

New Product Update

Next Generation High Voltage
Comparators for Robust
Monitoring Designs

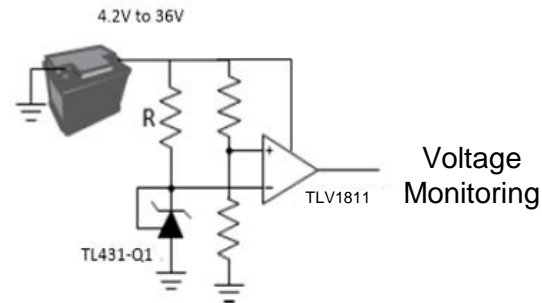
Pierce Nguyen
Comparators

Agenda

1. Introduction to New High-Voltage Comparators
 - a. [Advantages of Higher Voltage Comparators](#)
 - b. [History](#)
2. [High Voltage Family Overview](#)
 - a. [Special Features](#)
3. Applications
 - a. TLV181X/2X – [Voltage Monitoring](#)
 - b. TLV183X/4X – [Current Sensing](#)
 - c. TLV185X/6X – [Reverse Battery Protection](#)
 - d. TLV187X – [Zero Cross and PWM Generation](#)
 - e. TLV192X – [Over-Voltage Protection](#)

Wider Voltage Ranges Advantages

- Trend toward higher voltages
- Flexibility in ranges and types of voltages being monitored
 - 36V, 40V, and 65V comparators available
- Less components needed (i.e. resistor dividers, diodes)
- Additional protection against transients
- Useful in most housekeeping use cases including current sensing, voltage monitoring, level translation



History of TI's High Voltage Comparators

LM290X

LM111, 211, 311

Features:

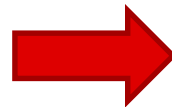
- Cost effective
- 30V supply voltage
- Multisource



TLV170X

Features:

- Lower power consumption
- Rail-to-rail
- 36V supply voltage



TLV18XX

Features:

- Even Lower power consumption
- Rail-to-rail
- 40V supply voltage
- Along with POR, Failsafe, etc.

And many others...

High Voltage Comparators Overview

	LM290X	TLV181X/2X	TLV183X/4X/7X	TLV185X/6X	TLV192X
Supply Voltage	2V to 30V	2.4V to 40V	2.4V to 40V	1.8V to 40V	5V to 65V
Vos (max over temp)	9mV	4mV	4mV	7mV	3mV
Iq per Channel (typ 25C)	450uA	7uA	70uA	560nA	20uA
Prop Delay (typ)	1.3us	450nS	65nS	25uS	1 us
Output Type	Open-Collector	Push-Pull/ Open-Drain	Push-Pull/ Open-Drain	Push-Pull/ Open-Drain	Open-Drain
Temperature Range	-40 to 125C	-40 to 125C EP: -55 to 125C	-40 to 125C	-40 to 125C	-40 to 125C
Additional Features	<ul style="list-style-type: none"> • Most cost optimized 	<ul style="list-style-type: none"> • Rail-to-Rail • Power On Reset 	<ul style="list-style-type: none"> • Rail-to-Rail • Power On Reset • TLV187X: Split input output supplies 	<ul style="list-style-type: none"> • Failsafe • Over-the-Rail • Reverse Battery Protection • Power On Reset 	<ul style="list-style-type: none"> • Integrated Reference Pin • Power On Reset

Features

Known Start-Up Conditions

Power-on-Reset (POR)

Feature Highlight

Problem: Start-up uncertainty creates a false state on start

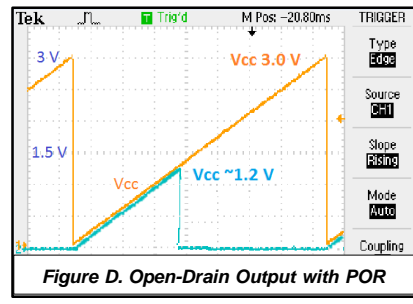
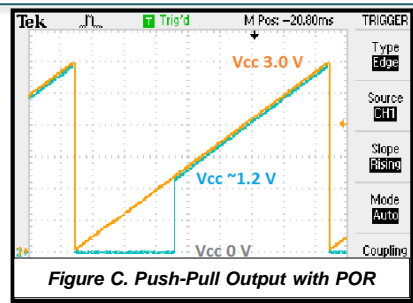
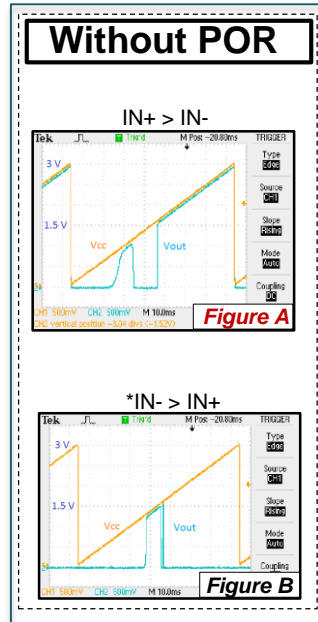
In *Figure A*, output should be logic high, but upon start-up, the output toggles between high and low before stabilizing at logic high. In *Figure B*, output should be logic low, but the output briefly transitions to logic high before stabilizing at logic low. This transition between a high and low state can cause the premature activation of the circuit

Solution: Integrated Power-On-Reset (POR) Circuitry

The integrated POR circuit forces the comparator output to a known state during start-up until the supply reaches the minimum supply value.

