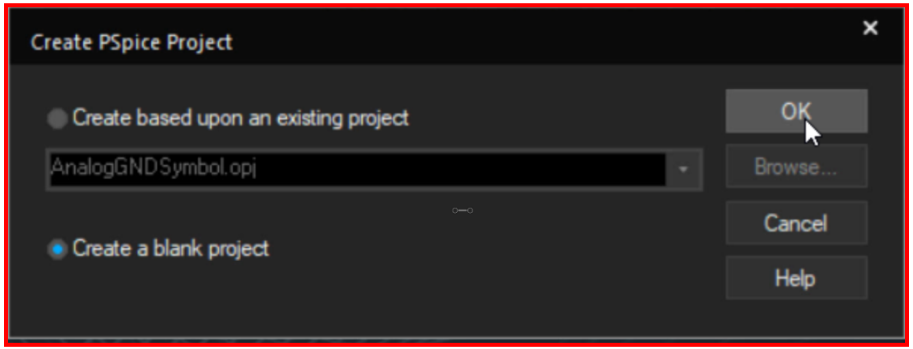
- In the toolbar go to File → New → Project



Creating Project

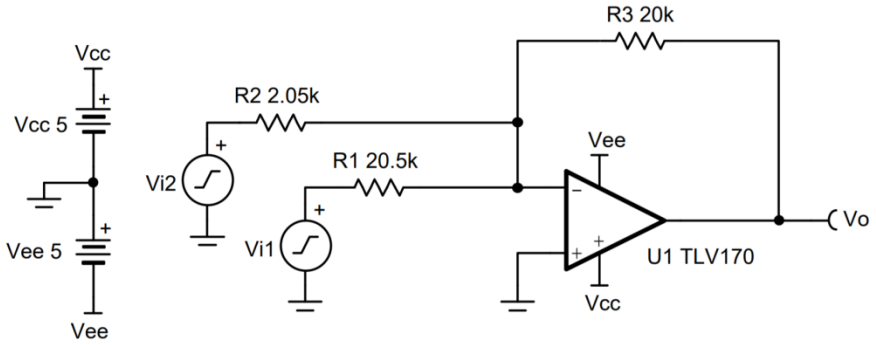
- Name the project
- Choose the file location for the project
  - Click OK
- Select “Create a Blank Project”
  - Click OK





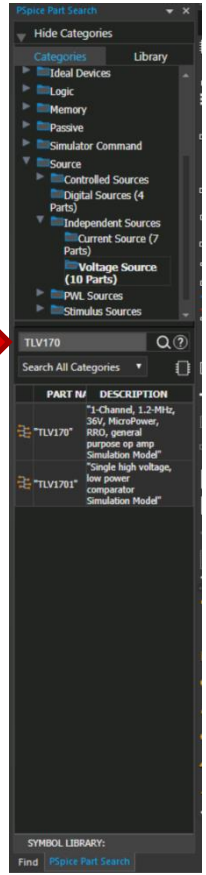
Circuit Template

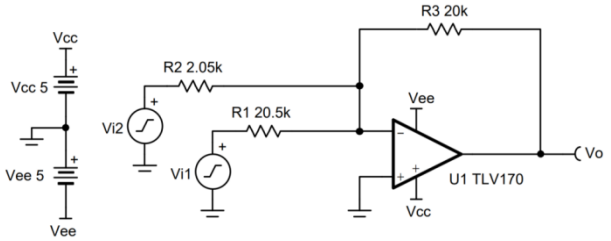
- This step-by-step guide uses the inverting summer circuit outlined in the Analog Engineer's Circuit Cookbook (Page 18)

