Industrial Systems

Solutions Guide

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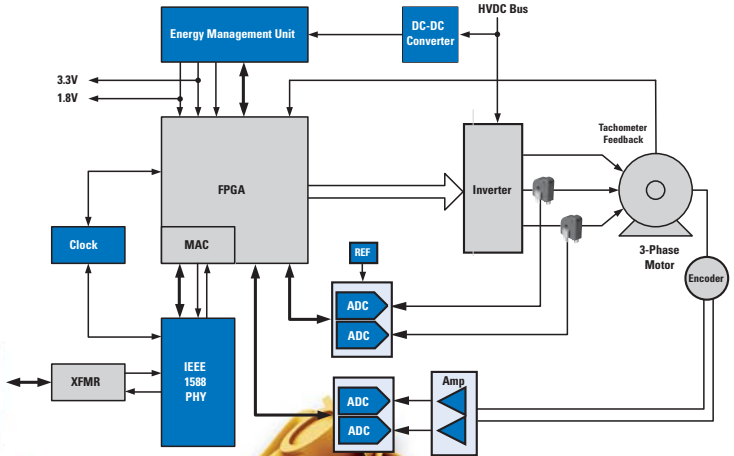
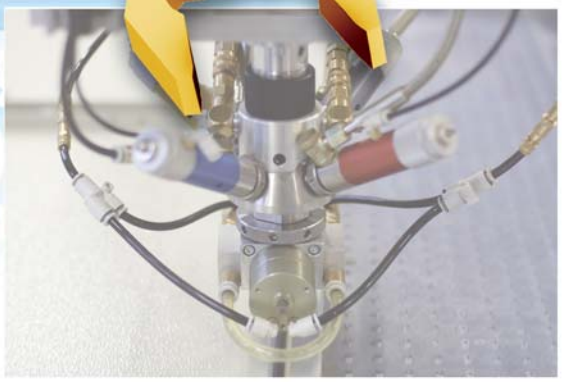
2009 Vol. 1

- Industrial Applications
- Amplifiers
- Data Converters
- Clock and Timing Solutions
- Interface Solutions
- Thermal Management
- Power Management

PowerWise®





National Semiconductor

Industrial Solutions

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National Semiconductor is a proven and trusted solutions provider and partner in the industrial market. National's highest-standard quality, reliable production, and world-class supply chain management make National the clear choice in analog semiconductor products for a variety of industrial applications.

National's analog and power management products and subsystems deliver robust system performance, diagnostics, precise timing control, and high-accuracy signal processing to production facilities and factory floor machinery. The company's energy-efficient products, combined with PowerWise subsystem reference designs, address process sensing and measurement, motor control, automation control networks, and machine vision applications. National's WEBENCH® Designer tools allow engineers to easily create designs that can be optimized for cost, efficiency, or size.

Automation Control Networks

National's precision PHYTER® 10/100 Ethernet PHY solutions provide high-bandwidth, low-latency networked solutions that enhance system reliability over temperature. The PHYTER transceiver with IEEE 1588 Precision Time Protocol (PTP) enables distributed control and provides high-precision timing synchronization.

Motor Control Sensing

National's precision amplifiers, data converters, temperature sensors, power management, and PHYTER transceivers enable higher-quality products at higher speeds via improved motor control, finer production control, and lower power consumption to reduce production costs. National solutions support high-performance simultaneous-sampling AC and servo motor control. National's IEEE 1588 solutions achieve high-speed synchronization (at tens of nanoseconds) for higher quality at higher speeds.

Machine Vision

National's 28-bit Channel-Link devices are the industry standard (Camera Link) for machine vision connectivity. The easy-to-use serializer/deserializer and signal conditioning devices extend cable reach over harsh industrial environments for high-resolution imaging applications. The company's camera synchronization solutions enable distribution and synchronization of high-resolution video content, while the wide industrial-grade portfolio enables smart cameras, nano-heads and processing nodes.

Sensing Applications

National's analog solutions support all key sensing applications. Precision amplifiers and data converters provide accuracy and speed to enable better process control and more uniform products, less fallout, and quicker response times. The WEBENCH Sensor Designer tool significantly reduces design time and cost by configuring a complete sensor signal path solution with just a few key strokes.

Powering Industrial Applications

Whether a system requires efficiency, reliability, ease of use, or precision, National offers a variety of power management products to meet the requirements. These solutions include a broad family of voltage references and low dropout (LDO) linear regulators to drive sensitive analog and digital loads as well as regulators and controllers that can convert wide input voltage ranges down to low output voltages needed at the Point of Load (PoL). In addition, the family of in-rush current controllers provides industrial systems with an additional layer of protection in over-current or short circuit events.

To see all of National's industrial solutions, visit: **www.national.com/industrial**

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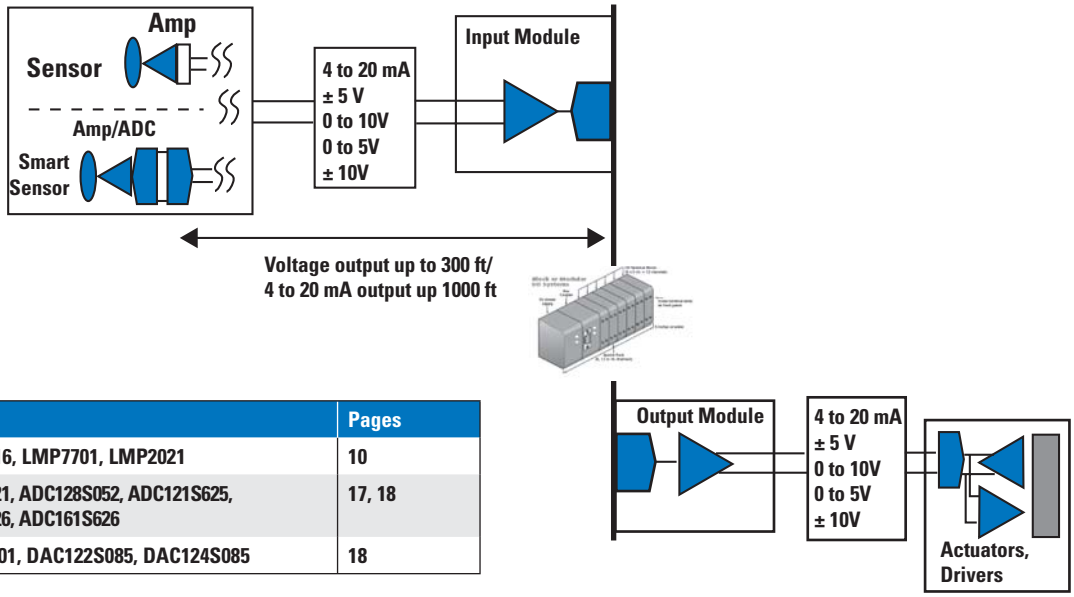
Industrial Application Overview

Input to I/O Module

Output from I/O Module



Solutions	Examples	Pages
Amplifier	LMP7715/16, LMP7701, LMP2021	10
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Industrial Control Networks

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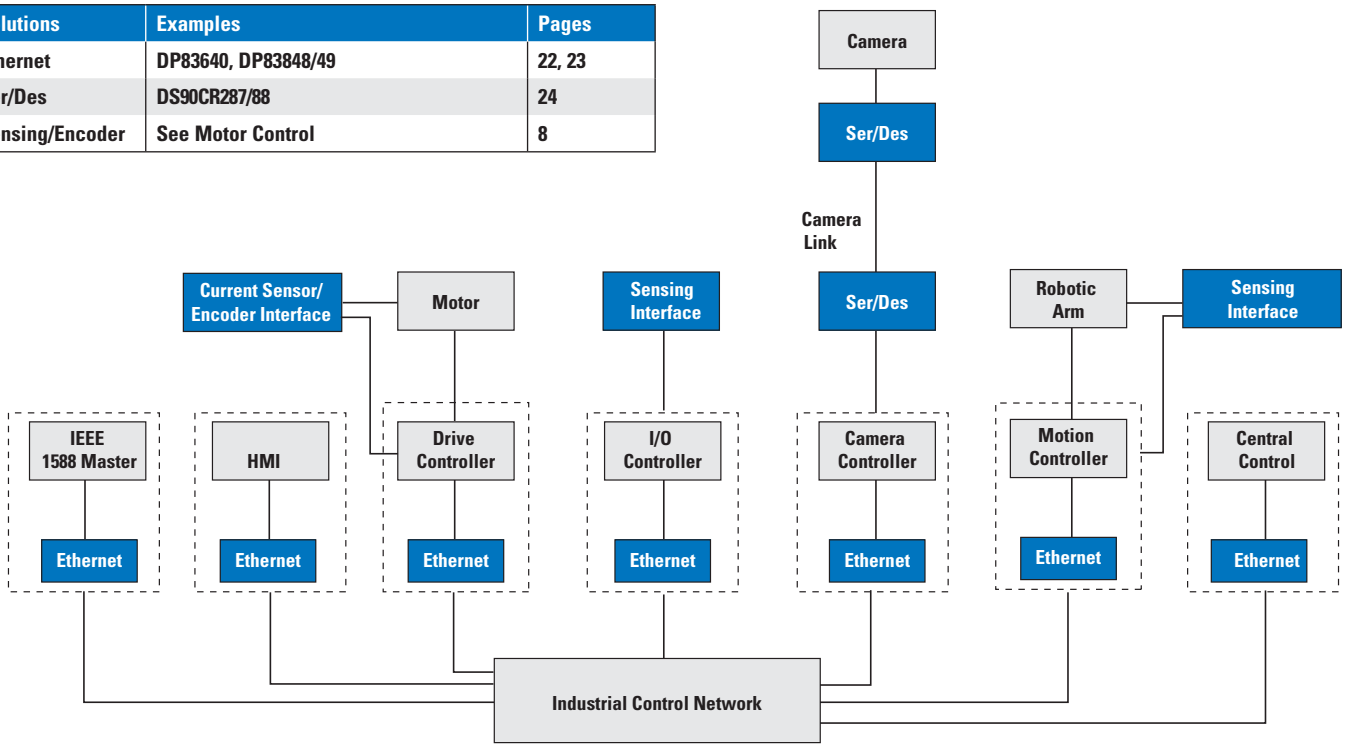
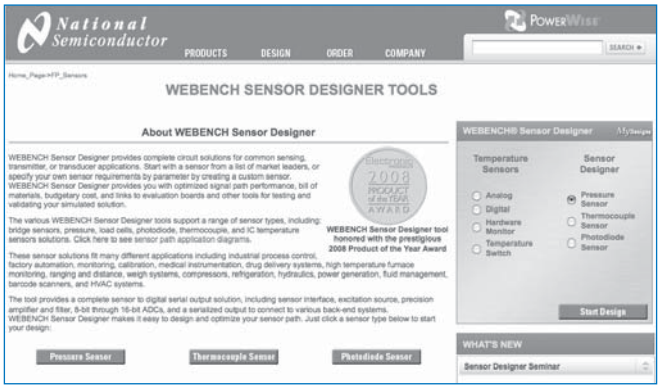