Feature Facts:

- Integrated POR circuitry will be designed into most new TI comparators



For a Push-Pull comparator, the output is held low until the minimum operating voltage is reached

*IN+ > IN-

For an open-drain comparator, the output follows the supply until the minimum operating voltage is reached

*IN- > IN+

Comparators with POR

	I_Q	V_{OS}	t_{PD}	Supply Range
Q100 TLV185X/6X	560nA	7mV	2.5uS	1.8V to 40V
Q100 TLV181X/2X	7µA	4mV	400ns	2.4V to 40V
Q100 TLV1805	135µA	500µV	250ns	3.3V to 40V
Q100 LM393LV/LM339LV	25µA	0.4mV	600ns	1.65V to 5.5V
Q100 TLV90X0/1/2/4	16µA	0.3mV	100ns	1.65V to 5.5V
TLV701X/2X	5µA	8mV	260ns	1.6V to 6.5V
Q100 TLV703X/4X	315nA	8mV	3µS	1.6V to 6.5V
TLV40X1	2µA	-	360ns	1.6V to 5.5V
Q100 TLV3601/2/3	6mA	5mV	2.5ns	2.4V to 5.5V

Benefits:

- Allows the comparator to consistently remain in a known state (POR state or reflective of input)
- Minimizes impact of brownout conditions by protecting against an accidental change in state
- Avoid false output conditions

Want to learn more? Check out these links:

- [How to Solve Comparator Startup Uncertainty with POR](#)
- [\[FAQ\] How Power on Reset Comparators Simplify Designs](#)

Integrated Fail-Safe Inputs

Feature Highlight

Problem: Input pins are dependent on power supply

Designing with input pins that are dependent on the power supply can lead to system damages in cases where the power supply ramps down faster than the input supply or during start-up where the input supply ramps faster than the output supply.

Solution: Make input pins independent of power supply

By giving the input pins their own absolute maximum ratings independent of the power supply, users can have more flexibility in designing without worrying about damage to the input pins.

System Care Abouts:

- High Input Impedance in absence of supply
- Input signal can go well beyond the supply voltage of the comparator as defined by Absolute Maximum Table

Comparators with Fail-Safe Inputs

	I_Q	V_{OS}	t_{PD}	Supply Range
C100 TLV185X/6X	560nA	7mV	2.5uS	1.8V to 40V
C100 LM393LV/LM339LV	25μA	0.4mV	600ns	1.65V to 5.5V
C100 TLV90X0/1/2/4	16μA	0.3mV	100ns	1.65V to 5.5V
TLV701X/2X	5μA	8mV	260ns	1.6V to 6.5V
C100 TLV703X/4X	315nA	8mV	3μS	1.6V to 6.5V

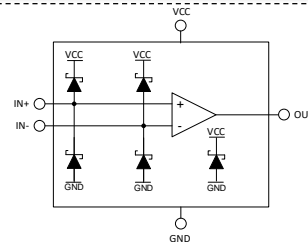
Without Fail-Safe Inputs

Absolute Maximum Ratings

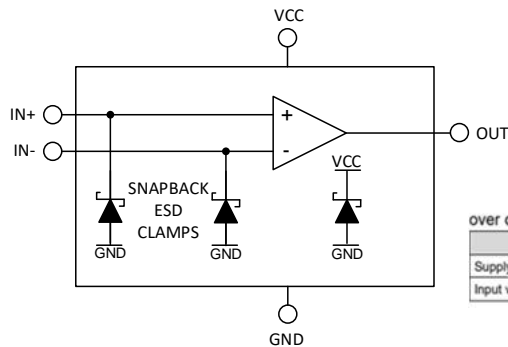
over operating free-air temperature range (unless otherwise noted)⁽¹⁾

		MIN	MAX	UNIT
Voltage	Supply voltage		7	V
	Signal input pins ⁽²⁾	-0.5	$(V_{CC}) + 0.5$	V

*Input limited by VCC



With Fail-Safe Inputs

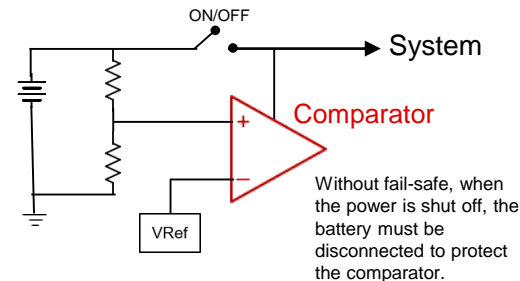


Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)⁽¹⁾

		MIN	MAX	UNIT
Supply voltage: $V_S = (V^+) - (V^-)$		-0.3	40	V
Input voltage (IN) from (V-) ⁽²⁾		-0.3	40	V

*Input independent of VCC



Benefits:

- You don't have to disconnect monitored signal from comparator input when powering down
- You don't have to worry about power supply sequencing
- You don't have to level-shift comparator output

Want to learn more? Check out these links:

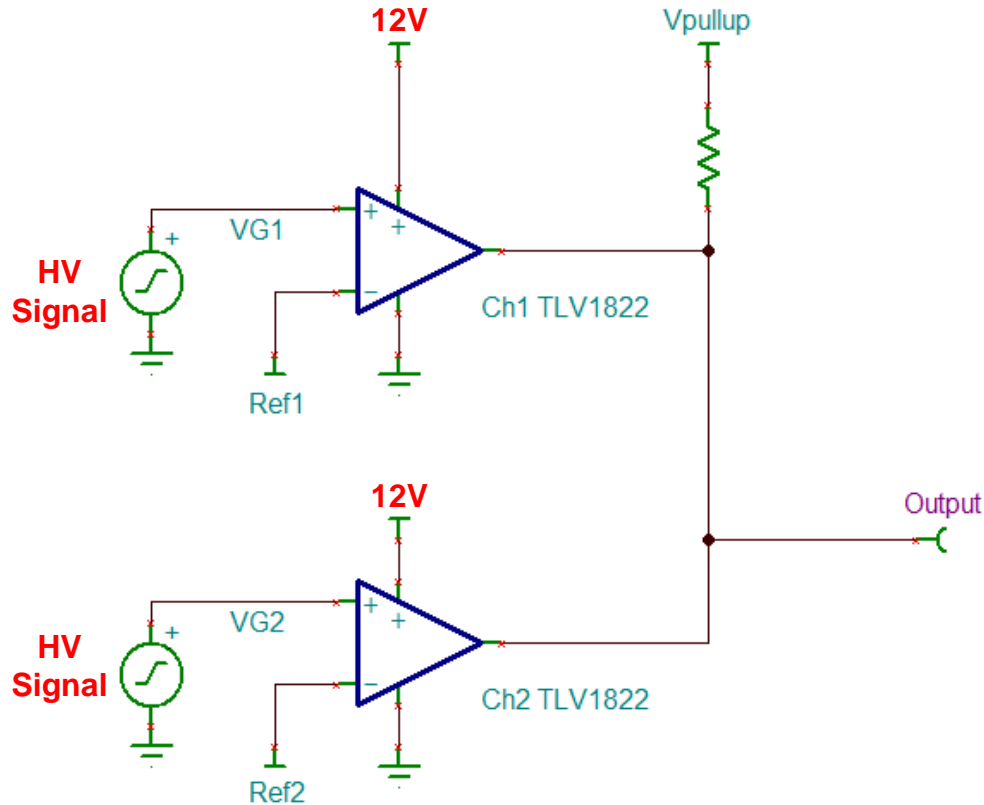
- [\[FAQ\] How to the apply inputs before powering the supply of my comparator?](#)

