

# New Product Update

The Most Versatile Operational Amplifiers  
for your Automotive Systems

TLV900x-Q1 and OPAx991-Q1

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**Esteban Garcia**

Product Marketing Engineer

# Agenda

- How and where to use amplifiers
- Factors when choosing the right amplifier
- New products: TLV900x-Q1 and OPAx991-Q1 overview
- Amplifiers in:
  - Electric vehicle communication controller
  - On-board charger
  - DC/DC converter
  - Battery management systems

# Why an Operational Amplifier?

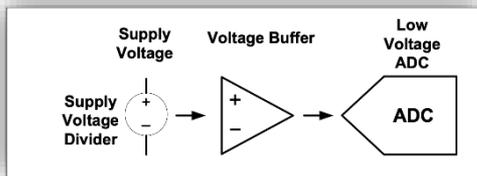
**Amplifier** noun

am-pli-fi-er

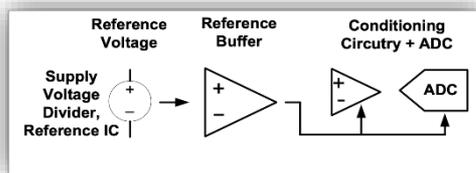
: one that **amplifies**

Specifically, an electronic device (as in a stereo system) for amplifying voltage, current or power.

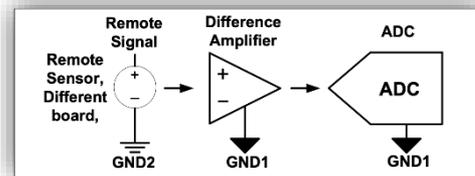
# How are amplifiers used?



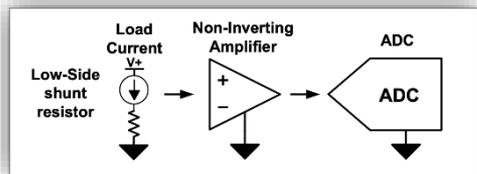
Voltage supervision



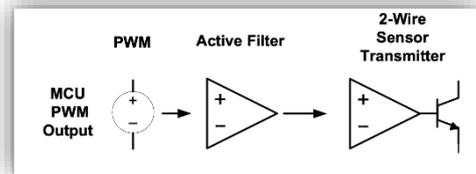
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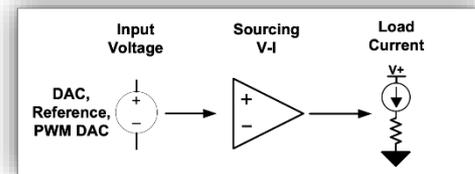
Difference amplifier



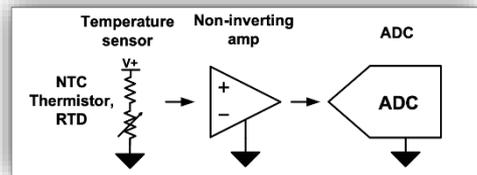
Current sensing



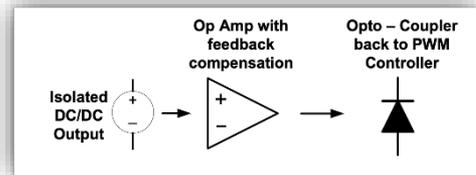
Active filter



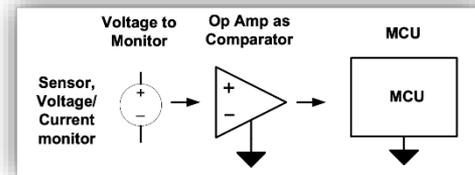
Voltage-to-current converter



Temperature & pressure sense

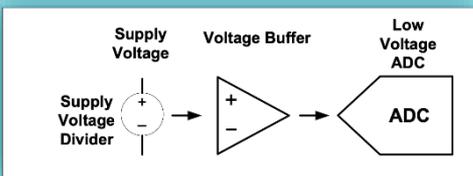


Power supply (flyback) feedback

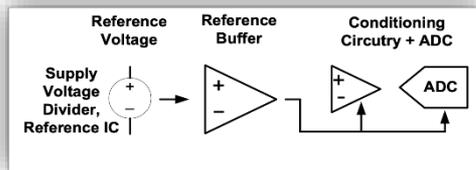


Op amp as a comparator

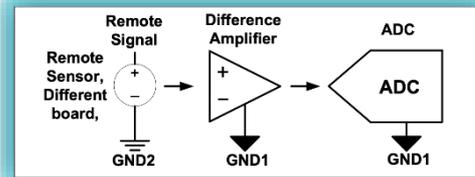
# How are amplifiers used?