Solutions for Pressure Sensors, Load Cells, Thermocouples, and Optical Sensors

Reduce design time – move rapidly from concept to design to prototyping

- Select a sensor
- Modify key parameters to meet specification application needs
- WEBENCH® Sensor Designer tool creates a complete design (schematic, BOM, detailed error analysis)
- Customized solution to meet specific performance needs
- A "Build It" option (PC board/components from design) expedites prototyping



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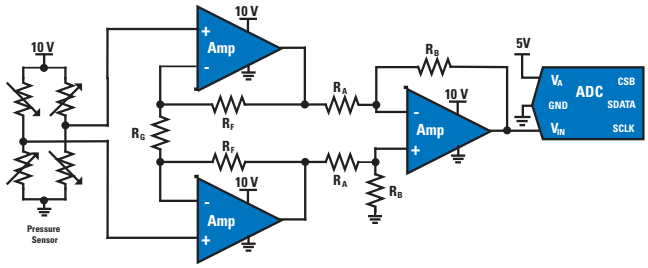
Pressure, Load, Force

Instrumentation Amplifier Configuration



Solutions	Examples	Pages
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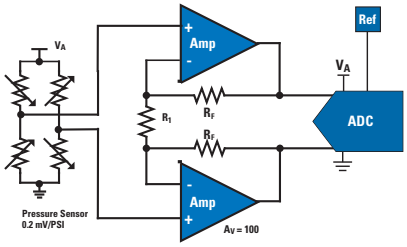
Differential Amplifier Configuration



Solutions	Examples	Pages
Amplifier	LMP7715/16, LMP2021/22	10
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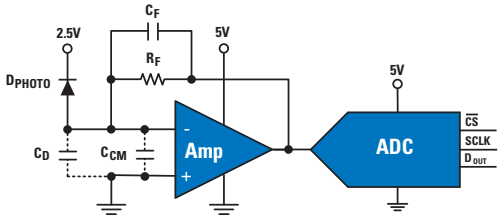
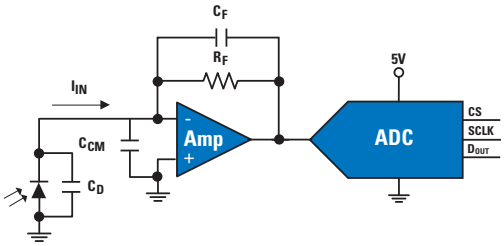
Photoconductive/Photovoltaic

Photoconductive diode is biased, provides faster response



Photovoltaic more linear, no leakage current. Generates voltage proportional to light



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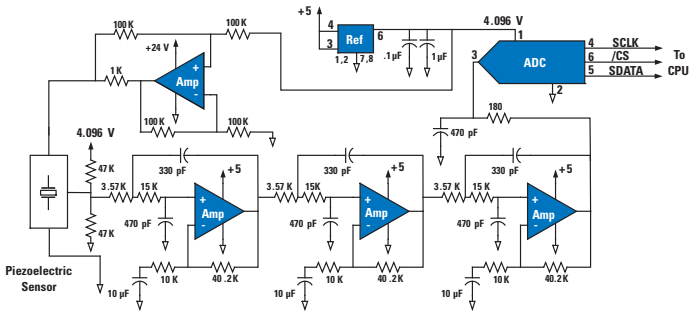
Precision Sensing

Vibration



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ADC	ADC141S626, ADC161S626	18
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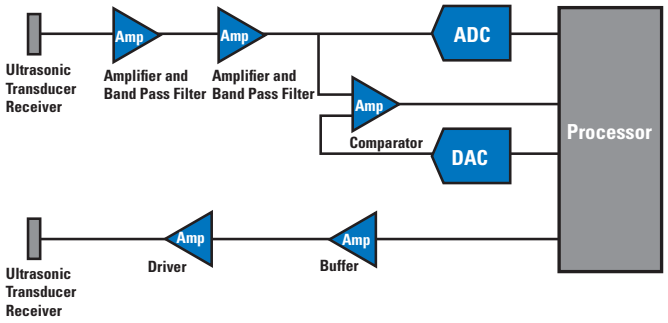
Ultrasonic Speed Sensing



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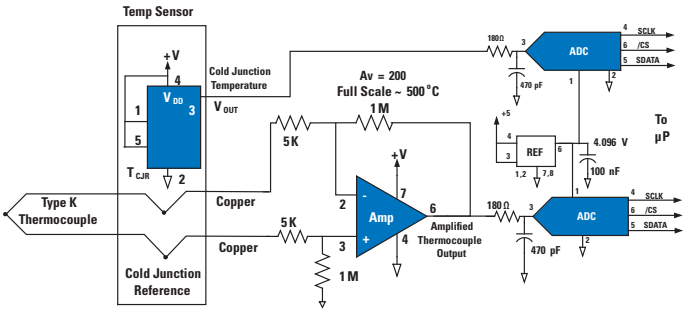
Temperature-Thermocouple Interface



Solutions	Examples	Pages
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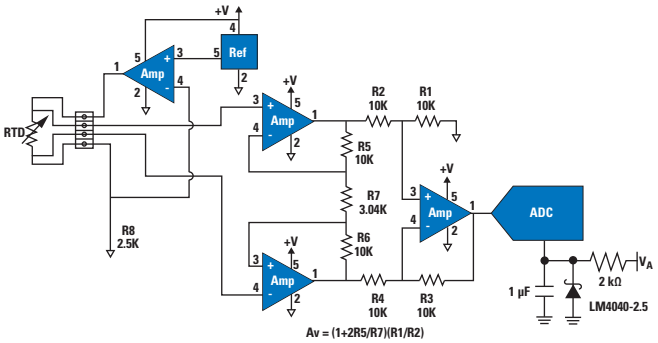
Temperature-RTD



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ADC	ADC121S021, ADC121C02x	17, 18
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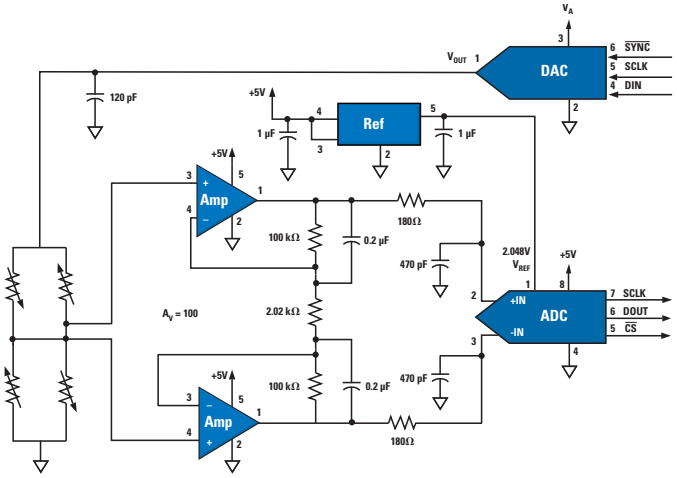
Setting Control Points/Sensor Drive

Variable Sensor Voltage Drive (adjusts sensor output)



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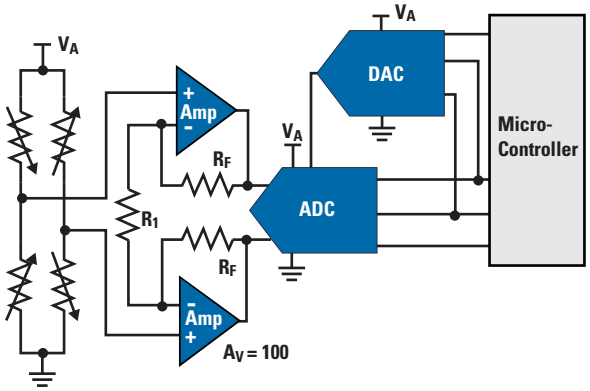
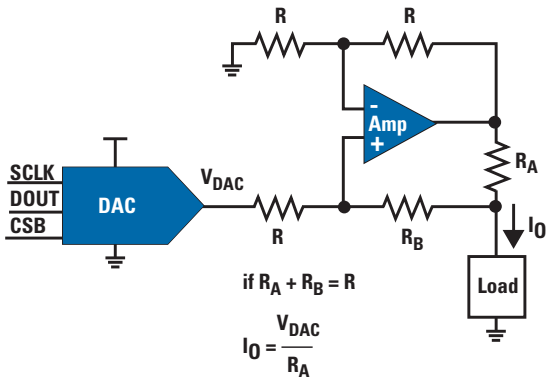
Adjustable ADC Reference (adjusts ADC range)



Solutions	Example	Pages
Amplifier	LMP7701/02	10
DAC	DAC101S101, DAC121S101	18
ADC	ADC121S625	18

Variable Current Source



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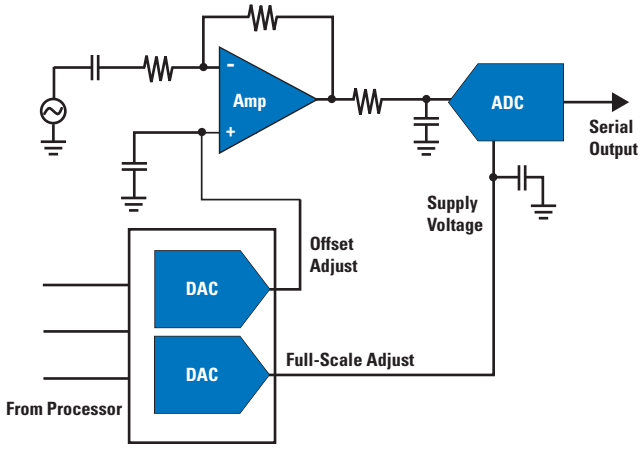
DAC	DAC081S101, DAC101S101	18

Offset and Gain Calibration



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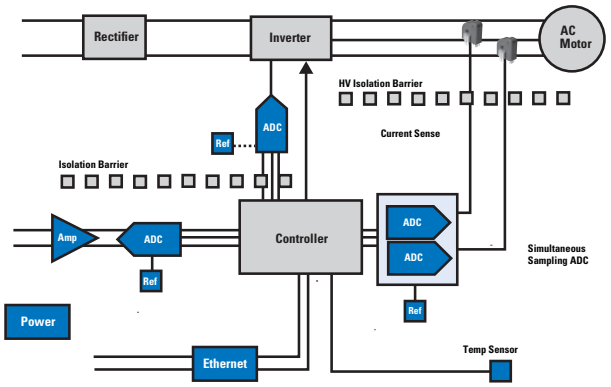
Motor Control Sensing