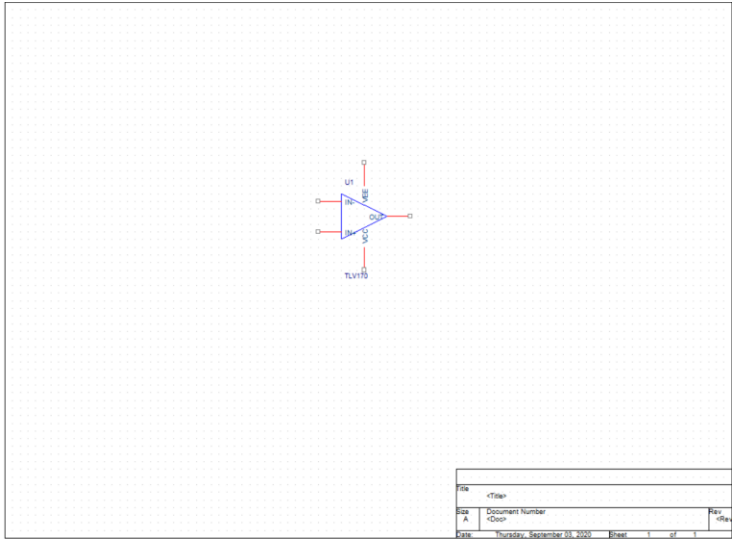


Placing the Op Amp

- Navigate to the right hand toolbar labeled “PSpice Part Search”
- Type “TLV170” into the search box, and click the magnifying glass icon
  - Alternatively, you can navigate the folders above the search bar and find it in Texas Instruments/Amplifiers/Operational Amplifiers/General Purpose Op Amps/TLV170
- Double-click “TLV170” mouse over the schematic click and place the op amp
  - Press ESC to stop placing TLV170

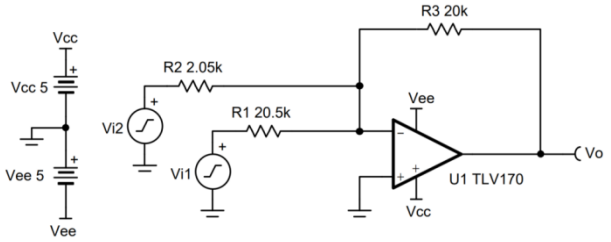


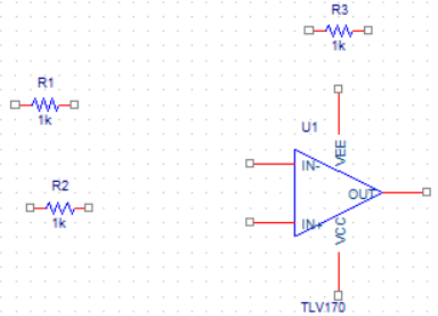




Placing the Resistors

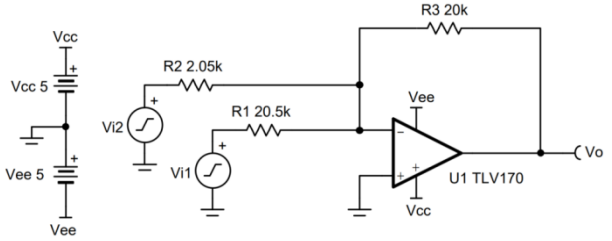
- In PSpice Part Search, search for “resistor”
  - Scroll down to “R”
  - Double-click “R” and click to place in circuit
  - Press ESC to stop placing resistors
- Alternatively, in the toolbar
  - Place → PSpice Component → Resistor
  - Place in circuit
    - Press ESC