Applications

High Voltage Comparators Overview

	LM290X	TLV181X/2X	TLV183X/4X/7X	TLV185X/6X	TLV192X
Supply Voltage	2V to 30V	2.4V to 40V	2.4V to 40V	1.8V to 40V	5V to 65V
Vos (max over temp)	9mV	4mV	4mV	7mV	3mV
Iq per Channel (typ 25C)	450uA	7uA	70uA	560nA	20uA
Prop Delay (typ)	1.3us	450nS	65nS	25uS	1 us
Output Type	Open-Collector	Push-Pull/ Open-Drain	Push-Pull/ Open-Drain	Push-Pull/ Open-Drain	Open-Drain
Temperature Range	-40 to 125C	-40 to 125C EP: -55 to 125C	-40 to 125C	-40 to 125C	-40 to 125C
Additional Features	<ul style="list-style-type: none"> • Most cost optimized 	<ul style="list-style-type: none"> • Rail-to-Rail • Power On Reset 	<ul style="list-style-type: none"> • Rail-to-Rail • Power On Reset • TLV187X: Split input output supplies 	<ul style="list-style-type: none"> • Failsafe • Over-the-Rail • Reverse Battery Protection • Power On Reset 	<ul style="list-style-type: none"> • Integrated Reference Pin • Power On Reset

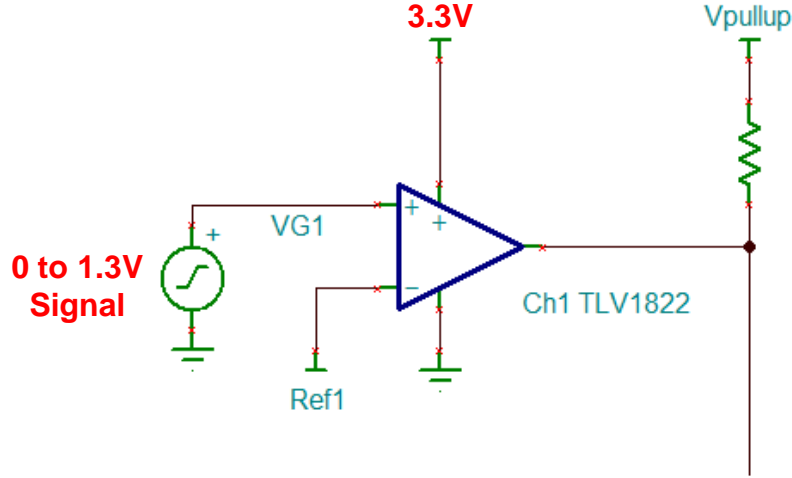
Voltage Monitoring Flexibility



Why TLV181x/2x?

- **Micropower** reduces power consumption for always-on battery monitoring systems
- **Open Drain Output** allows for OR'ed outputs and control over the output voltage for easy transition to digital logic input
- **Rail-to-rail inputs** allow for capability to monitor input voltages up to positive supply voltage and down to negative supply voltage for design flexibility
- **Extended Temp Range** on EP variants allow operation down to -55C, ideal for space applications

Voltage Monitoring Flexibility



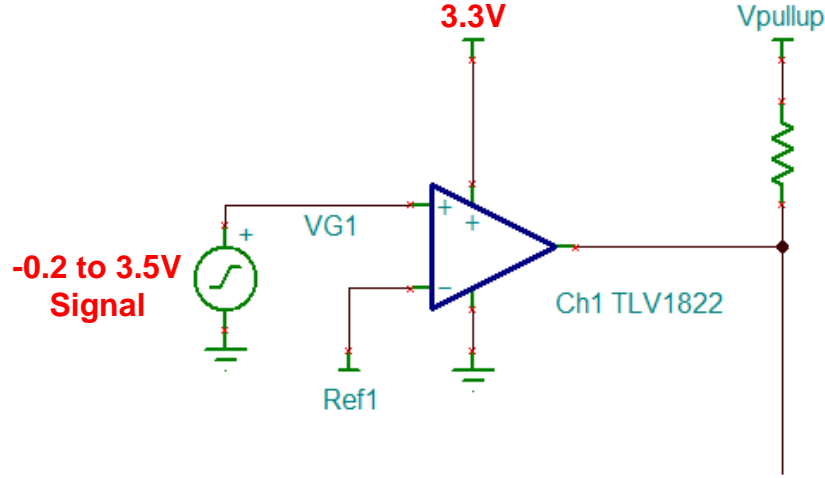
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- **Extended Temp Range** on EP variants allow operation down to -55C, ideal for space applications

Common mode range ⁽¹⁾	$V_S = 3 \text{ to } 36\text{V}$	(V-)	(V+) - 1.5
	$V_S = 3 \text{ to } 36\text{V}, T_A = -40^\circ\text{C to } +85^\circ\text{C}$	(V-)	(V+) - 2.0

LM2903 Common Mode Range

Voltage Monitoring Flexibility



Common-mode
voltage range

$V_S = 2.4 \text{ V to } 40 \text{ V}$
 $T_A = -40^\circ\text{C to } +125^\circ\text{C, Rail to Rail}$