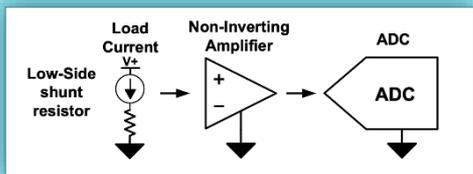
Voltage supervision



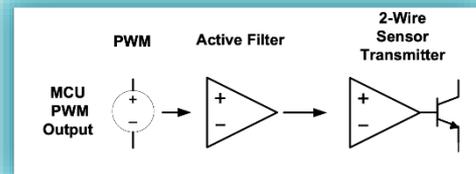
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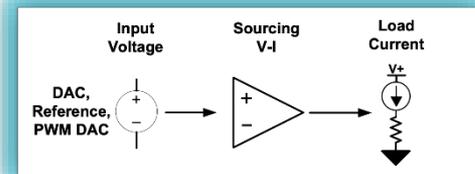
Difference amplifier



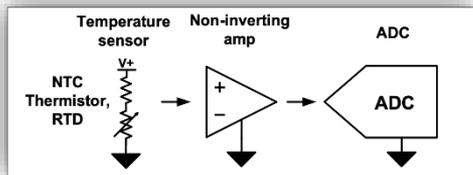
Current sensing



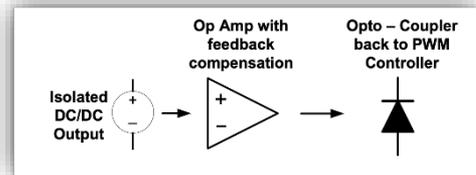
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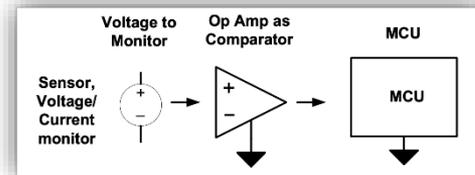
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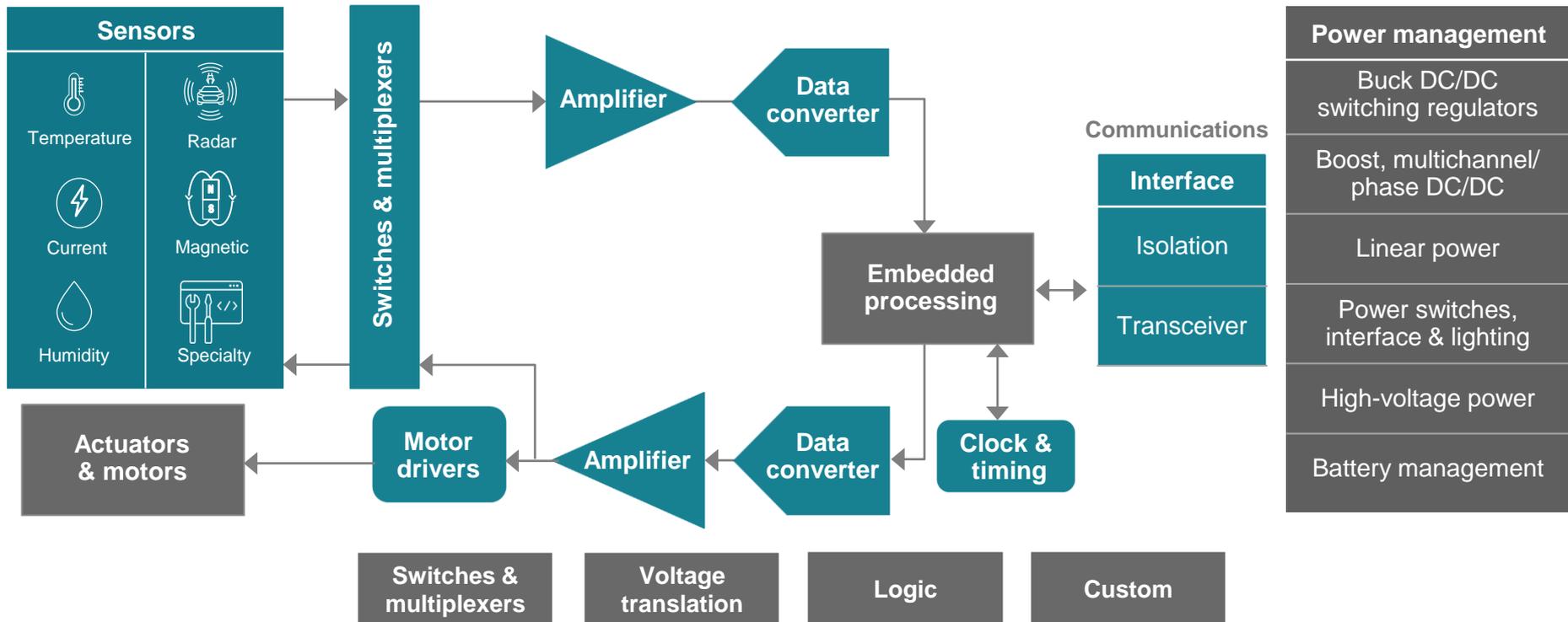