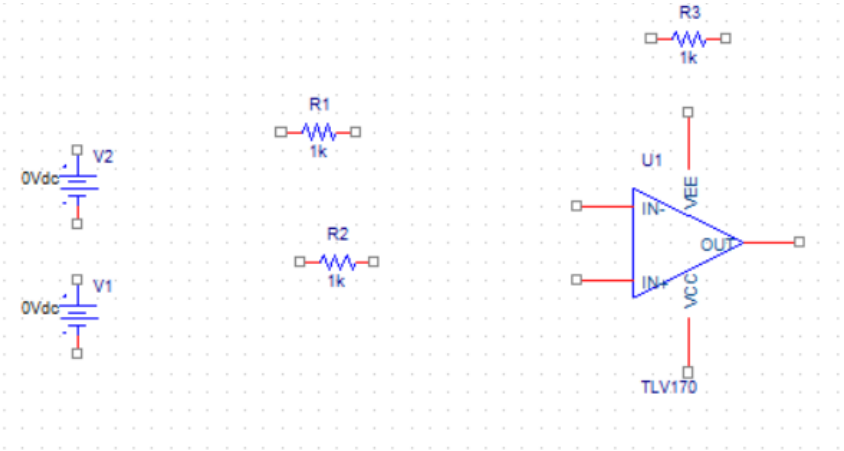




Placing DC Sources

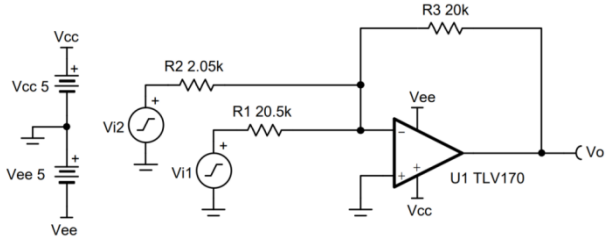
- In PSpice Part Search, search for VDC
  - Place two for the VEE and VCC rails
  - Press ESC to stop placing
- Alternatively, in the toolbar
  - Place → PSpice Component… → Source → Voltage Source → DC
  - Click to place sources
  - ESC to stop placing

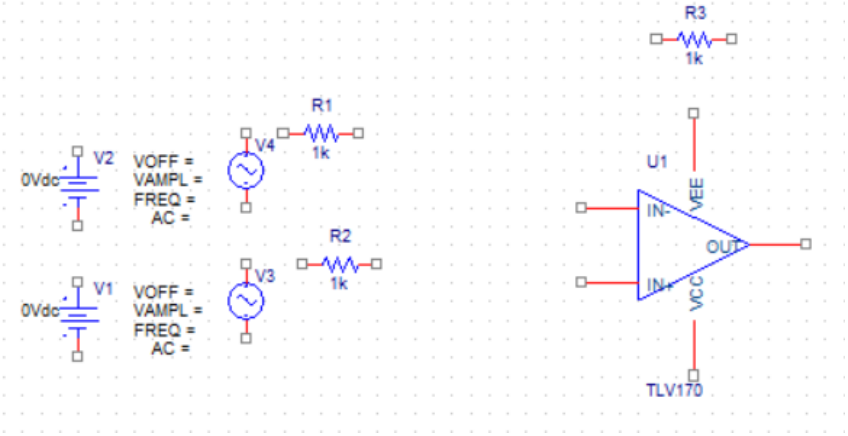




Placing Input Sources

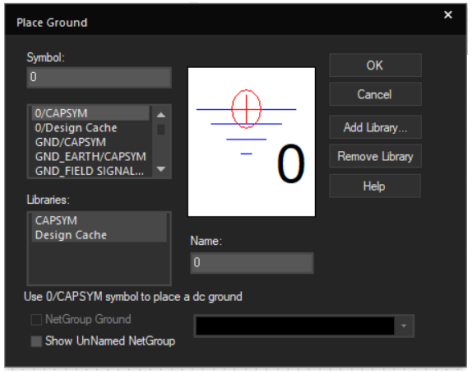
- In PSpice Part Search, search for VDC
  - Place two for the Vin1 and Vin2
  - Press ESC to stop placing
- Alternatively, in the toolbar
  - Place → PSpice Component… → Source → Voltage Sources → Sine
  - Click to place sources
  - ESC to stop placing

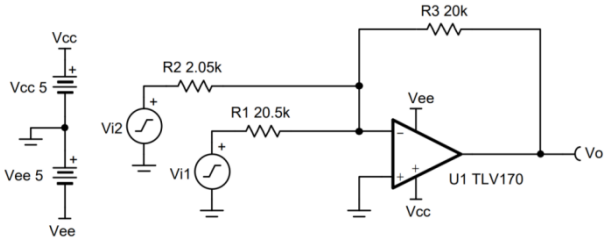


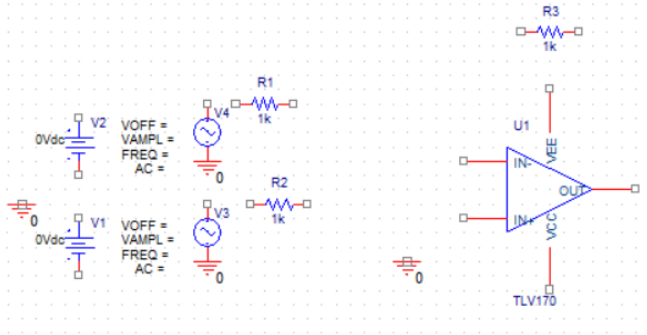


Placing Grounds

- Press “g” to start the “Place Ground tool
- Choose “0/CAPSYM” and place grounds in circuit
  - Press OK
  - Place in Circuit
  - Press ESC
- Alternatively
  - Navigate to the toolbar and click “Place”, select “Ground…”