$(V-) - 0.2$

$(V+) + 0.2$

TLV182X Common Mode Range

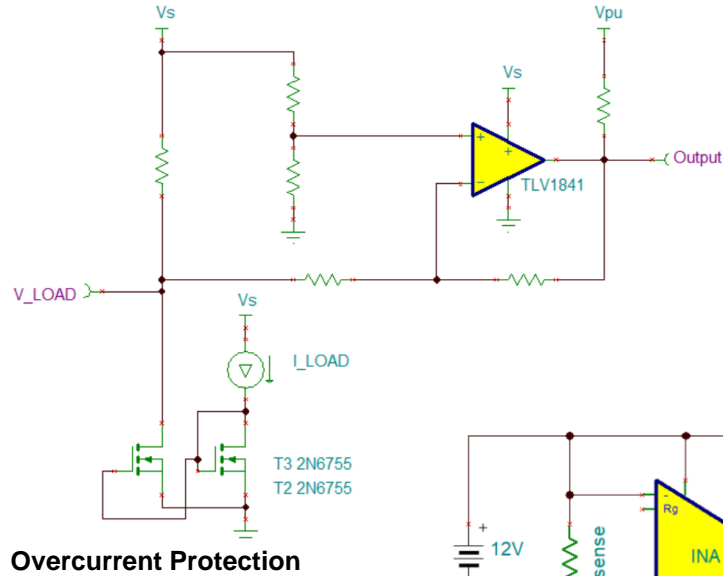
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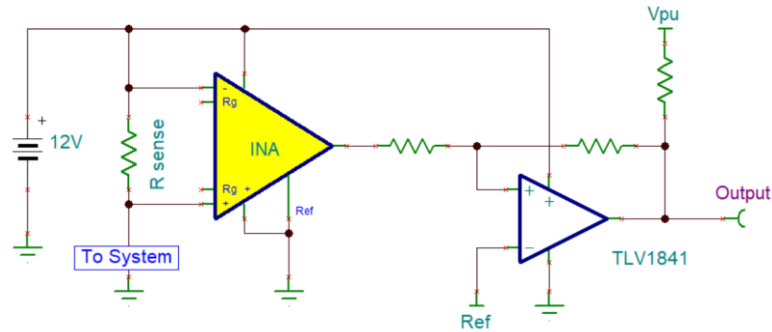
	LM290X	TLV181X/2X	TLV183X/4X/7X	TLV185X/6X	TLV192X
Supply Voltage	2V to 30V	2.4V to 40V	2.4V to 40V	1.8V to 40V	5V to 65V
Vos (max over temp)	9mV	4mV	4mV	7mV	3mV
Iq per Channel (typ 25C)	450uA	7uA	70uA	560nA	20uA
Prop Delay (typ)	1.3us	450nS	65nS	25uS	1 us
Output Type	Open-Collector	Push-Pull/ Open-Drain	Push-Pull/ Open-Drain	Push-Pull/ Open-Drain	Open-Drain
Temperature Range	-40 to 125C	-40 to 125C EP: -55 to 125C	-40 to 125C	-40 to 125C	-40 to 125C
Additional Features	<ul style="list-style-type: none"> • Most cost optimized 	<ul style="list-style-type: none"> • Rail-to-Rail • Power On Reset 	<ul style="list-style-type: none"> • Rail-to-Rail • Power On Reset • TLV187X: Split input output supplies 	<ul style="list-style-type: none"> • Failsafe • Over-the-Rail • Reverse Battery Protection • Power On Reset 	<ul style="list-style-type: none"> • Integrated Reference Pin • Power On Reset

Current sense & Short Circuit Protection



Overcurrent Protection

Current Sensing



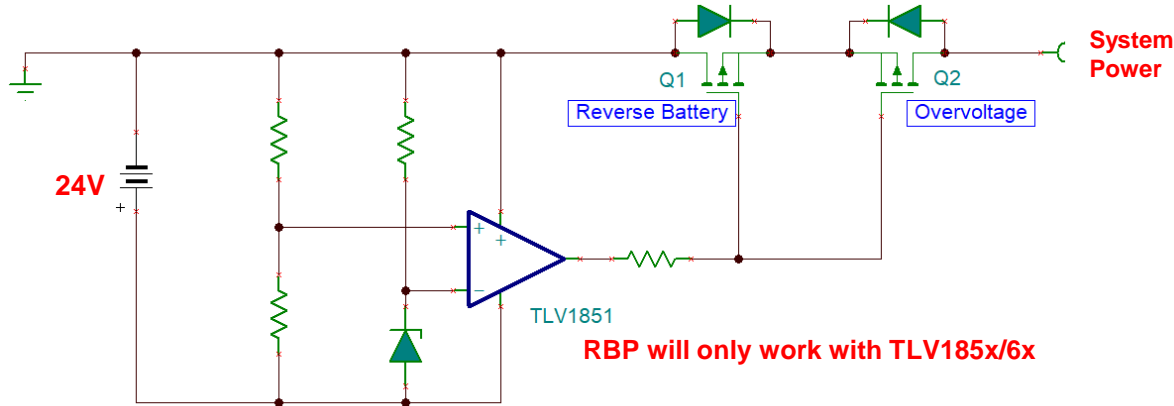
Why TLV183x/4x?

- **High speed** allows the comparator to react quickly to overcurrent condition, preventing damage to the system
- **Open-Drain** allows comparator to easily level shift from supply voltage to MCU operating voltage
- **Wide Voltage Range** allows comparator to be powered from the same supply that is being monitored, simplifying designs

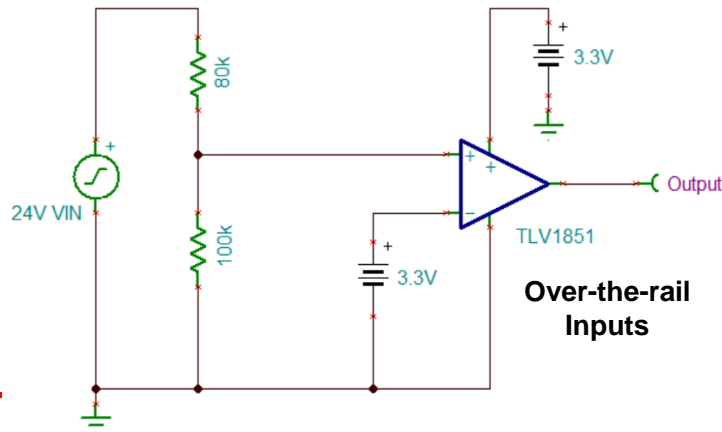
High Voltage Comparators Overview

	LM290X	TLV181X/2X	TLV183X/4X/7X	TLV185X/6X	TLV192X
Supply Voltage	2V to 30V	2.4V to 40V	2.4V to 40V	1.8V to 40V	5V to 65V
Vos (max over temp)	9mV	4mV	4mV	7mV	3mV
Iq per Channel (typ 25C)	450uA	7uA	70uA	560nA	20uA
Prop Delay (typ)	1.3us	450nS	65nS	25uS	1 us
Output Type	Open-Collector	Push-Pull/ Open-Drain	Push-Pull/ Open-Drain	Push-Pull/ Open-Drain	Open-Drain
Temperature Range	-40 to 125C	-40 to 125C EP: -55 to 125C	-40 to 125C	-40 to 125C	-40 to 125C
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Reverse Battery and Overvoltage Protection Scheme



Reverse Battery + Overvoltage Protection Scheme



Why TLV185x/6x?