AC Motor



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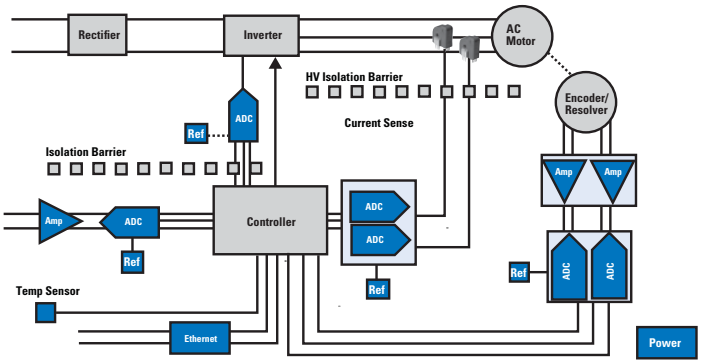
Servo Motor Control



Solutions	Examples	Pages
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ADC	ADC121S021, ADC121S625, ADC122Sxxx, ADC161S626	17, 18
Ethernet	DP83640, DP83848/49	22 - 23
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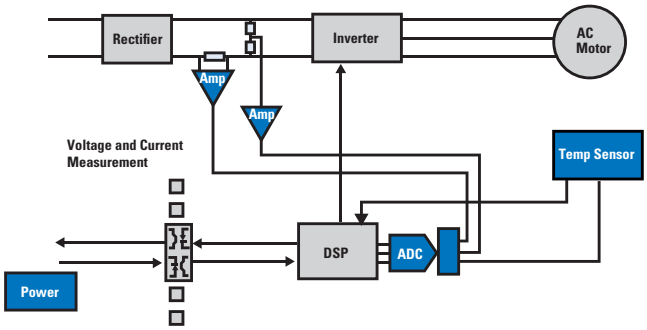
Low-Side Motor Control



Solutions	Examples	Pages
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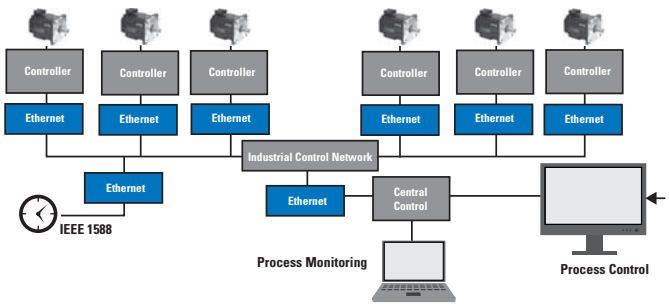
Multiple Motor Control Synchronization



Solutions	Examples	Pages
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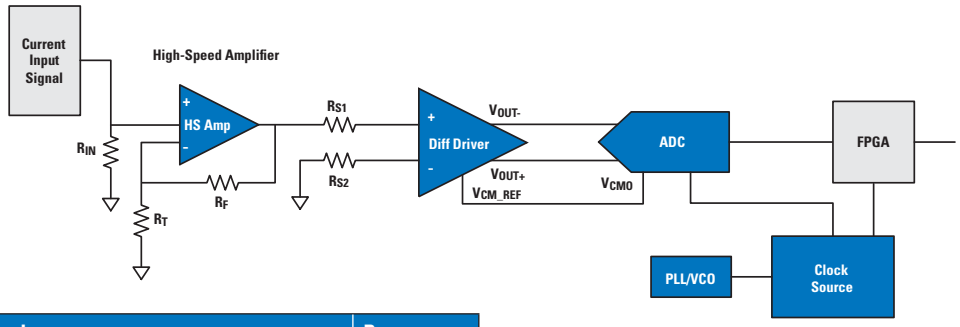
Distance Measurement LIDAR System



Solutions	Examples	Pages
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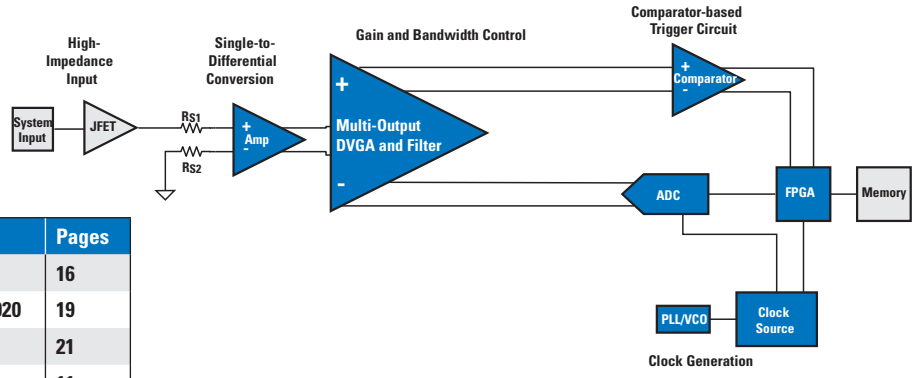
Industrial Data Acquisition - 1 GSPS Sample Rate



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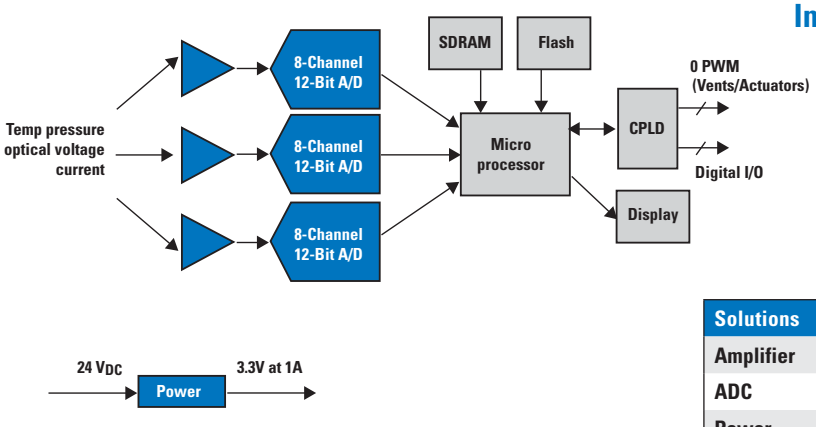
Industrial Data Acquisition - Up to 1 MSPS Sample Rate



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Power	LM25010	29, 31

Operational Amplifiers
Precision

Precision Operational Amplifiers

Product ID	Offset Voltage max, 25C (mV)	TcVos (µV/°C)	CMRR (dB)	PSRR (dB)	Avol (dB)	Voltage Noise (nV/√Hz)	Channels	Max Input Bias Current (nA)	Supply Current Per Channel (mA)	Supply Voltage Range (V)	Packaging
LMP2015 W	0.005	0.015	130	120	130	35	1	0.003	0.93	2.7 to 5.0	SOT23-5, SOIC-8
LMP2016 W	0.005	0.015	130	120	130	35	2	0.003	0.93	2.7 to 5.0	SOIC-8, MSOP-8
LMP2011 W	0.025	0.015	130	120	130	35	1	0.005	0.93	2.7 to 5.0	SOT23-5, MSOP-8
LMP2021 W	0.005	0.02 (max)	139	130	160	11	1	0.1	1.1	2.2 to 5.5	SOIC-8, SOT23-5
LMP2022 W	0.005	0.02 (max)	139	130	160	11	2	0.1	1.1	2.2 to 5.5	SOIC-8, MSOP-8
LMP2012 W	0.025	0.015	130	120	130	35	2	0.005	0.93	2.7 to 5.0	mini SOIC-8, SOIC-8
LMP2014 W	0.025	0.01	130	120	130	35	4	0.005	0.93	2.7 to 5.0	TSSOP-14
LMP7731 W	0.04	0.5	120	129	130	2.9	1	30	2.2	1.8 to 5.5	SOT-23
LMP7732 W	0.04	0.5	120	129	130	2.9	2	30	2.2	1.8 to 5.5	SOIC-8
LMP2231 E, W	0.15	0.3	97	120	120	60	1	0.001	0.016	1.6 to 5.5	SOIC-8, SOT23-5
LMP2232 E, W	0.15	0.3	97	120	120	60	2	0.003	0.014	1.6 to 5.5	SOIC-8, mini SOIC-8
LMP2234 E, W	0.15	0.3	97	120	120	60	4	0.001	0.009	1.8 to 5.0	TSSOP-14, SOIC-14
LMP7711 W	0.15	1.0	100	100	110	5.8	1	0.1	1.15	1.8 to 5.5	TSOT-6
LMP7712 W	0.15	1.75	100	100	95	5.8	2	0.1	1.3	1.8 to 5.5	MSOP-10
LMP7715 W	0.15	1.0	100	98	110	5.8	1	0.1	1.15	1.8 to 5.0	SOT23-5
LMP7716 W	0.15	1.8	100	98	110	5.8	2	0.1	1.3	1.8 to 5.0	MSOP-8
LMP7717 W	0.15	1.0	100	98	110	5.8	1	0.1	1.15	1.8 to 5.0	SOIC-8, SOT23-8
LMP7718 E, W	0.15	1.8	100	98	110	5.8	2	0.1	1.3	1.8 to 5.0	SOIC-8, MSOP-8
LMP7721 E, W	0.15	1.5	100	96	120	6.5	1	0.00002	1.3	1.8 to 5.5	SOIC-8 Narrow
LMP7701 W	0.2	1.0	130	100	119	9	1	0.05	0.715	2.7 to 12	SOT-23, SOIC-8
LMP7707 W	0.2	1.0	138	98	119	9	1	0.05	0.715	2.7 to 12	SOT-23
LMP7708 E, W	0.2	1.0	138	98	119	9	2	0.05	0.715	2.7 to 12	MSOP-8
LMP7709 W	0.2	1.0	138	98	119	9	4	0.05	0.715	2.7 to 12	TSSOP-14
LMP7702 W	0.22	1.0	130	100	119	9	2	0.4	0.75	2.7 to 12	SOIC-8, MSOP-8
LMP7704 W	0.22	1.0	130	100	119	9	4	0.4	0.725	2.7 to 12	TSSOP-14
LMV771 E, W	0.85	0.35	90	90	100	12	1	0.1	0.6	2.7 to 5.0	SC70-5
LMC6062 W	0.8, 0.35	1.0	85	85	140	83	1	0.004, 0.1	0.016	4.5 to 15.5	SOIC-8 Narrow, MDIP-8