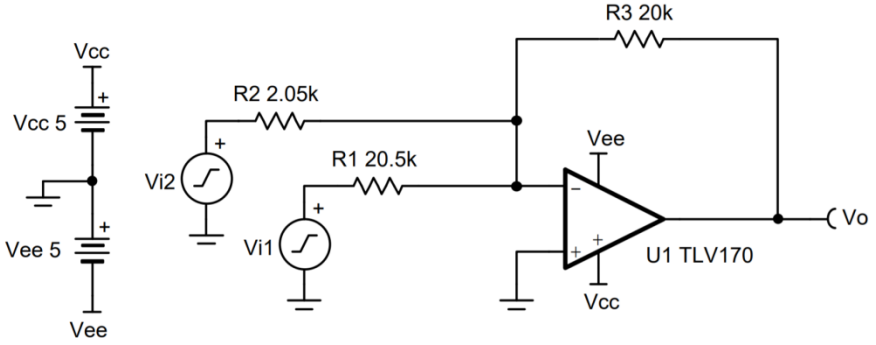


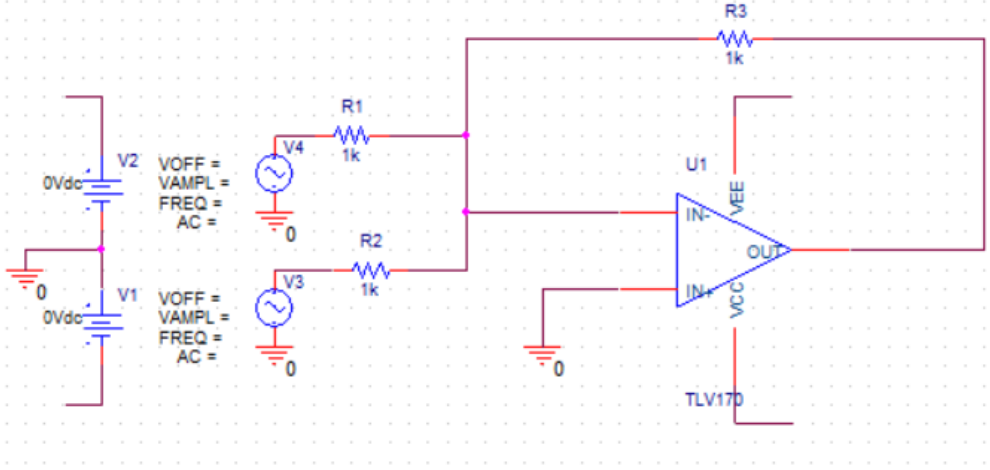




Wiring the Circuit

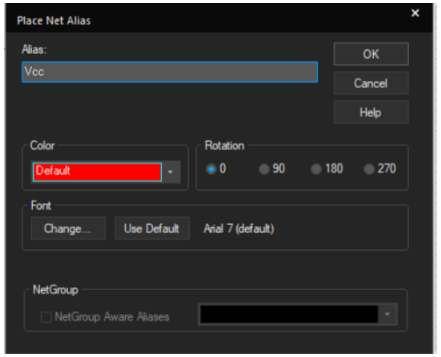
- Press “w” to start the wiring tool
  - Alternatively, in the toolbar:
    - Place → Wire
    - Press ESC to exit the wiring tool
- Connect components based on the inverting summer circuit
- Note: Place wires on V1, V2, and U1 as shown to attach net labels to them