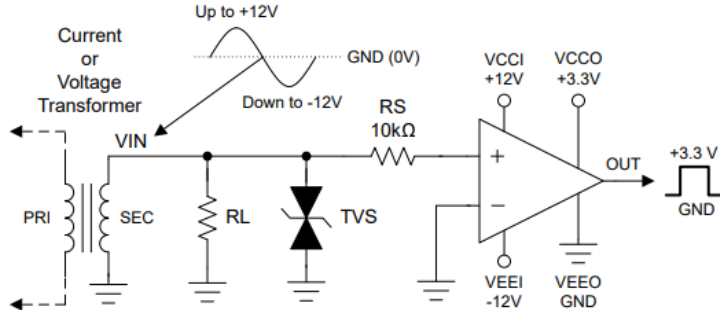
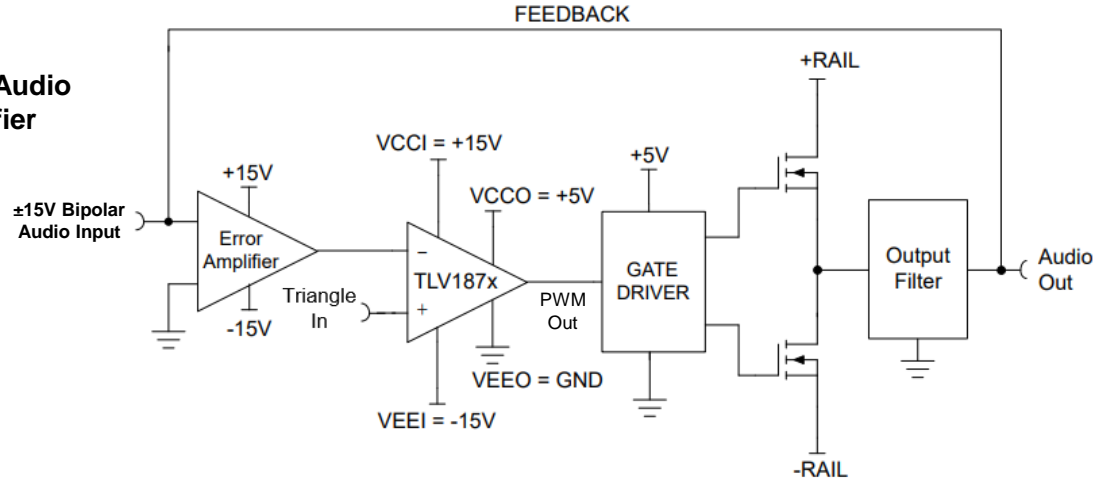
- **Nanopower** reduces power consumption for always-on battery monitoring systems
- **Reverse battery protection** prevents damage to the overall system in the event of improper battery installation
- **Over-the-rail inputs** allow the capability to monitor high voltages on the inputs while operating at low supply voltages
- **Fail-safe inputs** remain high impedance with no damage even when the comparator is unpowered

High Voltage Comparators Overview

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Output Type	Open-Collector	Push-Pull/ Open-Drain	Push-Pull/ Open-Drain	Push-Pull/ Open-Drain	Open-Drain
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PWM Generation and Zero Cross

Class D Audio Amplifier



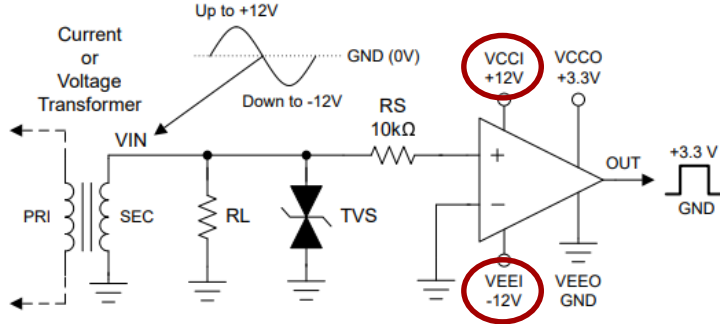
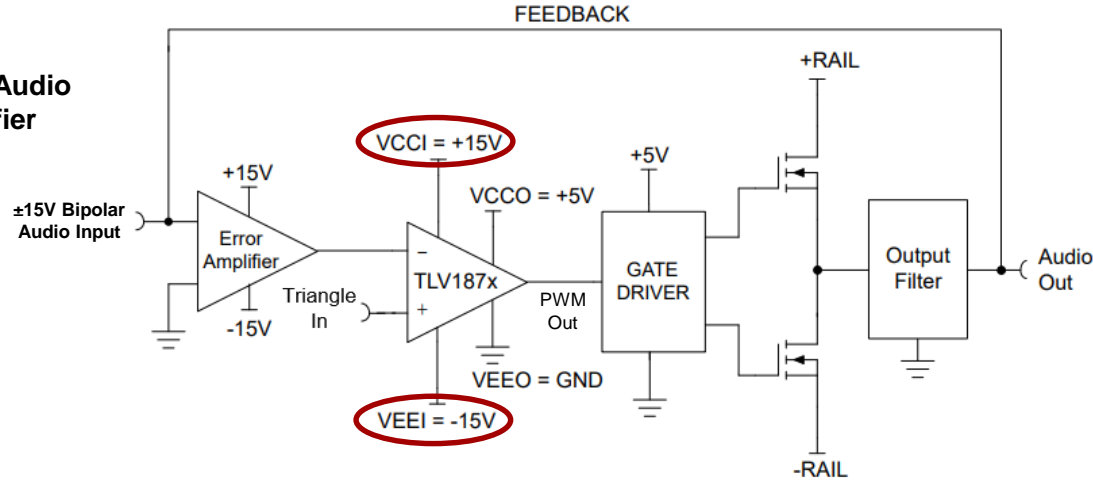
Bipolar Zero Cross Circuit

Why TLV187x?