PowerWise product E Evaluation board W WEBENCH enabled

CMOS-Input Operational Amplifiers

Product ID	Description	Vos Max (mV)	TcVos (µV/°C)	CMRR (dB)	IsTyp (mA)/ Ch	PSRR (dB)	Temperature Range (°C)	Packaging
LMP2015 W	Auto-correcting RRO precision op amp	0.005	0.05 max	130	0.93	120	-40 to 125	SOT23-5, SOIC-8
LMP2016 W	Auto-correcting RRO precision dual op amp	0.005	0.05 max	130	0.93	120	-40 to 125	MSOP-8, SOIC-8
LMP7711 W	Precision, 17 MHz, single, low-noise CMOS input op amp	0.15	1.0	100	1.15	100	-40 to 125	SC70-6
LMP7715 W	17 MHz, single, precision, low-noise, CMOS input, 1.8V op amp	0.15	1.0	100	1.15	98	-40 to 125	SOT23-5
LMP7716 W	17 MHz, dual, precision, low-noise, CMOS input, 1.8V op amp	0.15	1.8	100	1.3	98	-40 to 125	MSOP-8
LMP7701 W	Precision, single CMOS input RRIO, wide supply range op amp	0.2	1.0	130	0.715	100	-40 to 125	SOT23-5
LMP7702 W	Precision, dual, CMOS input RRIO, wide supply range op amp	0.22	1.0	130	0.75	100	-40 to 125	MSOP-8
LMP7704 W	Precision, quad CMOS input RRIO, wide supply range op amp	0.22	1.0	130	0.725	100	-40 to 125	TSSOP-14
LMC6001AI W	Ultra-low input bias current op amp	0.35	2.5	83	0.45	83	-40 to 85	Plastic DIP-8
LMC6061AI W	Precision, CMOS, single, micropower RRO op amp	0.35	1.0	85	0.02	85	-40 to 85	SOIC-8
LMC6062AI W	Precision, CMOS, dual, micropower RRO op amp	0.35	1.0	85	0.016	85	-40 to 85	SOIC-8
LMC6064AI W	Precision, CMOS, quad, micropower RRO op amp	0.35	1.0	85	0.016	85	-40 to 85	SOIC-14
LMV771 E, W	Low offset, low-noise, single RRO op amp	0.85	0.35	90	0.6	90	-40 to 125	SC70-5
LMV751 W	Low offset, low-noise, CMOS input op amp	1.0	1.0	103	0.6	107	-40 to 85	SOT23-5
LMV772 E, W	Low offset, low-noise, dual RRO op amp	1.0	0.35	90	0.6	90	-40 to 125	SOIC-8
LMV791 W	17 MHz, single, low-noise, CMOS input, 1.8V op amp with shutdown	1.35	1.0	100	1.15	98	-40 to 125	SC70-6
LMV792 W	17 MHz, dual low-noise, CMOS input, 1.8V op amp with shutdown	1.35	1.8	100	1.3	98	-40 to 125	MSOP-10
LMV796 W	17 MHz, single, low-noise, CMOS input, 1.8V op amp	1.35	1.0	100	1.15	98	-40 to 125	SOT23-5
LMV797 W	17 MHz, dual low-noise, CMOS input, 1.8V op amp	1.35	1.8	100	1.3	98	-40 to 125	MSOP-8
LM6211 W	Low-noise, RRO op amp with CMOS input and 24V operation	2.5	2.0	98	0.96	98	-40 to 125	SOT23-5
LMV716 W	5 MHz, low-noise, RRO CMOS input op amp	5.0	5.0	80	1.6	82	-40 to 85	MSOP-8

High-Speed Comparators

Product ID	Channels	Response Time (µs)	Offset Voltage max, 25C (mV)	Supply Voltage Range (V)	Supply Current Per Channel (mA)	Input Bias Current (µA)	Output Compatibility	Temperature Range (°C)	Packaging
LMV7219	1	0.007	6	2.7 to 5	1.1	0.45	Push-pull	-40 to 85	SC70-5, SOT23-5
LMV7235/39	1	0.045	6	2.7 to 5	0.065	0.03	Open drain/ Push-pull	-40 to 85	SC70-5, SOT23-5
LMH7220	1	0.0029	2.7	2.7 to 12	7.5	1.5	LVDS	-40 to 125	TSOT-6
LMH7322 E	2	0.0007	8	2.7 to 12	22.8	2.6	RS(P)ECL, LVDS	-40 to 125	LLP-24
LMH7324 E	4	0.0007	9.5	5 to 12	17.2	2.6	RS(P)ECL, LVDS	-40 to 125	LLP-32

PowerWise product E Evaluation board W WEBENCH enabled

Operational Amplifiers
Low Noise

Low-Noise Operational Amplifiers

Product ID	Channels	Voltage Noise (nV/√Hz)	Max Input Bias Current (nA)	Offset Voltage max, 25C (mV)	Supply Current Per Channel (mA)	Gain Bandwidth (MHz)	Supply Voltage Range (V)	Temperature Range (°C)	Packaging
LMP7721 [E, W]	1	6.5	.00002	.15	1.3	17	1.8 to 5.5	-40 to 125	SOIC-8 Narrow
LMP7707 [W]	1	9.0	.05	0.2	0.715	14	2.7 to 12	-40 to 125	SOT-23
LMP7708 [W]	2	9.0	.05	0.2	0.715	14	2.7 to 12	-40 to 125	MSOP-8
LMP7709 [W]	4	9.0	.05	0.2	0.715	14	2.7 to 12	-40 to 125	TSSOP-14
LMH6624 [W]	1	0.92	25000	0.5	12	1500	5.0 to 12	-40 to 125	SOIC-8, SOT23-5
LMH6626 [W]	2	1	25000	0.5	12	1300	5.0 to 12	-40 to 125	SOIC-8, MSOP-8
LMH6622 [W]	2	1.6	15000	1.2	4.3	160	5.0 to 12	-40 to 85	SOIC-8, MSOP-8
LMH6702 [W]	1	1.83	34000	4.5	12.5	1700	10 to 12	-40 to 85	SOIC-8, SOT23-5
LMH6703	1	2.3	23000	7.0	11	1200	8.0 to 12	-40 to 85	SOIC-8 Narrow, SOT23-6
LMH6628 [W]	2	2.0	20000	2.0	9.0	300	5.0 to 12	-55 to 125	MSOP-8,
LMP7731 [W]	1	2.9	30	0.04	2.2	22	1.8 to 5.5	-40 to 125	SOT23-5
LMP7732 [W]	2	2.9	30	0.04	2.2	22	1.8 to 5.5	-40 to 125	SOIC-8
LM833 [W]	2	4.5	1050	5.0	2.5	15	10 to 36	-40 to 85	SOIC-8, MDIP-8, MSOP-8
LMP7711 [W]	1	5.8	0.05	0.15	1.15	17	1.8 to 5.5	-40 to 125	TSOT-6
LMP7712 [W]	2	5.8	0.05	0.15	1.3	17	1.8 to 5.5	-40 to 125	MSOP-10
LMP7715 [W]	1	5.8	0.05	0.15	1.15	17	1.8 to 5.0	-40 to 125	SOT23-5
LMP7716 [W]	2	5.8	0.05	0.15	1.3	17	1.8 to 5.0	-40 to 125	MSOP-8
LMP7717 [W]	1	5.8	0.05	0.15	1.15	88	1.8 to 5.0	-40 to 125	SOIC-8, SOT23-5
LMP7718 [W]	2	5.8	0.05	0.15	1.15	88	1.8 to 5.0	-40 to 125	SOIC-8, MSOP-8
LMV791 [W]	1	5.8	0.001	1.35	1.15	17	1.8 to 5.0	-40 to 125	TSOT-6
LMV792 [W]	2	5.8	0.001	1.35	1.3	17	1.8 to 5.0	-40 to 125	MSOP-10
LMV793 [W]	1	5.8	0.001	1.35	1.15	88	1.8 to 5.0	-40 to 125	SOIC-8, SOT23-5
LMV794 [W]	2	5.8	0.001	1.35	1.3	88	1.8 to 5.0	-40 to 125	SOIC-8, MSOP-8
LMV796 [W]	1	5.8	0.001	1.35	1.15	17	1.8 to 5.0	-40 to 125	SOT23-5
LMV797 [W]	2	5.8	0.001	1.35	1.3	17	1.8 to 5.0	-40 to 125	SOIC-8
LM6211 [W]	1	6.0	0.005	2.5	0.96	17	5.0 to 24	-40 to 125	SOT23-5
LMV751 [W]	1	6.5	0.1	1.0	0.6	5.0	2.7 to 5.5	-40 to 85	SOT23-5
LMP7701 [W]	1	9.0	0.001	0.2	0.715	2.5	2.7 to 12	-40 to 125	SOIC-8, SOT23-5
LMP7702 [W]	2	9.0	0.001	0.22	0.75	2.5	2.7 to 12	-40 to 125	SOIC-8, MSOP-8
LMP7704 [W]	4	9.0	0.001	0.22	0.725	2.5	2.7 to 12	-40 to 125	TSSOP-14
LMV771 [W]	1	12	0.1	0.85	0.6	3.5	2.7 to 5.0	-40 to 125	SC70-5
LMV772 [W]	2	12	0.1	1.0	0.6	3.5	2.7 to 5.0	-40 to 125	SOIC-8, MSOP-8