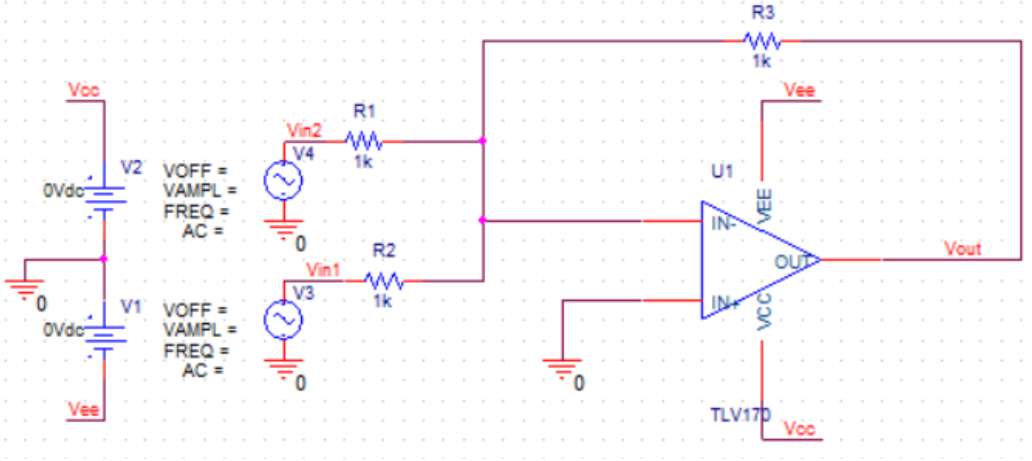




Labeling Nets

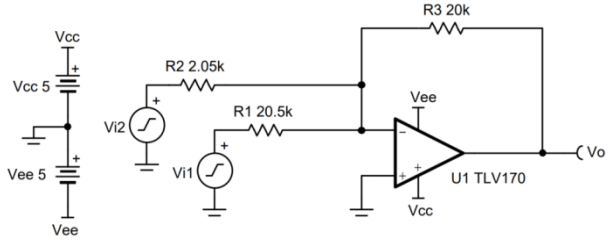
- Press “n” to open the “Place Net Alias” tool
  - Alternatively, in the toolbar:
    - Place → Net Alias…
- Enter the name of the net and click a wire to place the label
  - For this example, place the following nets:
    - Vcc
    - Vee
    - Vin1
    - Vin2
    - Vout

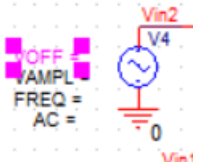


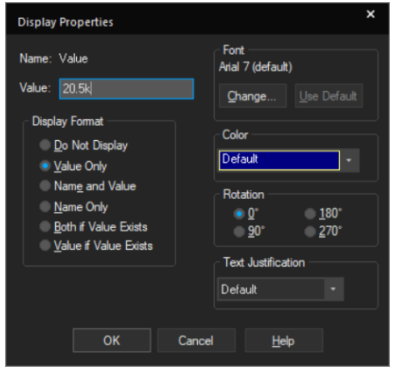


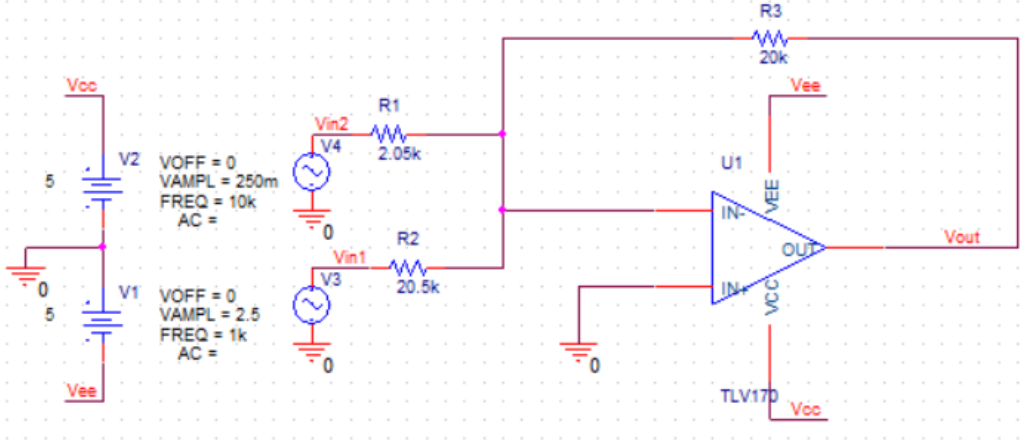
Assigning Values to Components

- Double-click the value you wish to edit (not the component)
- Enter the value based upon the inverting summer circuit from the Analog Engineer's Cookbook
- Repeat process until all values match the cookbook circuit