- **Separate input and output supplies** allows for easy level shifting from high voltage supplies to low voltage domains needed by MCU/Gate Drivers
- **High speed** allows the comparator to react quickly to overcurrent condition, preventing damage to the system
- **Push-Pull output** allows for symmetrical rise and fall times
- **Wide Voltage Range** allows comparator to be powered from the same supply that is being monitored, simplifying designs

PWM Generation and Zero Cross

Class D Audio Amplifier



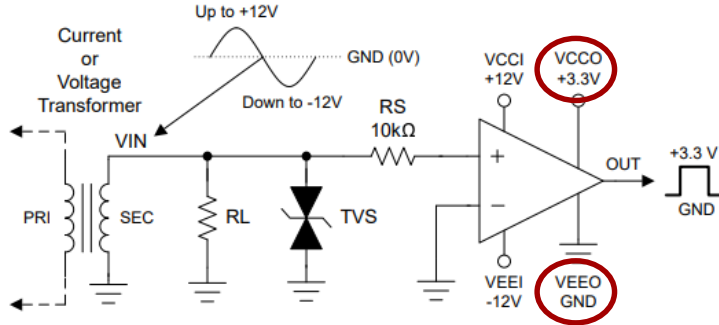
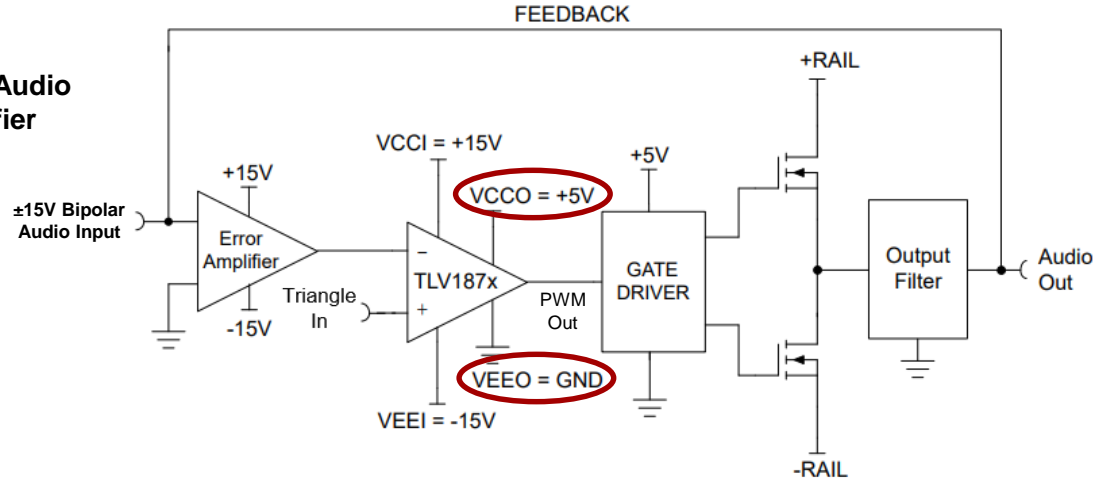
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Class D Audio Amplifier



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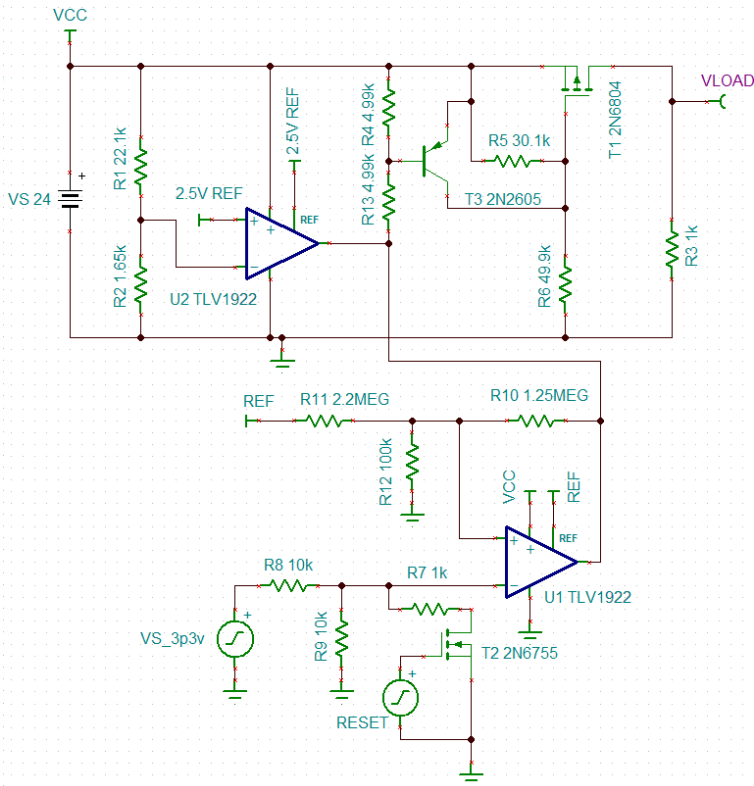
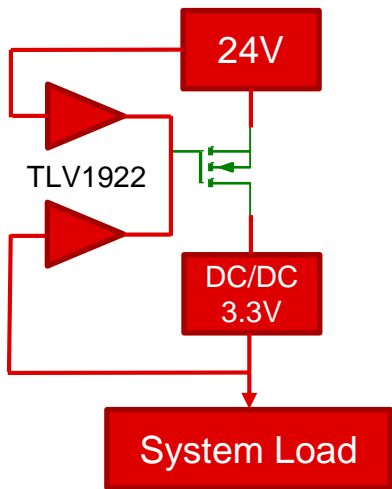
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Over-Voltage Protection



Why TLV192x?