PowerWise product [E] Evaluation board [W] WEBENCH enabled

Rail-to-Rail Operational Amplifiers

Product ID	Channels	Offset Voltage max, 25C (mV)	Max Input Bias Current (nA)	Supply Voltage Range (V)	Supply Current Per Channel (mA)	Gain Bandwidth (MHz)	Voltage Noise (nV/√Hz)	Output Swing High (MV)	Output Swing Low (mV)	Temperature Range (°C)	Packaging
LMP7707 W	1	0.2	.05	2.7 to 12	0.715	14	9.0	110	80	-40 to 125	SOT-23
LMP7708 E, W	2	0.2	.05	2.7 to 12	0.715	14	9.0	120	120	-40 to 125	MSOP-8
LMP7709 W	4	0.2	.05	2.7 to 12	0.715	14	9.0	120	120	-40 to 125	TSSOP-14
LMH6618 E, W	1	0.6	2400	2.7 to 11	1.25	140	10	255	270	-40 to 125	TSOT-6
LMH6619 E, W	2	0.6	2400	2.7 to 11	1.25	140	10	255	275	-40 to 125	SOIC-8 Narrow
LMP8601 E	1	1.0	7200	3.0 to 5.5	1.1	.060	890	4980	20	-40 to 125	SOIC-8 Narrow
LMP8602	1	1.0	7200	3.0 to 5.5	1.1	.060	890	4980	20	-40 to 125	SOIC-8, MSOP-8
LMP8603	1	1.0	7200	3.0 to 5.5	1.1	.060	890	4980	20	-40 to 125	SOIC-8, MSOP-8
LMP7731 W	1	0.04	30	1.8 to 5.5	2.2	22	2.9	50	50	-40 to 125	SOT23-5
LMP7732 W	2	0.04	30	1.8 to 5.5	2.2	22	2.9	50	50	-40 to 125	SOIC-8
LMP7701 W	1	0.2	0.001	2.7 to 12	0.715	2.5	9.0	110	80	-40 to 125	SOIC-8, SOT23-5
LMP7702 W	2	0.22	0.001	2.7 to 12	0.75	2.5	9.0	120	120	-40 to 125	SOIC-8, MSOP-8
LMP7704 W	4	0.22	0.001	2.7 to 12	0.725	2.5	9.0	120	120	-40 to 125	TSSOP-14
LMV841 E	1	0.5	0.01	2.7 to 12	1.02	4.5	20	100	120	-40 to 125	SC70-5
LMV842	2	0.5	0.01	2.7 to 12	1.02	4.5	20	100	120	-40 to 125	SOIC-8, MSOP-8
LMV844	4	0.5	0.01	2.7 to 12	1.02	4.5	20	100	120	-40 to 125	TSSOP-14
LMC6462	2	0.5	0.005	3.0 to 15.5	0.02	0.05	80	4980	20	-40 to 85	SOIC-8, MDIP-8
LMC6482	2	0.75	0.004	3.0 to 15.5	0.5	1.5	37	4700	240	-40 to 85	SOIC-8, MDIP-8
LPV511	1	3.0	1.9	2.7 to 12	0.00097	0.027	320	4890	200	-40 to 85	SC70-5
LMC7101	1	3.0	0.064	2.7 to 15.5	0.5	1.1	37	4700	200	-40 to 85	SOT23, SOIC-8
LMC6484	4	3.0	0.004	3.0 to 15	0.5	1.5	37	4980	20	-40 to 85	SOIC-14, MDIP-14
LMC6494	4	3.0	0.2	2.5 to 15.5	0.5	1.5	37	4980	20	-40 to 125	SOIC-14
LMC8101	1	5.0	0.064	2.7 to 10	0.7	1.0	36	4730	-4950	-40 to 85	SOT23-5, micro SMD
LM7301	1	6.0	250	2.2 to 30	0.6	4.0	36	4930	120	-40 to 85	SOIC-8, SOT23-5
LMC6492	2	6.0	0.2	2.5 to 15.5	0.5	1.5	37	4900	240	-40 to 125	SOIC-8

PowerWise product E Evaluation board W WEBENCH enabled

Operational Amplifiers
Micropower and Low Voltage

Micropower Operational Amplifiers

Product ID	Channels	Supply Current Per Channel (mA)	Gain Bandwidth (MHz)	Offset Voltage max, 25C (mV)	Voltage Noise (nV/√Hz)	Output Current (mA)	Packaging
LMC6442	2	0.00095	0.01	3.0	170	0.9	SOIC-8, MDIP-8
LPV511 [W]	1	0.00097	0.027	3.0	320	0.5	SC-70
LMP2234 [W]	4	0.009	0.13	0.15	60	22	SOIC-14, TSSOP-14
LPV321 [W]	1	0.009	0.152	7.0	146	17	SOT-23
LM4250	1	0.01	0.25	6.0	40	12	SOIC-8, MDIP-8, TO99-8
LMC6042	2	0.01	0.1	3.0	83	21	SOIC-8, MDIP-8
LMC6044	4	0.01	0.1	6.0	83	21	SOIC-15, MDIP-14
LMC6041	1	0.014	0.075	6.0	83	21	SOIC-8, MDIP-8
LMC6061/62/64	1/2/4	0.02/.016	0.1	0.35	83	21	SOIC-8, MDIP-8/14, CERDIP-8
LMC7111	1	0.025	0.05	7.0	110	7.0	SOT23-5
LMV551/52/54 [W]	1/2/4	0.037	3.0	3.0	70	10	SC70-5, SOIC-8, TSSOP-14
LMV651 [W]	1	0.11	12	1.5	17	15	SC70-5
LMV641 [E]	1	0.158	10	0.5	14	26	SOIC-8, SC70-5
LPV531	1	0.425	4.6	4.5	25	15	TSOT-6
LMP2231 [W]	1	0.016	0.13	0.15	60	22	SOIC-8, SOT23-5
LMP2232 [W]	2	0.014	0.13	0.15	60	22	SOIC-8, mini SOIC-8
LPV324	4	0.0075	0.152	7.0	146	17	SOIC-14 Narrow, TSSOP-14
LPV358	2	0.007	0.152	7.0	146	17	SOIC-8, mini SOIC-8
LMC6061	1	0.024	0.1	0.8, .35	83	21	SOIC-8, MDIP-8
LMC6062 [W]	2	0.019	0.1	0.8, .35	83	21	SOIC-8, MDIP-8
LMC6064 [W]	4	0.019	0.1	0.8, .35	83	21	SOIC-14, MDIP-14

PowerWise product [E] Evaluation board [W] WEBENCH enabled

Low-Voltage Operational Amplifiers

Product ID	Channels	Supply Voltage Range (V)	Offset Voltage max, 25C (mV)	Supply Current Per Channel (mA)	Gain Bandwidth (MHz)	Voltage Noise (nV/√Hz)	Shutdown	Temperature Range (°C)	Packaging
LMV951	1	0.9 to 3.0	2.8	0.57	2.8	25	✔	-40 to 125	TSOT-6
LM10	1	1.1 to 45	4.0	0.3	0.09	50	—	0 to 70	SOIC-14, MDIP-8, TO5-8
LMC6442	2	1.8 to 11	3.0	0.00095	0.01	170	—	-40 to 85	SOIC-8, MDIP-8
LM6142 [W]	2	1.8 to 24	1.0	0.65	17	16	—	-40 to 85	SOIC-8, MDIP-8
LM6144 [W]	4	1.8 to 24	2.5	0.65	17	16	—	-40 to 85	SOIC-14, MDIP-14
LMP7716 [W]	2	1.8 to 5.0	0.15	1.3	17	5.8	—	-40 to 125	MSOP-8
LMP7717 [W]	1	1.8 to 5.0	0.15	1.15	88	5.8	—	-40 to 125	SOIC-8, SOT23-5
LMV791 [W]	1	1.8 to 5.0	1.35	1.15	17	5.8	✔	-40 to 125	TSOT-6
LMV792 [W]	2	1.8 to 5.0	1.35	1.3	17	5.8	✔	-40 to 125	MSOP-10
LMV793 [W]	1	1.8 to 5.0	1.35	1.15	88	5.8	—	-40 to 125	SOIC-8, SOT23-5
LMV794 [W]	2	1.8 to 5.0	1.35	1.15	88	5.8	—	-40 to 125	SOIC-8, MSOP-8
LMV796 [W]	1	1.8 to 5.0	1.35	1.15	17	5.8	—	-40 to 125	SOT23-5
LMV797	2	1.8 to 5.0	1.35	1.3	17	5.8	—	-40 to 125	MSOP-8
LMP7711/12 [W]	1/2	1.8 to 5.5	0.15	1.15/1.3	17	5.8	✔	-40 to 125	TSOT-6
LMC6035	2	2.0 to 15.5	5.0	0.4	1.4	27	—	-40 to 85	micro SMD-8, SOIC-8, MSOP-8
LM4250	1	2.0 to 36	6.0	0.01	0.25	40	—	0 to 70	SOIC-8, MDIP-8, TO99-8
LM7301 [W]	1	2.2 to 30	6.0	0.6	4.0	36	—	-40 to 85	SOIC-8, SOT23-5
LMP2231 [W]	1	1.6 to 5.5	0.15	0.016	0.13	60	—	-40 to 125	SOIC-8, SOT23-5
LMP7721 [E,W]	1	1.8 to 5.5	0.15	1.3	17	6.5	—	-40 to 125	SOIC-8 Narrow

PowerWise product [E] Evaluation board [W] WEBENCH enabled

Low-Power Operational Amplifiers

Product ID	Channels	Supply Current Per Channel (mA)	Gain Bandwidth (MHz)	Offset Voltage max, 25C (mV)	Max Input Bias Current (nA)	Voltage Noise (nV/√Hz)	Supply Voltage Range (V)	Temp Range (°C)	Packaging
LM4250	1	0.01	0.25	6.0	20	40	2 to 36	0 to 70	SOIC-8, MDIP-8, TO99-8
LM346	4	0.035	1.2	6.0	250	28	3 to 36	0 to 70	SOIC-16, MDIP-16
LMC6572/74	2/4	0.038	0.22	3.0/7.0	0.01	45	2.7 to 10	-40 to 85	SOIC-8, SOIC-14
LPC660	4	0.04	0.35	3.0	0.004	42	5 to 15	-40 to 85	SOIC-14
LMV651 [E]	1	0.11	12	1.5	100	17	2.7 to 5.5	-40 to 125	SC70-5
LMV652 [E]	2	0.11	12	1.5	100	17	2.7 to 5.5	-40 to 125	SOIC-8
LMV981 [E]	1	0.116	1.5	4.0	50	50	1.8 to 5	-40 to 125	micro SMD-6, SC70-5, SOT23-5
LMV654 [E]	4	0.119	12	1.8	300	17	2.7 to 5.5	-40 to 125	TSSOP-14
LMV641 [E]	1	0.158	10	0.5	105	14	2.7 to 12	-40 to 125	SOIC-8, SC70-5
LF442	2	0.2	1	5.0	3	35	6 to 36	0 to 70	TO99-8, MDIP-8
LM10	1	0.3	0.09	4.0	40	50	1.1 to 45	0 to 70	SOIC-14, MDIP-8, TO5-8
LM6132/34 [W]	2/4	0.36	10	6.0/2.0	350/300	27	2.7 to 24	-40 to 85	SOIC-8, MDIP-8, SOIC-14, MDIP-14
LMV851 [E]	1	0.41	8	1.0	0.5	11	2.7 to 5	-40 to 125	SC70-5
LMV852 [E]	2	0.41	8	1.0	0.5	11	2.7 to 5	-40 to 125	SOIC-8
LMV854 [E]	4	0.41	8	1.0	0.5	11	2.7 to 5	-40 to 125	TSSOP-14
LPV531	1	0.425	4.6	4.5	0.01	25	2.7 to 5	-40 to 85	TSOT-6
LMC6001 [W]	1	0.45	1.3	0.35	0.002	22	4.5 to 15.5	-40 to 85	MDIP-8
LMV951	1	0.57	2.8	2.8	85	25	0.9 to 3	-40 to 125	TSOT-6
LM7301	1	0.6	4	6.0	250	36	2.2 to 30	-40 to 85	SOIC-8, SOT23-5
LMV771 [E]	1	0.6	3.5	0.85	0.1	12	2.7 to 5	-40 to 125	SC70-5
LMV772	2	0.6	3.5	1.0	0.1	12	2.7 to 5	-40 to 125	SOIC-8, MSOP-8
LMV774	4	0.6	3.5	1.0	0.1	12	2.7 to 5	-40 to 125	TSSOP-14
LM6142 [W]	2	0.65	17	1.0	526	16	1.8 to 24	-55 to 125	SOIC-8, MDIP-8
LM6144 [W]	4	0.65	17	2.5	526	16	1.8 to 24	-40 to 85	SOIC-14, MDIP-14
LMP7704	4	0.725	2.5	0.22	0.001	9.0	2.7 to 12	-40 to 125	TSSOP-14
LMP7702	2	0.75	2.5	0.22	0.001	9.0	2.7 to 12	-40 to 125	SOIC-8, MSOP-8