Power supply (flyback) feedback

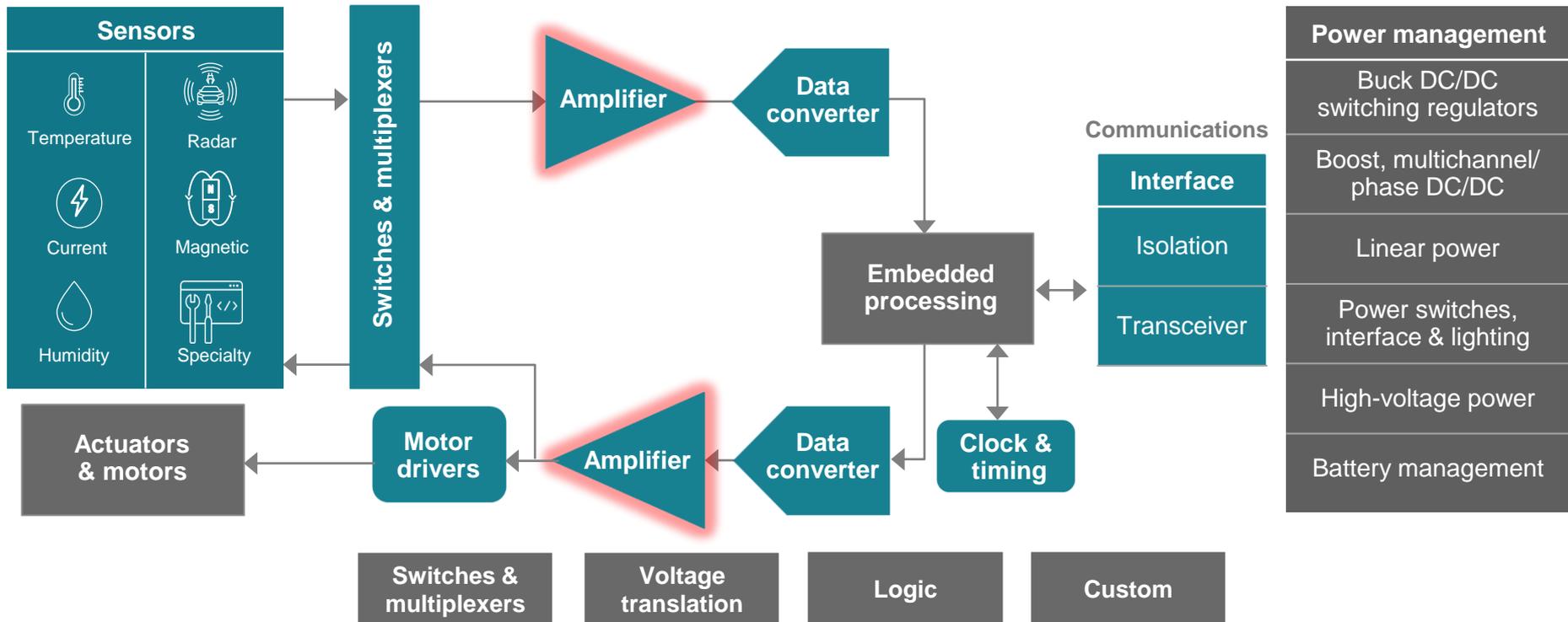


Op amp as a comparator

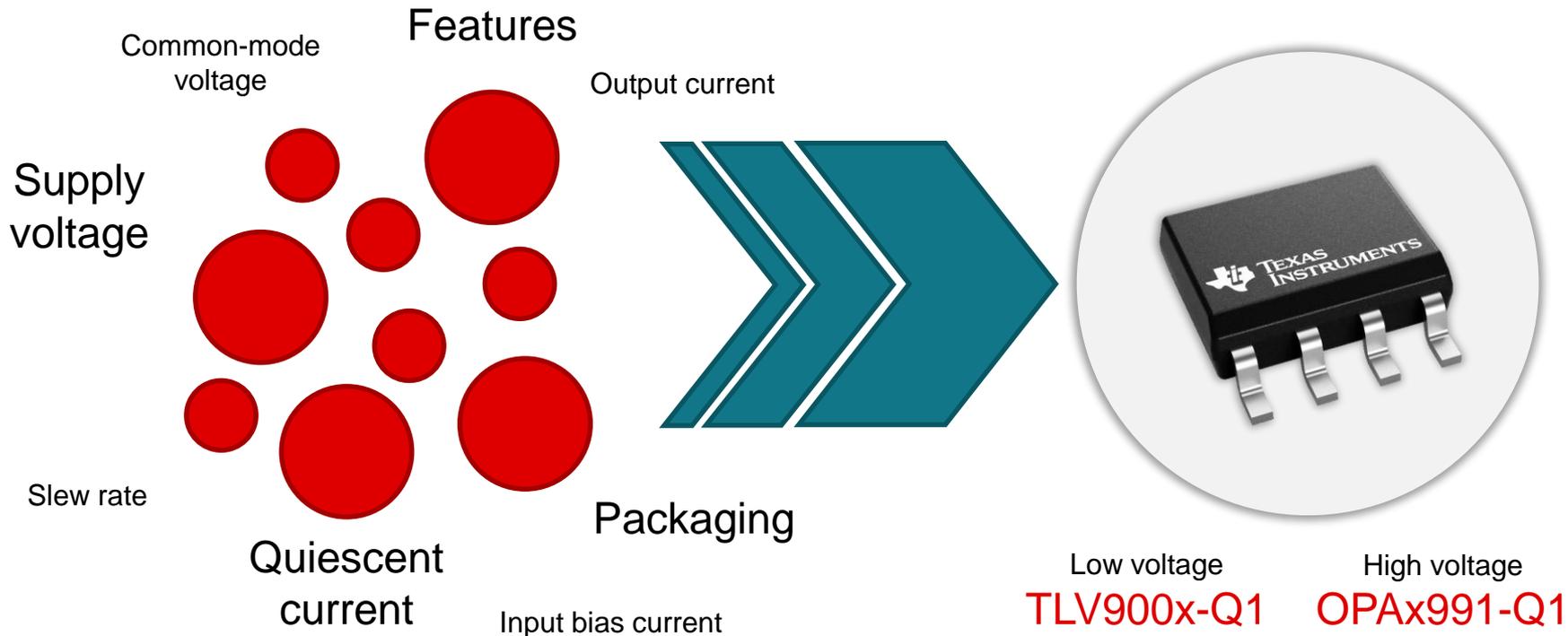
# Analog signal chain



# Analog signal chain



# Choosing the right operational amplifier



# Choosing the right operational amplifier

## TLV900x-Q1

- **Supply voltage:** 1.8V to 5.5V
- **Quiescent current:** 60µA per channel
- **Gain bandwidth:** 1MHz, unity gain stable
- **Slew rate:** 2V/µs
- **Offset voltage:** 0.4mV (Typ.), 1.85mV (max.)
- **Offset voltage drift:** 0.6 µV/°C (Typ.)
- **Input bias current:** 10pA
- **Output current:** 40mA