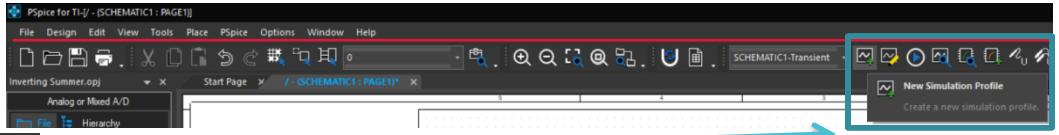


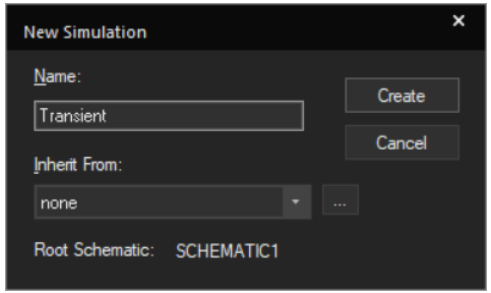


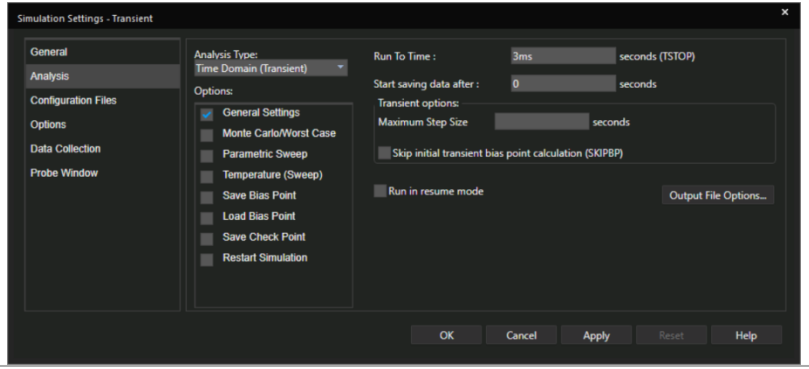


Analyzing the Circuit

- In the toolbar, click the "New Simulation Profile" button 
- Enter a name for your simulation
- Press "Create"
- Edit the "Run To Time" to 3ms
  - This will show 3 periods of the longest waveform
- Press "OK"