- **Wider Voltage Range up to 65V** allows comparator to be powered from the same supply that is being monitored, and allows plenty of headroom for monitoring high voltage supplies
- **Integrated reference** allows for design flexibility in voltage protection systems by removing the need for an external reference

One Pagers

TLV181X/182X

AEC Q100 Planned

300
nm

40V Single/Dual/Quad High Voltage PP/OD Comparators

Features

EC Table specifications:

- Wide Supply Range: +2.4V to +40V
- Low IQ : **5uA/Ch** (typ)
- Low IB : 150fA (typ)
- Prop Delay: 420-ns (typ @ 100mV OD)

Key Performance:

- ESD: 2kV HBM, 500V CDM
- Input Voltage Range: **(V-) - 0.2 V to (V+) + 0.2 V**
- Output structure: Push-Pull (181X)/Open Drain(182X)

Additional Features:

- **Known Start-Up Condition**
- Operating Temp: - 40°C to 125°C
- Package Options:

TLV1811 → SOT-23, SC-70-5, SC-70-6

TLV1812 → SOIC, TSSOP, VSSOP, SOT, WSON

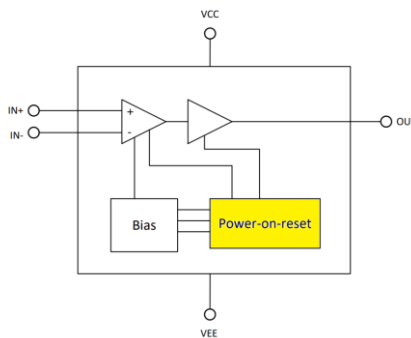
TLV1814 → SOIC, SOT23-THIN, TSSOP, WQFN

Applications

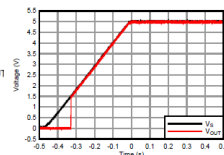
- Smart Meter (Gas/Water/Electric)
- Medical
- Communications
- Lighting
- Motor Drives
- Factory Automation and Control

Benefits

- Wide supply range and **Rail to Rail** capability enables easy level translation & precise diagnostic functions across power supplies
- **Lower IQ** and Smaller propagation delay provides excellent figure of merit and delivers value for powered constrained applications
- POR circuitry provides known startup condition even as supply voltage ramps – eliminates need for power sequencing
- Smaller Leadless options saves board space and Standard Leaded package options provides pin to pin compatibility

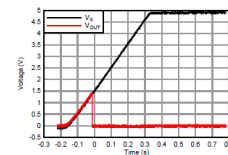


Push-Pull



output is held low
+IN > -IN

Open Drain



output is high-impedance
+IN < -IN

TLV183X/184X

AEC Q100 Planned

300
mm

40V Single, Dual, and Quad Channel High Speed Comparator Family

Features

- Wide Supply Voltage Range: +2.4V to +40V
- Propagation Delay ($V_{OD} = 100\text{mV}$): 50nS
- Low Offset Voltage (Max): 4 mV
- Quiescent current (per channel): 65uA
- R2R inputs and outputs
- Known Start-up Conditions
- Outputs: Open Drain and Push Pull
- Sourcing (PP only) and Sinking Capability: 30mA
- Operating Temperature Range: -40°C to 125°C

Additional Features:

- Known Start-Up Condition**
- Operating Temp: -40°C to 125°C
- Package Options:

TLV1831/41 → SOT-23, SC-70-5, SC-70-6

TLV1832/42 → SOIC, TSSOP, VSSOP, SOT, WSON

TLV1834/44 → SOIC, SOT23-THIN, TSSOP, WQFN

Applications

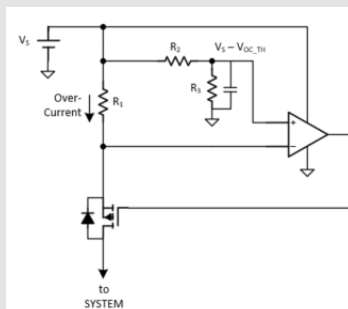
- Body Electronics and Lighting
- Passive Safety
- Grid Infrastructure
- Appliances
- Voltage Monitoring
- Short Circuit Current Monitoring

Benefits

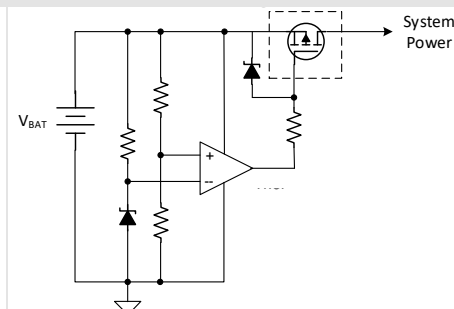
- Wide supply range and low propagation delay offers high speed performance for both high and low voltage systems
- Low input Offset delivers excellent DC precision for accurate voltage detection
- Wide input dynamic range from $(V_{EE})-0.2$ to $(V_{CC})+0.2\text{V}$
- Known start-up conditions for all variants removes output glitches that impact downstream devices
- Open drain outputs allow for level shifting

Common Functionality

Short Circuit Current



Over-Voltage



TLV185X/6X

AEC Q100 Planned

Nanopower 40V Single/Dual/Quad OD/PP Comparator

Features

Key Specifications:

- Quiescent Current: **560 nA**
- Supply Range: **1.8V to 40V**

Key Features:

- Input: up to 40V independent of supply
- Output: Push-Pull (5X) / Open-Drain (6X)
- Known Start-Up Conditions
- Reverse Battery Protection

Package/Operating Temp:

- Temperature Range: -40°C to 125°C
- Single (TLV1851/61): SOT-23
- Dual (TLV1852/62): SOIC, VSSOP
- Quad (TLV1854/64): SOIC, TSSOP

Applications

- Mobile phones and tablets
- Headsets/headphones & earbuds
- PC & notebooks
- Gas Detector
- Smoke & heat detector
- Motion Detector
- Gas Meter
- Servo drive position sensor

Benefits

- Wide supply range and over the rail common mode input capability **broadens end equipment adoption**
- Lower IQ well suited for powered constrained systems
- Reverse battery protection provides additional protection in applications where the comparator is directly connected to a battery.
- Smaller Leadless options saves board space and Standard Leaded package options provides pin to pin compatibility