- **Noise, THD+N:** 30nV/√Hz, 0.0001%
- Rail-to-rail input/output and no phase reversal

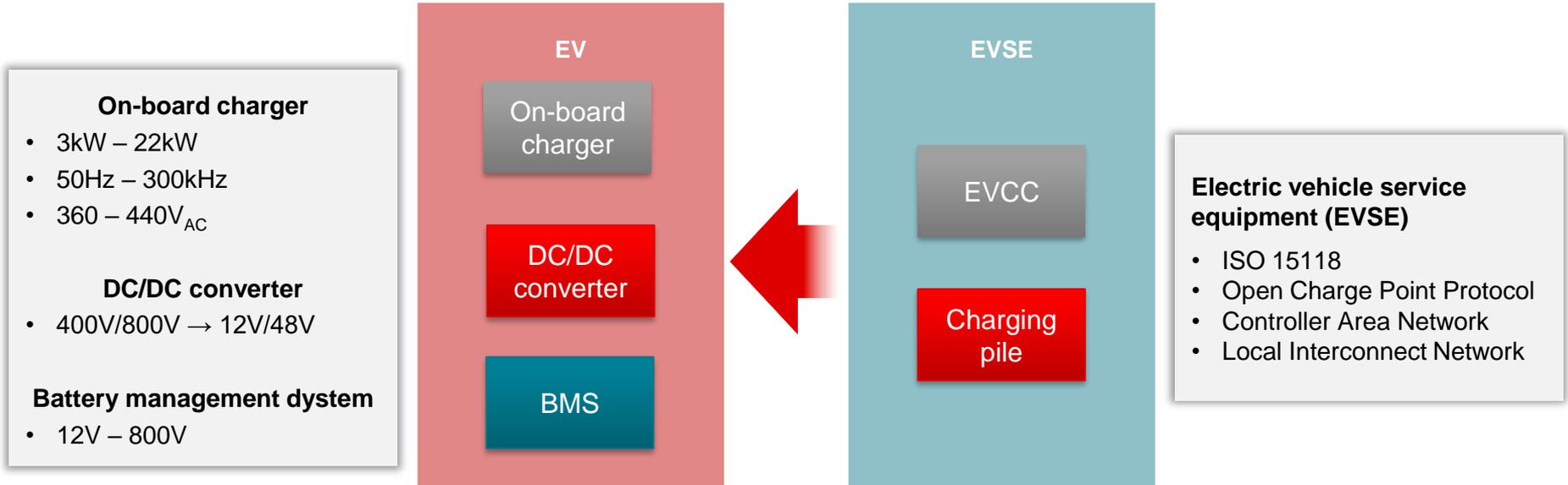
	TLV9001-Q1	TLV9002-Q1	TLV9004-Q1
<b>Package</b>	SOT23-5 SC70-5	SOIC-8 VSSOP-8	SOT-23-14

## OPAx991-Q1

- **Supply voltage:** 2.7V to 40V
- **Quiescent current:** 560µA per channel
- **Gain bandwidth:** 4.5MHz, unity gain stable
- **Slew rate:** 21V/µs
- **Offset voltage:** 0.75mV (Typ.), 0.0896mV (max.)
- **Offset voltage drift:** 0.3µV/°C (Typ.)
- **Input bias current:** 10pA
- **Output current:** 75mA
- **Noise, THD+N:** 10.8 nV/√Hz, 0.0001%
- Rail-to-rail input/output and no phase reversal