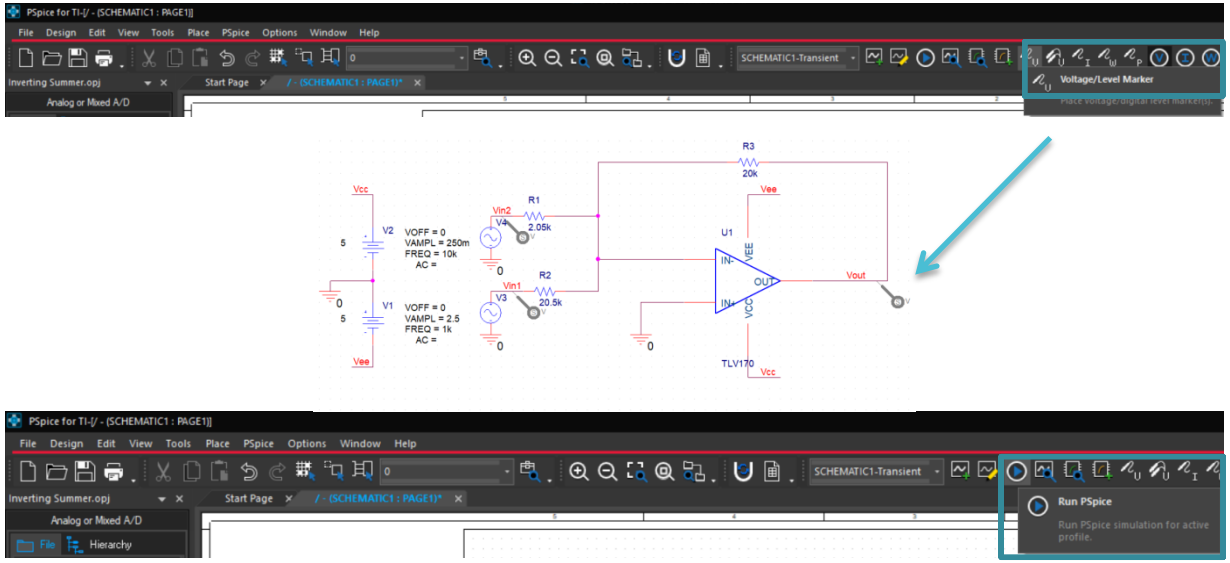






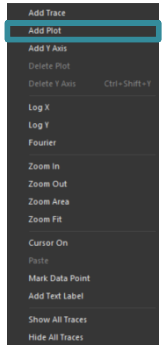
Running the Simulation

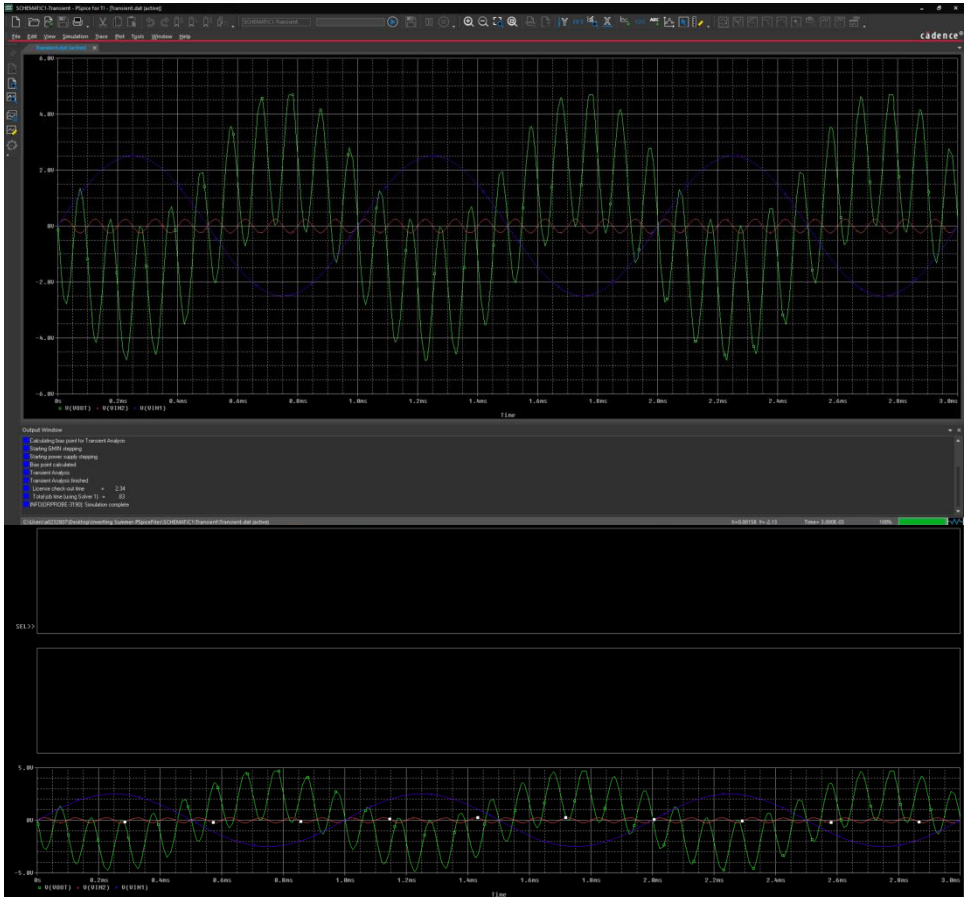
- In the toolbar, click the “Voltage/Level Marker” button
- Place Voltage markers on Vout, Vin1, and Vin2
- Press the “Run PSpice” button
- Open the PSpice simulation window 
- Note: The first simulation may take several minutes…