PowerWise product [E] Evaluation board [W] WEBENCH enabled

Current-Sense Amplifiers

Product ID	Description	Vcm Range (V)	Vos (mV) (max)	Max TCVOS (µV/°C)	Gain Output (V/V)	Supply Voltage Range (V)	Supply Current (mA)	PSRR (dB)	Packaging
LMP8601	High common-mode, AV = 20, bidirectional	-22 to 60 (5V supply)	1.0	10	20	3 to 5.5	1.1	90	SOIC-8 Narrow
LMP8602	High common-mode, AV = 50, bidirectional	-22 to 60 (5V supply)	1.0	10	50	3 to 5.5	1.1	90	SOIC-8, MSOP-8
LMP8603	High common-mode, AV = 100, bidirectional	-22 to 60 (5V supply)	1.0	10	100	3 to 5.5	1.1	90	SOIC-8, MSOP-8

Operational Amplifiers
High Speed and High Voltage

High-Voltage Operational Amplifiers

Product ID	Channels	Supply Voltage Range (V)	Supply Current Per Channel (mA)	Gain Bandwidth (MHz)	Slew Rate (V/µs)	Offset Voltage max, 25C (mV)	Voltage Noise (nV/√Hz)	Output Current (mA)	Tempe Range (°C)	Packaging
LM6144 W	4	1.8 to 24	0.65	17	25	1.0	16	8.0	-40 to 85	SOIC-14
LM6142 W	2	1.8 to 24	0.65	17	25	2.5	16	8.0	-40 to 85	SOIC-8, MDIP-8, MDIP-14
LM833 E	2	10 to 36	2.5	15	7.0	5.0	4.5	40	-40 to 85	SOIC-8, MDIP-8, MSOP-8
LM4250	1	2.0 to 36	0.01	0.25	0.2	6.0	40	12	0 to 70	TO99-8, SOIC-8, MDIP-8
LM7301 W	1	2.2 to 30	0.6	4.0	1.25	6.0	36	9.5	-40 to 85	SOIC-8, SOT23-5
LM8272 W	2	2.5 to 24	0.9	13	12	5.0	15	100	-40 to 85	MSOP-8
LM8262 W	2	2.5 to 30	1.05	21	12	7.0	15	60	-40 to 85	MSOP-8
LM8261 W	1	2.5 to 30	0.97	21	12	5.0	15	53	-40 to 85	SOT23-5
LMC8101	1	2.7 to 10	0.7	1.0	1.0	5.0	36	49	-40 to 85	micro SMD-8, SOIC-8
LMC7101	1	2.7 to 15.5	0.5	1.1	1.1	7.0	37	24	-40 to 85	SOT23-5, SOIC-8
LM6154 W	4	2.7 to 24	1.4	75	30	5.0	9.0	6.2	0 to 70	SOIC-14
LM6152 W	2	2.7 to 24	1.4	75	30	2.0	9.0	6.2	0 to 70	SOIC-8
LM6134 W	4	2.7 to 24	0.36	10	14	2.0	27	4.3	-40 to 85	SOIC-14, MDIP-14
LM6132 W	2	2.7 to 24	0.36	10	14	6.0	27	4.3	-40 to 85	SOIC-8, MDIP-8
LM7121 W	1	4.5 to 33	4.8	175	1300	8.0	17	52	-40 to 85	SOIC-8, SOT23-5
LM6211 W	1	5.0 to 24	0.96	17	5.5	2.5	6.0	16	-40 to 125	SOT23-5
LM6171	1	5.5 to 34	2.5	100	3600	3.0	12	135	-40 to 85	SOIC-8, MDIP-8
LM6172	2	5.5 to 36	2.3	100	3000	3.0	12	85	-40 to 85	SOIC-8, MDIP-8
LF444	4	6.0 to 36	0.15	1.0	1.0	1.0	35	8.0	0 to 70	SOIC-14, MDIP-14
LF442	2	6.0 to 44	0.15	1.0	1.0	1.0	35	6.8	-55 to 125	TO99-8, MDIP-8
LM6181	1	7.0 to 32	7.5	100	1400	5.0	4.0	130	-40 to 85	SOIC-8, SOIC-16, MDIP-8
LMC6462	2	3.0 to 15.5	0.02	0.05	0.015	0.5, 3.0	80	27	-55 to 125	SOIC-8, MDIP-8
LMC6464	4	3.0 to 15.5	0.02	0.05	0.015/0.028	0.5, 3.0	80	27	-55 to 125	SOIC-14, MDIP14
LMC6482	2	3.0 to 15.5	0.5	1.5	1.3	0.75, 3.0	37	30	-55 to 125	SOIC-8, MDIP-8, mini SOIC-8
LMC6484	4	3.0 to 15.5	0.5	1.5	1.3	3.0	37	30	-55 to 125	SOIC-14, MDIP-14, mini SOIC-14
LMC6061	1	4.5 to 15.5	0.0016, .02	0.1	0.035	0.8, 0.35	83	21	40 to 85	SOIC-8, MDIP-8
LMC6062	2	4.5 to 15.5	0.0016, .02	0.1	0.035	0.8, 0.35	83	21	40 to 85	SOIC-8, MDIP-8
LMC6064	4	4.5 to 15.5	0.0016, .02	0.1	0.035	0.8, 0.35	83	21	40 to 85	SOIC14, MDIP-14
LMC660	4	4.75 to 15.5	0.38	1.4	1.1	6.0, 3.0	22	21	-40 to 85	SOIC-14 Narrow, MDIP-14
LMC662	2	4.75 to 15.5	0.38	1.4	1.1	6.0, 3.0	22	21	-40 to 85	SOIC-14 Narrow, MDIP-14

High-Speed Fully Differential Amplifiers

Product ID	Unity Gain BW (MHz) at AVCL (V/V)	Slew Rate (V/µs)	Supply Voltage Range (V)	Supply Current per Channel (mA)	Channels	Voltage Noise (nV/√Hz)	2nd/3rd HD (dBc)	Packaging
LMH6550	400 at 1	3000	5.0 to 12	20	1	6.0	-92/-103 at V_O = 2 V_{PP}, f = 5 MHz, RL = 800Ω	SOIC-8, MSOP-8
LMH6551	370 at 1	2400	3.0 to 12	12.5	1	6.0	-94/-96 at V_O = 2 V_{PP}, f = 5 MHz, RL=800Ω	SOIC-8, MSOP-8
LMH6552 E	1500 at 1	3800	4.5 to 12	19	1	1.1	-92/-93 at V_{OUT} = 2 V_{PP}, f = 20 MHz, RL = 800Ω	SOIC-8, LLP-8
LMH6553 E	900 at 1	2300	4.5 to 12	29.5	1	1.1	-79/-90 at V_{OUT} = 2 V_{PP}, f = 20 MHz, RL = 800Ω	PSOP-8, LLP-8
LMH6554	2500 at 1	6200	4.7 to 5.3	52	1	0.9	-68/-70 at V_{OUT} = 2 V_{PP}, f = 250 MHz, RL = 200Ω	FCOL-14
LMH6555 E	1200 at 13.6 dB	1300	3.0 to 3.6	120	1	19	-60/-67 at V_{OUT} = 0.8 V_{PP}, f = 250 MHz, RL = 100Ω	LLP-16