	OPA1991-Q1	OPA2991-Q1	OPA4991-Q1
<b>Package</b>	SOT-23-14	SOIC-8 TSSOP-8 VSSOP-8	SOIC-14 TSSOP-14 SOT-23-14

# EV and EV service equipment architecture

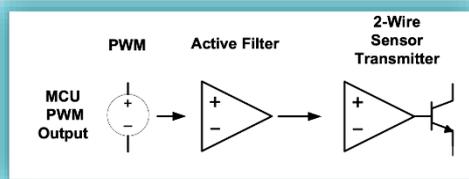


# EVSE → EV communications controller

## EVSE → On-board charger

- L1: Single-phase AC voltage
- L2: 3-phase AC Voltage
- L3: 3-phase AC Voltage
- N: Neutral
- PP: Proximity pilot
- PE: Protective Earth
- CP: Control pilot

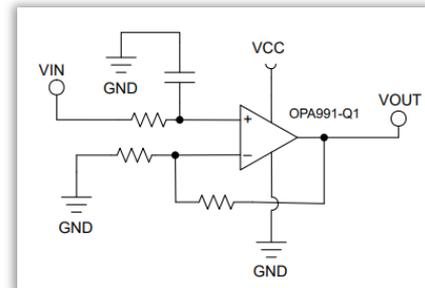
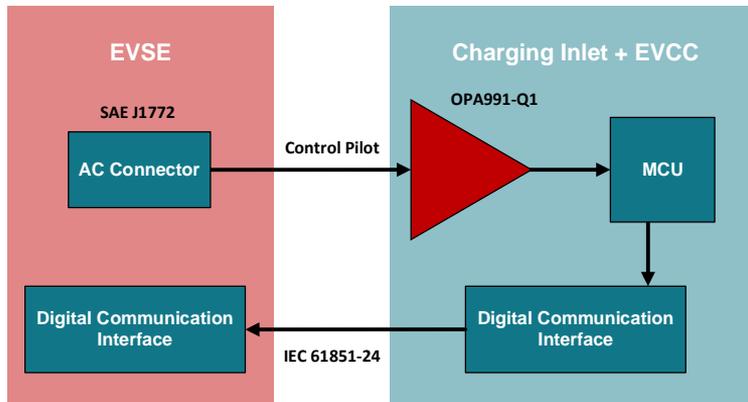
OPA991-Q1	
Supply voltage	2.7V to 40V
$V_{CM}$	$(V-) - 0.1V$ $(V+) + 0.1V$
GBW	4.5MHz
Slew rate	21V/ $\mu$ s



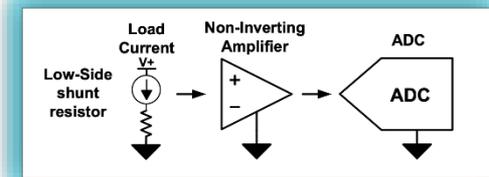
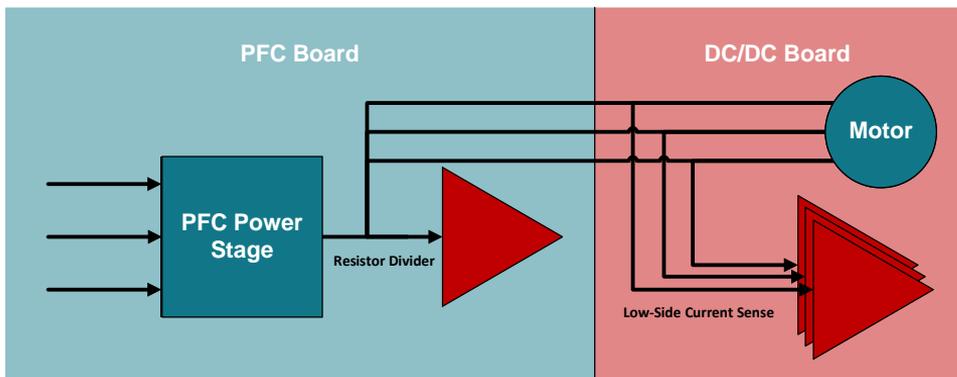
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Pilot signal = 1kHz, -12V to +12V square wave