Specs	TLV185X / TLV186X	TLV370X / TLV340x
	P2P	P2P
AEC-Q100	Yes	Yes / No
Supply Voltage	1.8V to 40V	2.7V to 16V
V _{OS} (max @ 25C)	3.6 mV	5 / 3.6 mV
I _Q per channel	560 / 440 nA	560 / 470 nA
Prop Delay (typ)	13 μ s	36 / 55 μ s
Output Type	Push-Pull (TLV185X) Open-Drain (TLV186X)	Push-Pull (TLV370X) Open-Drain (TLV340X)
Temperature (C)	-40 to 125	-40 to 125
Additional Features	Reverse battery protection up to 40V Failsafe inputs Known Start-Up Condition	Reverse battery protection up to 18V

TLV187x Input & Output Supplies

36V Single, Dual Channel High Speed Comparator Family

AEC Q100 Planned

300
mm

Features

Specifications:

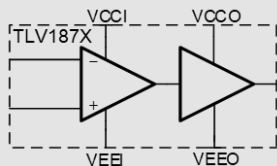
- Propagation Delay **65ns**
- Input Offset Voltage: 4 mV (max @ 25C)
- Quiescent Current: 65 uA

Key performance:

- Differential Input Supply Range: **+2.7V to +40V**
±1.35V to ±20V
0V to VCCI
- GND referenced outputs Range:

Additional Features:

- R2R Inputs
- Known Start-up Conditions
- Package Options:



WSOP-10 (Dual)
VSSOP-10 (Dual)

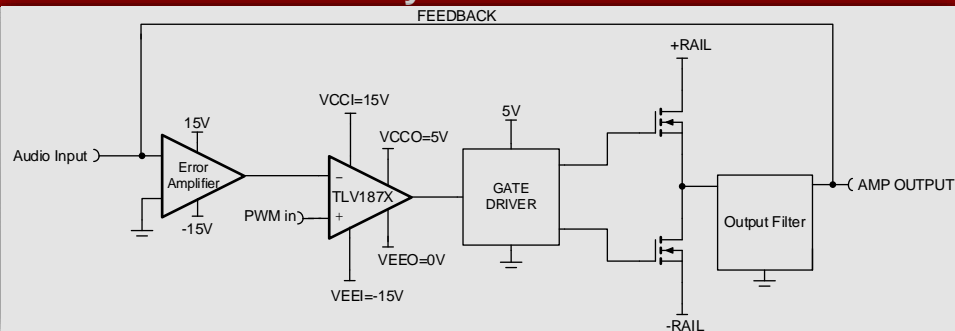
Applications/EE

- High Speed Current Detection
- Passive Safety
- Grid Infrastructure
- Level Shifting HV/LV
- Zero Cross Detect
- Class-D Amplifier Level Shifting

Benefits

- Take bipolar signals on inputs with split supply operation to level shift outputs to single supply, push-pull outputs
- Wide supply range and low propagation delay offers high speed performance for both high and low voltage systems
- Separate, push-pull output supplies eliminate the need for a pull-up resistor and offers propagation delay symmetry

Common Functionality



TLV192x: 65V Comparator

AEC Q100 Planned

300 nm

Single and Dual Channel with Integrated REF

Features

Specifications:

- Propagation Delay: **< 1 us**
- Input Offset Voltage: **3 mV (max @ 25C)**
- Output Type: **Open-Drain**

Key performance:

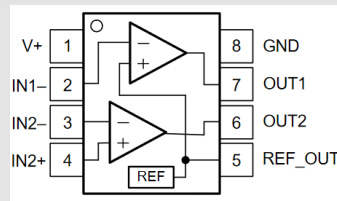
- Supply Range: **4.5V to 65V**
- Input range: **Up to 65V**
- Quiescent Current: **20 uA**

Additional Features:

- **65V Fail Safe Inputs**
- Externally Available Int. Ref: **2.5V, 1.75%**
- Package Options: **Dual: WSON-8, SOIC-8
Single: WSON-8**

Applications/EE

- PELV/SELV voltage monitoring
- Power loss dual UV detection
- DC-DC Conversion protection
- 24V Industrial Backplane voltage monitoring

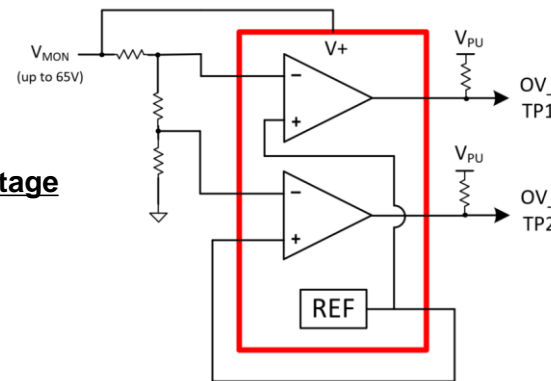


Benefits

- Wide supply range and low quiescent current offers low power performance for **PELV/SELV** voltage supplies
- 65V inputs eliminates concern for HV shorts or opens in divider network
- Externally available reference allows for health checks and design flexibility

Common Functionality

Dual Over-Voltage Application



Getting started

You can start evaluating this device leveraging the following:

Content type	Content title	Link to content or more details
Product folder	TI 40V+ Comparators Portfolio	https://www.ti.com/amplifier-circuit/comparators/products.html#358max=40%3B40&
Customer training series	High Voltage Comparators Selection Guide	https://www.ti.com/video/6329361150112
	Comparator Input Types	https://www.ti.com/lit/pdf/snoaa91
Applications Documentation	(Product Overview) SAE J1772 Pilot Wire System in EV Charging Stations w/ Comparators	https://www.ti.com/lit/pdf/snot034
	(Application Brief) Voltage Supervision with a Comparator	https://www.ti.com/lit/pdf/snoaaa2
	(Circuit Design) High-Side Current Sensing with Comparator Circuit	https://www.ti.com/lit/pdf/sboa306
Selection and design tools and models	TLV1872 PSpice Model TLV1872 TINA-TI Model (also available for all TLV18XX variants)	https://www.ti.com/product/TLV1872#design-tools-simulation

Visit www.ti.com/npu

For more information on the New Product Update series, calendar and archived recordings



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