PowerWise product E Evaluation board W WEBENCH Enabled

SPI Interface, Single-Ended Input ADCs*

Product ID	Pin/Func. Comp. Family	Res. (bit)	Input Channels	Sample Rate Range (sps)	INL (LSB)	ENOB (bit)	SINAD (dB)	Supply Voltage Range (V)	Temperature Range (°C)	Packaging
ADC081S021 E, W		8	1	50K to 200K	+0.45; -0.3	7.9	49.5	2.7 to 5.25	-40 to 85	SOT23-6, LLP-6
ADC081S051 E, W		8	1	200K to 500K	+0.06; -0.04	7.9	49.5	2.7 to 5.25	-40 to 85	SOT23-6, LLP-6
ADC081S101 E, W		8	1	500K to 1M	±0.05	7.9	49.7	2.7 to 5.25	-40 to 85	SOT23-6, LLP-6
ADC101S021 E, W		10	1	50K to 200K	+0.14; -0.13	9.9	61.5	2.7 to 5.25	-40 to 85	SOT23-6, LLP-6
ADC101S101 E, W		10	1	500K to 1M	±0.2	9.9	61.7	2.7 to 5.25	-40 to 85	SOT23-6, LLP-6
ADC121S021 E, W		12	1	50K to 200K	+0.45; -0.4	11.7	72	2.7 to 5.25	-40 to 85	SOT23-6, LLP-6
ADC121S051 E, W		12	1	200K to 500K	+0.45; -0.4	11.6	72	2.7 to 5.25	-40 to 85	SOT23-6, LLP-6
ADC121S101 E, W		12	1	500K to 1M	±0.4	11.7	72	2.7 to 5.25	-40 to 125	SOT23-6, LLP-6
ADC101S051 E, W		10	1	200K to 500K	+0.15; -0.09	9.9	61.5	2.7 to 5.25	-40 to 85	SOT23-6, LLP-6
ADC082S021 E, W		8	2	50K to 200K	±0.04	7.9	49.6	2.7 to 5.25	-40 to 85	mini SOIC-8
ADC082S051 E, W		8	2	200K to 500K	+0.12; -0.06	7.9	49.5	2.7 to 5.25	-40 to 85	mini SOIC-8
ADC082S101 E, W		8	2	500K to 1M	±0.13	7.9	49.6	2.7 to 5.25	-40 to 85	mini SOIC-8
ADC102S021 E, W		10	2	50K to 200K	±0.13	9.9	61.8	2.7 to 5.25	-40 to 85	mini SOIC-8
ADC102S051 E, W		10	1	200K to 500K	+0.2; -0.1	10	61.7	2.7 to 5.25	-40 to 85	mini SOIC-8
ADC102S101 E, W		10	2	500K to 1M	+0.4; -0.1	9.9	61.6	2.7 to 5.25	-40 to 85	mini SOIC-8
ADC122S021 E, W		12	2	50K to 200K	±0.35	11.7	72	2.7 to 5.25	-40 to 85	mini SOIC-8
ADC122S051 E, W		12	2	200K to 500K	±0.5	11.7	72	2.7 to 5.25	-40 to 85	mini SOIC-8
ADC122S101 E, W		12	2	500K to 1M	±0.64	11.7	72	2.7 to 5.25	-40 to 85	mini SOIC-8
ADC084S021 E, W		8	4	50K to 200K	±0.04	7.9	49.6	2.7 to 5.25	-40 to 85	mini SOIC-10
ADC084S051 E, W		8	4	200K to 500K	+0.12; -0.06	7.9	49.5	2.7 to 5.25	-40 to 85	mini SOIC-10
ADC084S101 E, W		8	4	500K to 1M	±0.13	7.9	49.6	2.7 to 5.25	-40 to 85	mini SOIC-10
ADC104S021 E, W		10	4	50K to 200K	±0.13	9.9	61.8	2.7 to 5.25	-40 to 85	mini SOIC-10
ADC104S051 E, W		10	4	200K to 500K	+0.2; -0.1	10	61.7	2.7 to 5.25	-40 to 85	mini SOIC-10
ADC104S101 E, W		10	4	500K to 1M	+0.4; -0.1	9.9	61.6	2.7 to 5.25	-40 to 85	mini SOIC-10
ADC124S021 E, W		12	4	50K to 200K	±0.35	11.7	72	2.7 to 5.25	-40 to 85	mini SOIC-10
ADC124S051 E, W		12	4	200K to 500K	±0.5	11.7	72	2.7 to 5.25	-40 to 85	mini SOIC-10
ADC124S101 E, W		12	4	500K to 1M	±0.64	11.7	72	2.7 to 5.25	-40 to 85	mini SOIC-10
ADC088S022 E, W		8	8	50K to 200K	±0.04	7.9	49.5	2.7 to 5.25	-40 to 105	TSSOP-16
ADC088S052 E, W		8	8	200K to 500K	±0.05	7.9	49.6	2.7 to 5.25	-40 to 105	TSSOP-16
ADC088S102 E, W		8	8	500K to 1M	±0.05	7.9	49.6	2.7 to 5.25	-40 to 105	TSSOP-16
ADC108S022 E, W		10	8	50K to 200K	±0.10	10	61.8	2.7 to 5.25	-40 to 105	TSSOP-16
ADC108S052 E, W		10	8	200K to 500K	±0.10	10	61.8	2.7 to 5.25	-40 to 105	TSSOP-16
ADC108S102 E, W		10	8	500K to 1M	±0.2	10	61.8	2.7 to 5.25	-40 to 105	TSSOP-16
ADC128S022 E, W		12	8	50K to 200K	±0.4	11.8	73	2.7 to 5.25	-40 to 105	TSSOP-16
ADC128S052 E, W		12	8	200K to 500K	±0.4	11.8	73	2.7 to 5.25	-40 to 105	TSSOP-16
ADC128S102 E, W		12	8	500K to 1M	±0.5	11.8	73	2.7 to 5.25	-40 to 105	TSSOP-16

* Reference Source: Supply

PowerWise product E Evaluation board W WEBENCH enabled

ADCs and DACs
SPI and I²C Interface

SPI Interface DACs

Product ID	Pin/Func. Comp. Family	Resolution (bit)	Input Channels (Count)	Settling Time (µs)	INL (LSB)	Reference Source	Supply Voltage Range (V)	Temperature Range (°C)	Packaging
DAC081S101 E		8	1	3.0	±0.2	Supply	2.7 to 5.5V	-40 to 105	TSOP-6, MSOP-8
DAC101S101 E		10	1	8.0	±0.6	Supply	2.7 to 5.5V	-40 to 105	TSOP-6, MSOP-8
DAC121S101 E		12	1	8.0	±2.6	Supply	2.7 to 5.5V	-40 to 105	TSOP-6, MSOP-8
DAC082S085 E		8	2	4.5	±0.14	External	2.7 to 5.5V	-40 to 105	mini SOIC-10, LLP-10
DAC084S085 E		8	4	8.5	±0.14	External	2.7 to 5.5V	-40 to 105	mini SOIC-10, LLP-10
DAC102S085 E		10	2	6.0	±0.7	External	2.7 to 5.5V	-40 to 105	mini SOIC-10, LLP-10
DAC104S085 E		10	4	8.5	±0.7	External	2.7 to 5.5V	-40 to 105	mini SOIC-10, LLP-10
DAC122S085 E		12	2	8.5	±2.4	External	2.7 to 5.5V	-40 to 105	mini SOIC-10, LLP-10
DAC124S085 E		12	4	8.5	±2.4	External	2.7 to 5.5V	-40 to 105	mini SOIC-10, LLP-10
DAC088S085 E		8	8	8.0	±0.5	External	2.7 to 5.5V	-40 to 125	TSSOP-16, LLP-16
DAC108S085 E		10	8	8.0	±2.0	External	2.7 to 5.5V	-40 to 125	TSSOP-16, LLP-16
DAC128S085 E		12	8	8.0	±8.0	External	2.7 to 5.5V	-40 to 125	TSSOP-16, LLP-16

Single-Ended Input I²C Compatible A/D Converters with Alarm and Multiple Addresses

Product ID	Res (bits)	Inputs	Pin and Function Compatible	Speed Range (kSPS)	Supply Voltage Range(V)	Typ Power (mW)		INL (LSB)	Temp Range (°C)	Multi Address	Alarm	Packaging
						3V	5V					
NEW! ADC081C021 E W	8	1		5.5 to 189	2.7 to 5.5	0.26	0.78	±0.2	-40 to 105	✔	✔ ✔	TSOT-6, MSOP-8
NEW! ADC101C021 E W	10	1		5.5 to 189	2.7 to 5.5	0.26	0.78	±0.5	-40 to 105	✔	✔ ✔	TSOT-6, MSOP-8
NEW! ADC121C021 E W	12	1		5.56 to 189	2.7 to 5.5	0.26	0.78	±0.5	-40 to 105	✔	✔ ✔	TSOT-6, MSOP-8
ADC081C027 E W	8	1		5.5 to 189	2.7 to 5.5	0.26	0.78	±0.5	-40 to 105	✔		TSOT-6
ADC101C027 E W	10	1		5.5 to 189	2.7 to 5.5	0.26	0.78	±0.5	-40 to 105	✔		TSOT-6
ADC121C027 E W	12	1		5.56 to 189	2.7 to 5.5	0.26	0.78	±0.5	-40 to 105	✔		TSOT-6

Differential-Input SPI A/D Converters

Product ID	Res (bits)	Inputs	Pin and Function Compatible	Speed Range (kSPS)	Supply Voltage Range(V)	Typ Power (mW)		Static Perform (Typ)		ENOB (bits) typ	Temp Range (°C)	Packaging
						3V	5V	INL (LSB)	DNL (LSB)			
ADC121S625 E W	12	1		50 to 200	4.5 to 5.5	—	2.25	- 0.5 / -0.3	±0.4	11.8	-40 to 85	MSOP-8
ADC121S655 E W	12	1		200 to 500	4.5 to 5.5	—	9	±0.6	±0.4	11.7	-40 to 105	MSOP-8
ADC121S705 E W	12	1		500 to 1000	4.5 to 5.5	—	11.5	±0.6	±0.4	11.7	-40 to 105	MSOP-8
ADC122S625 E W	12	2		50 to 200	4.5 to 5.5	—	—	±1.0	±0.95	11.25	-40 to 105	MSOP-10
ADC122S655 E W	12	2		200 to 500	4.5 to 5.5	—	25	±1.0	±0.95	11.25	-40 to 105	MSOP-10
ADC122S706 E W	12	2	—	500 to 1000	4.5 to 5.5	20	25	±1	±0.95	11.25	-40 to 105	TSSOP-14
ADC141S626 E W	14	1	—	50 to 250	2.7 to 5.5	2	4.8	±0.5	±0.5	13.7	-40 to 85	MSOP-10
ADC161S626 E W	16	1	—	50 to 250	4.5 to 5.5	—	5.8	±0.8	±0.5/ ±0.8	14.3	-40 to 85	MSOP-10

PowerWise® product E Evaluation board W WEBENCH enabled

ADC083000 – PowerWise® 8-Bit, 3 GSPS ADC Delivers Unsurpassed Performance without Heat Sinks

Features

- Adjustable sampling clock phase
- Multiple ADC synchronization capability
- Choice of single or dual data rate output clocking
- Serial interface for extended control (including gain and offset)
- Full-speed test patterns for system testing and debugging
- ADC08B3000 4k byte on-chip FIFO memory
- Reference board available with LMX2531 clock conditioner and LMH6555 high-speed amplifier, for inputs between DC and 750 MHz

GSPS Family Performance (typical)

- Energy-efficient PowerWise® products
- High 7.2 to 7.5 Effective Number of Bits (ENOB)
- Full power bandwidth beyond 3 GHz (ADC083000)
- Up to 3 GSPS sampling speed
- DNL ±0.20 LSB
- Operating power between 0.8W and 1.9W *(No heat sink required)*
- Power-down mode: under 25 mW

Applications

Ideal for use in direct RF down conversion, digital oscilloscopes, communications transceivers, test instrumentation, and ranging applications such as LIDAR and RADAR

8-Bit and 10-Bit GSPS A/D Converters

Product ID	Sampling Rate (MSPS)	Power	ENOB (Bits)	SNR (dB)	SFDR (dB)	THD (dBc)	Packaging
ADC081000	1000	1.43	7.5	48	58.5	-57	eLQFP-128
ADC08D1000	1000	1.6	7.4	47.1	55	-55	eLQFP-128
ADC08D1020	1000	1.6	7.4	46.8	58	-58	eLQFP-128
ADC081500	1500	1.2	7.4	47	56	-54.5	eLQFP-128
ADC08D1520	1500	2	7.4	46.8	58	-58	eLQFP-128
ADC083000	3000	1.9	7.2	45.3	57	-57	eLQFP-128
ADC08B3000	3000	1.6	7.2	45.3	55.4	-54.8	eLQFP-128
ADC10D1000	1000/2000	2.77	9.1	57	66	-66	TEPBGA-292

8-Bit MSPS A/D Converters

Product ID	Sampling Rate (MSPS)	Power	ENOB (Bits)	SNR (dB)	SFDR (dB)	THD (dBc)	Packaging
ADC08060	20 to 60	1.3 mW/MSPS	7.5	44.6	64	-57	TSSOP-24
ADC08L060	10 to 60	0.65 mW/MSPS	7.6	48	59.1	-57	TSSOP-24
ADC08100	100	1.3 mW/MSPS	7.5	47	60	-60	TSSOP-24
ADC08200	200	1.05 mW/MSPS	7.4	46	58	-58	TSSOP-24
ADC08B200*	200	2 mW/MSPS	7.4	47	56	-55	TQFP-48
ADC08D500**	500	1.4W	7.5	48	55	-55	LQFP-128
ADC08500	500	0.8W	7.5	47.5	56	-56	LQFP-128