- Common-mode voltage: At least to 24V

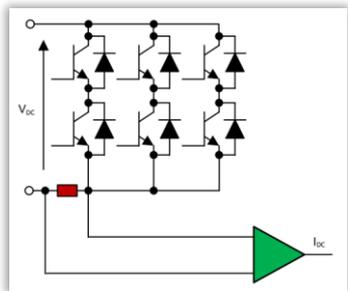


# On-board charger

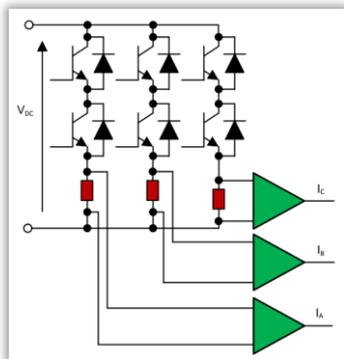


Current sensing

Single-shunt



Three-shunt



## TLV9001-Q1

Supply voltage	1.8V to 5.5V
$V_{CM}$	$(V-) - 0.1V$ $(V+) + 0.1V$
GBW	1MHz

## Configuration

## Benefits

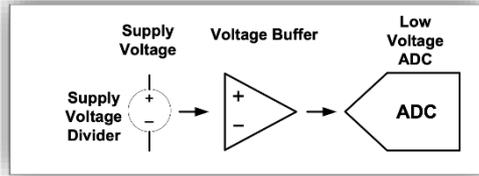
Single-shunt

- Can measure the power supply current
- Quicker current sensing

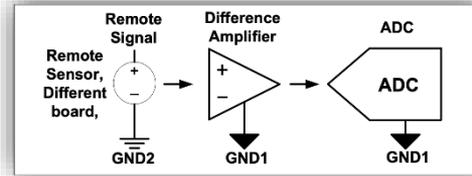
Three-shunt

- Robust
- Achievable with slower/cheaper op amps
- Easier to achieve circuit overmodulation

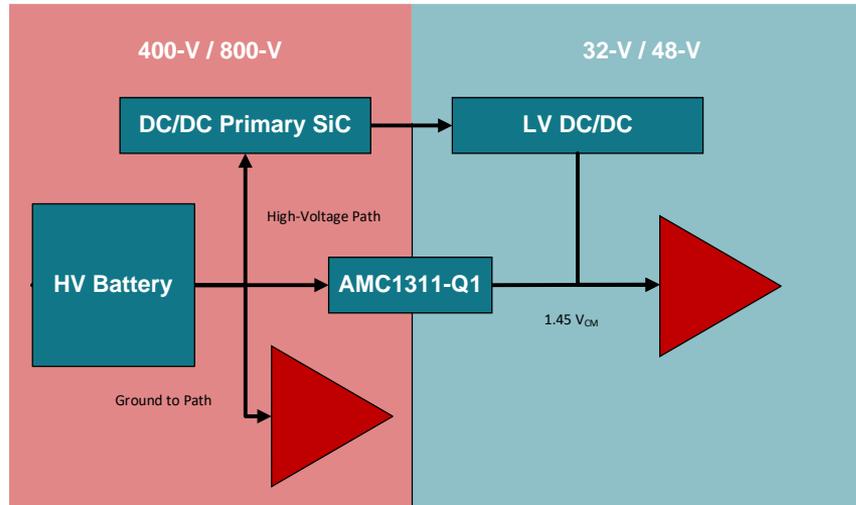
# DC/DC converter



Voltage supervision

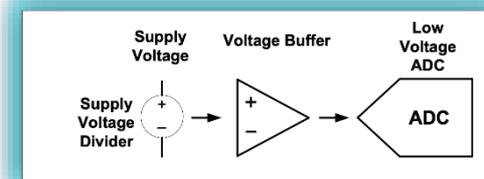


Difference amplifier

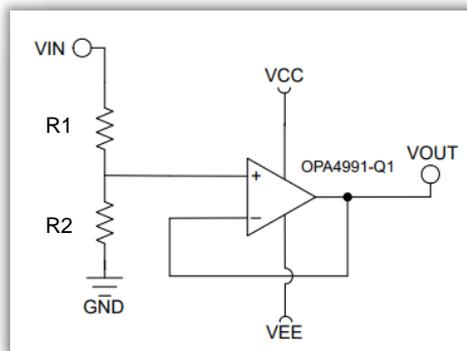
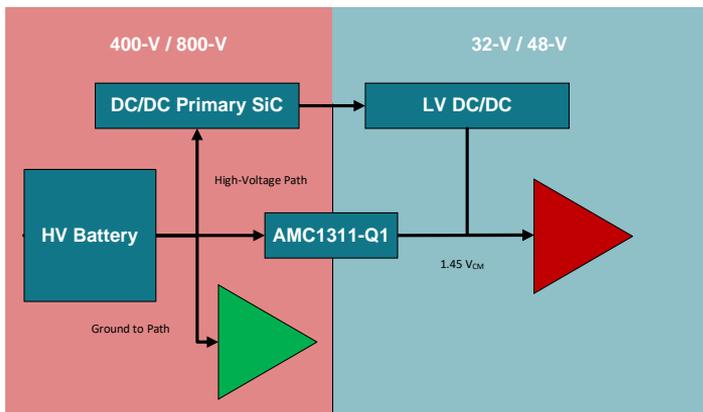


# DC/DC converter

OPA991-Q1	
Supply Voltage	2.7V to 40V
$V_{CM}$	(V-) - 0.1V (V+) + 0.1V
GBW	4.5MHz