Viewing the Results

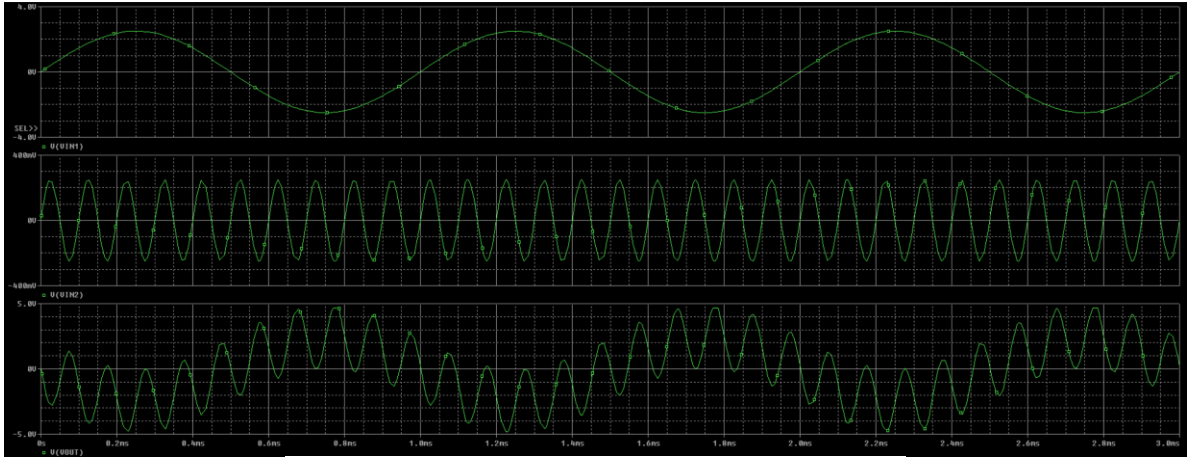
- To split traces, right click the plot and select “Add Plot”
- Repeat the above step so there are three plots total
- Click the name of the trace in the bottom left corner
- Cut the trace and paste one on each plot

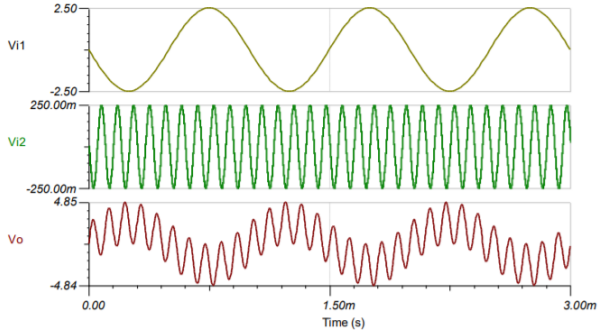




Comparing Simulation to Cookbook Results

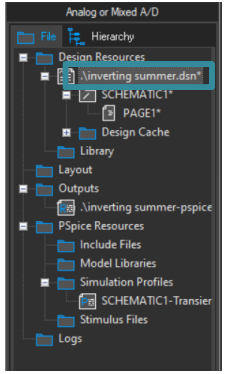
- Simulation matches the expected output!

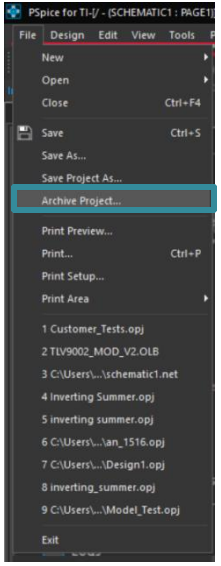


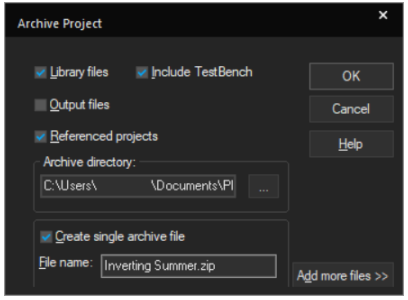


Exporting Project

- Back in the PSpice for TI window
- Click on the .dsn file in the project directory
- In the toolbar, navigate to “File” then to “Archive Project”
- Make sure “Library files”, “Include TestBench”,“Referenced projects”, and “Create single archive file” are selected
- Select the archive directory and name the file, then hit “OK”
- The zipped project can easily be sent for analysis

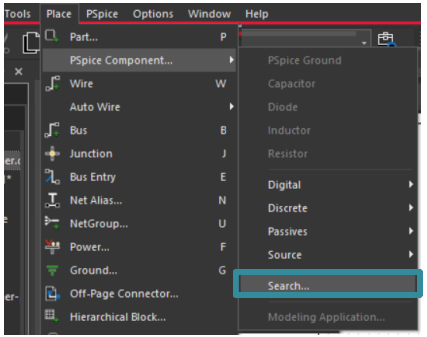






Helpful Notes

- If PSpice part search is not open by default, you can open it by navigating to “Place”, “PSpice Component”, “Search…”



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