Voltage supervision

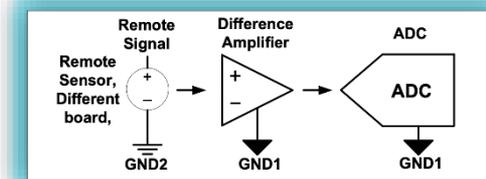


## Resistor Divider for voltage scaling

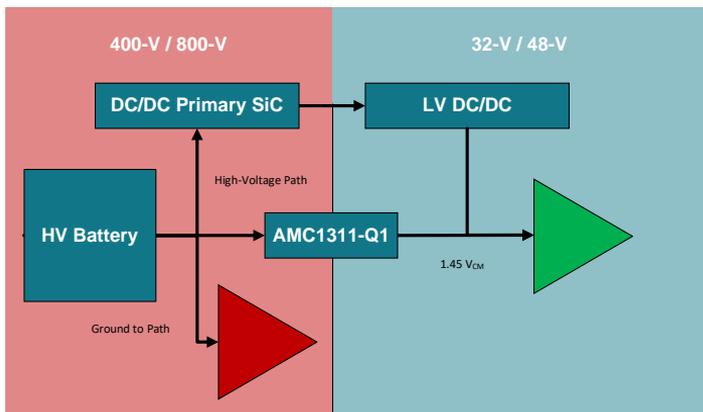
- Cheap
- Simple
- Power-hungry
- Isolation is not achieved

# DC/DC converter

TLV9001-Q1	
Supply voltage	1.8V to 5.5V
$V_{CM}$	$(V-) - 0.1V$ $(V+) + 0.1V$
GBW	1MHz



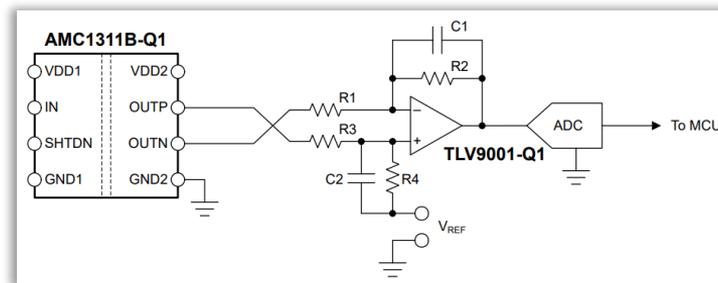
Difference amplifier



AMC1311-Q1 Analog Output Specs.	
Output common-mode voltage	1.44 V
Output bandwidth	220 kHz – 275 kHz

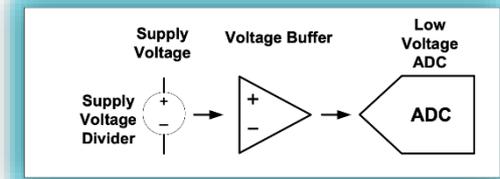
Current Sensing with an Isolated Amplifier

- Isolation is achieved
- Additional external passives required

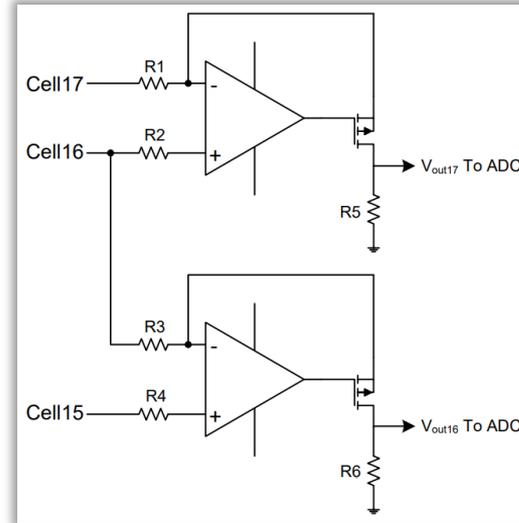
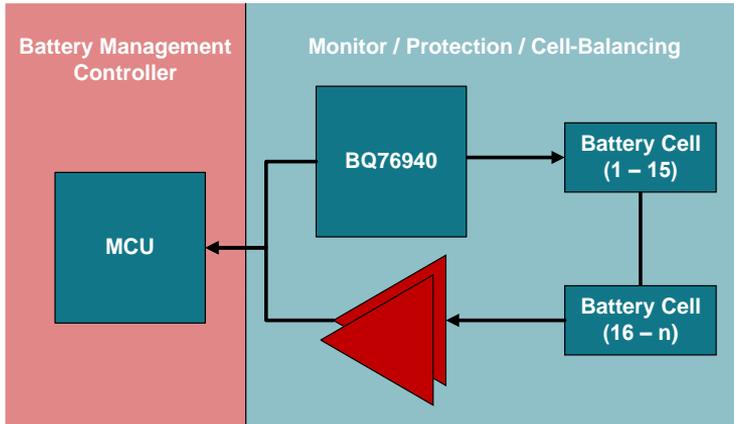


# Battery management system

OPA991-Q1	
Supply Voltage	2.7V to 40V
$V_{CM}$	(V-) - 0.1V (V+) + 0.1V
GBW	4.5MHz



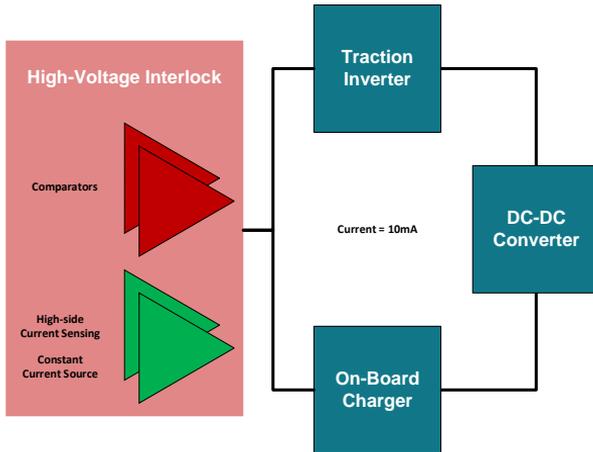
Voltage supervision



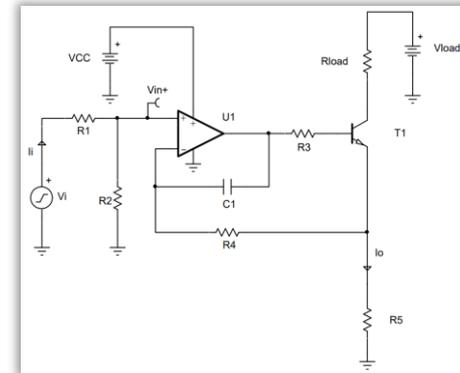
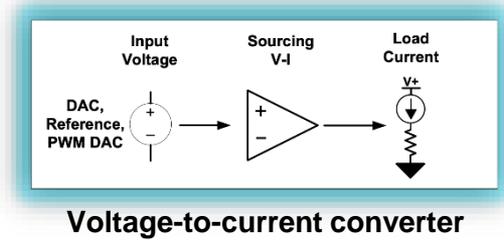
# Battery management system

## Key notes

- OEM requirement of 5mA – 30mA HVIL current is satisfied
- Ability to detect four situations
  - Normal operation
  - Open connection
  - Short to battery
  - Short to ground



TLV900x-Q1	
Supply voltage	1.8V to 5.5V
$V_{CM}$	$(V-) - 0.1V$ $(V+) + 0.1V$
GBW	1MHz



Input	Output	Supply		
$V_i$	$I_o$	$V_{cc}$	$V_{ee}$	$V_{load}$
5V	10mA	5V	0V	5V

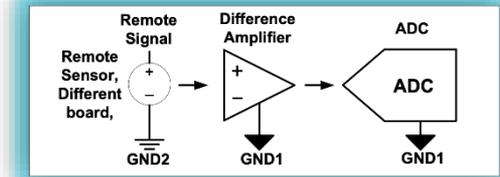
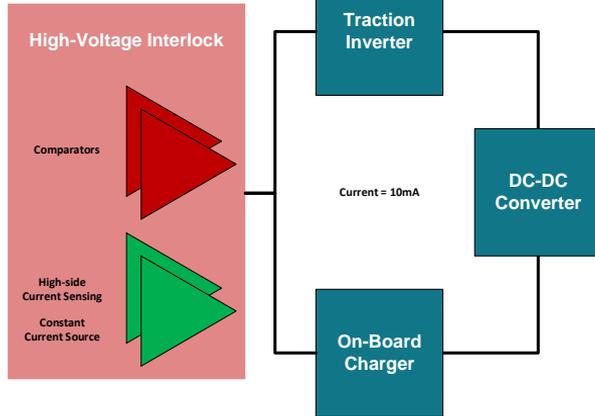
# Battery management system

## Key Notes

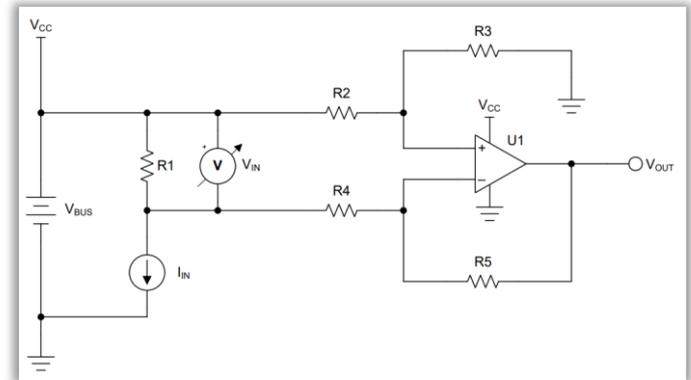
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## TLV900x-Q1

Supply voltage	1.8V to 5.5V
$V_{CM}$	$(V-) - 0.1V$ $(V+) + 0.1V$
GBW	1MHz



Difference amplifier



Input	Output	Supply	
$I_{IN}$	$V_{OUT}$	$V_{CC}$	$V_{EE}$
10mA	2.5V	5V	0V

# Getting started

You can start evaluating this device leveraging the following:

Content type	Content title	Link to content or more details
Product folder	TLV9002-Q1 product folder OPA2991-Q1 product folder	<a href="#">TLV9002-Q1</a> <a href="#">OPA2991-Q1</a>
Reference design	Automotive high-voltage interlock loop (HVIL)	<a href="#">Learn more here</a>
Reference design	Automotive shunt-based isolated current sensor for DC/DC and OBC applications	<a href="#">Learn more here</a>
Application Brief	Interfacing a differential-output (Isolated) amp to a single-ended input ADC	<a href="#">Learn more here</a>
Application Brief	Charging the Future of EVs with Operational Amplifiers	<a href="#">Learn more here</a>
Development tool or evaluation kit	DIP-ADAPTER-EVM	<a href="#">Get started here</a>



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