* Buffer
** Dual
PowerWise® product

A/D Converters
MSPS High-Speed

High-Speed MSPS A/D Converters

Product ID	Channels	Speed (MSPS)	Power (mW)	SNR (dB)	SFDR (dB)	Outputs	Packaging
16-Bit							
ADC16V130 [E]	1	130	755	78.5	95.5	LVDS	LLP-64
14-Bit							
ADC14155 [E]	1	155	967	71.3	87	CMOS	LLP-48
ADC14V155 [E]	1	155	951	71.7	86.9	Parallel LVDS	LLP-48
ADC14DS080/105 [E]	2	80/105	800/1000	74.2/73	90	Serial LVDS	LLP-60
ADC14DC080/105 [E]	2	80/105	600/800	73/74	90	CMOS	LLP-60
ADC14C080/105 [E]	1	80/105	300/400	74.2/74	90	CMOS	LLP-32
ADC14L040 [E]	1	40	235	73	90	CMOS	LQFP-32
ADC14L020 [E]	1	20	150	74	93	CMOS	LQFP-32
12-Bit							
ADC12C170 [E]	1	170	715	67.2	85.4	CMOS	LLP-48
ADC12V170 [E]	1	170	781	67.2	85.8	Parallel LVDS	LLP-48
ADC12C105 [E]	1	105	400	71	90	CMOS	LLP-32
ADC12DS080/105 [E]	2	80/105	800/1000	71	88	Serial LVDS	LLP-60
ADC12DC080/105 [E]	2	80/105	600/800	71.5/71	90	CMOS	LLP-60
ADC12C080 [E]	1	80	300	71.2	90	CMOS	LLP-32
ADC12DL080 [E]	2	80	447	69	82	CMOS	TQFP-64
ADC12L080/81 [E]	1	80	425	66	80	CMOS	LQFP-32
ADC12L066	1	66	357	66	80	CMOS	LQFP-32
ADC12QS065 [E]	4	65	800	69	83	Serial LVDS	LLP-60
ADC12DL065 [E]	2	65	360	69	86	CMOS	TQFP-64
ADC12L063	1	62	354	66	78	CMOS	LQFP-32
ADC12EU050 [E]	8	50	384	69.3	77	Serial LVDS	LLP-68
ADC12DL040 [E]	2	40	210	69	85	CMOS	TQFP-64
ADC12D040 [E]	2	40	600	68	80	CMOS	TQFP-64
ADC12040 [E]	1	40	340	69.5	84	CMOS	LQFP-32
ADC12020	1	20	185	70	86	CMOS	LQFP-32
11-Bit							
NEW **ADC11DV200** [E]	2	200	450	62.5	82	CMOS or LVDS	LLP-60
ADC11C170 [E]	1	170	715	65.1	85.4	CMOS	LLP-48
ADC11C125 [E]	1	125	608	65.5	88.2	CMOS	LLP-48
ADC11DL066	2	66	686	64	80	CMOS	TQFP-64
ADC11L066	1	66	357	65	78	CMOS	LQFP-32
10-Bit							
ADC10DV200 [E]	2	200	450	59.9	82	CMOS or LVDS	LLP-60
ADC10080 [E]	1	80	78.6	59.5	79	CMOS	TSSOP-28
ADC10DL065	2	65	370	61	85	CMOS	TQFP-64
ADC10065	1	65	68.4	59.6	80	CMOS	TSSOP-28
ADC10D040	2	40	267	60	72	CMOS	TQFP-48
ADC10040	1	40	55.5	59.6	80	CMOS	TSSOP-28
ADC10D020	2	20	150	59	75	CMOS	TQFP-48

PowerWise® product [E] Evaluation board

LMK Clock Conditioner Family

Jitter Cleaning + Multiplication + Distribution

LMK01000 Family Features

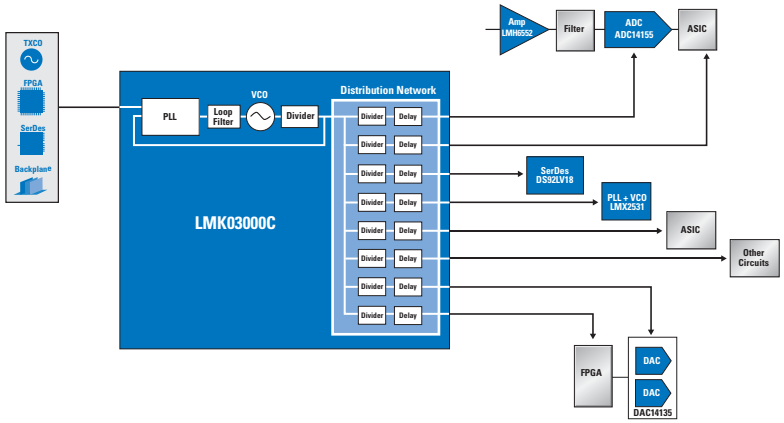
- 2-input and 8-output clock buffer, divider, and distributor
- < 30 fs of additive RMS jitter (typ) at 800 MHz
- Up to 1600 MHz clock frequency

LMK02000 Family Features

- 4- and 8-outputs clock cleaner/generator/distributor with external voltage-controlled crystal oscillator (VCXO)
- < 0.2 ps of RMS jitter (typical)

LMK03000 Family Features

- 4- and 8-output clock cleaner/generator/distributor with integrated low-noise VCO
- < 0.4 ps RMS jitter (typical)
- Lower bill of materials (BOM) cost and footprint using internal VCO
- Three performance grades (premium, standard, value)



Applications:

Ideal for use in 2G/3G basestations, data converter clocking, networking, medical equipment, instrumentation, military, and aerospace applications

LMK Clock Conditioner Family

Product ID	LVPECL Outputs	LVDS Outputs	VCO	PLL	Output Clock Range (MHz)	VCO Frequency (MHz)	RMS Jitter (typ)
LMK01000ISQ	5	3	—	—	0 to 1600	NA	30 fs (additive)
LMK01010ISQ	0	8	—	—	0 to 1600	NA	30 fs (additive)
LMK01020ISQ	8	0	—	—	0 to 1600	NA	30 fs (additive)
LMK02000ISQ	5	3	—	✔	0 to 860	NA	0.2 ps (+VCXO)
LMK02002ISQ	4	0	—	✔	0 to 860	NA	0.2 ps (+VCXO)
LMK03000CISQ	5	3	✔	✔	0 to 648	1185 to 1296	0.4 ps
LMK03001CISQ	5	3	✔	✔	0 to 785	1470 to 1570	0.4 ps
LMK03002CISQ	4	0	✔	✔	0 to 860	1566 to 1724	0.4 ps
LMK03000ISQ	5	3	✔	✔	0 to 648	1185 to 1296	0.8 ps
LMK03001ISQ	5	3	✔	✔	0 to 785	1470 to 1570	0.8 ps
LMK03002ISQ	4	0	✔	✔	0 to 860	1566 to 1724	0.8 ps
LMK03000DISQ	5	3	✔	✔	0 to 648	1185 to 1296	1.2 ps
LMK03001DISQ	5	3	✔	✔	0 to 785	1470 to 1570	1.2 ps
LMK03033ISQ	4	4	✔	✔	1 to 1080	1840 to 2160	0.8
LMK03033CISQ	4	4	✔	✔	1 to 1080	1840 to 2160	0.4

PowerWise® product

High-Speed Industrial Ethernet
Advanced 10/100 Ethernet PHYs

PHYTER® 10/100 Family of Ethernet PHYs for Commercial, Industrial, and Extreme Applications

Features

- Industry's first PHY with support for IEEE 1588 v1 and v2
- 8 ns timestamp resolution
- Internal IEEE 1588 clock
- Industry's lowest deterministic latency
- Software utility support
- Selectable MII/RMII interface
- Flexible interrupt capability
- Reference clock output (to MAC)
- Controlled I/O during power up
- Very low power consumption
  < 23 mW (energy detect mode)
  < 250 mW (normal operation)
- Built-in Self-Test (Packet BIST)

Applications

Ideal for use in industrial automation, test and measurement, telecom, military, and aerospace applications

Precision PHYTER 10/100 IEEE 1588 PHY

Product ID	DP83640T [E]
Parameter	Industrial
Temp Range (°C)	-40 to 85
Number of Ports	Single
Interface	MII/RMII
IEEE 1588 Precision Time Protocol v1 and v2	<10 nS
Cable Health Diagnostics	•
Fiber Support	•
Synchronized GPIOs	12
Synchronized Clock Output	•
IEEE 1149.1 (JTAG)	•
LEDs	3
Packaging	LQFP-48
Package Size (mm)	7 x 7 x 1.4

Single PHYTER Transceiver

Product ID	DP83848C [E]	DP83848I [E]	DP83848VYB	DP83848YB [E]
Parameter	Commercial	Industrial	Extended	Extreme
Temp Range (°C)	0 to 70	-40 to 85	-40 to 105	-40 to 125
Number of Ports	Single			
Interface	MII/RMII/SNI			
Low, Deterministic Delay	•	•	•	•
IEEE 1149.1 (JTAG)		•	•	•
Packaging	LQFP-48			
Package Size (mm)	7 x 7 x 1.4			

Mini PHYTER Transceiver

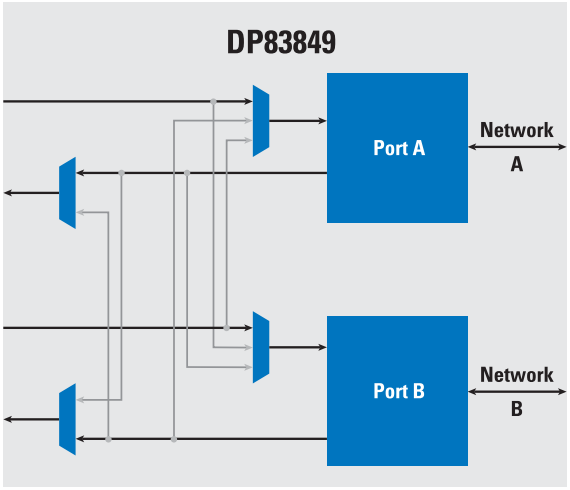
Product ID	DP83848M [E]	DP83848J [E]	DP83848K [E]	DP83848T [E]	DP83848H [E]
Parameter	Commercial	Commercial	Industrial	Industrial	Extreme
Temp Range (°C)	0 to 70	0 to 70	-40 to 85	-40 to 85	-40 to 125
Number of Ports	Single				
Interface	MII/RMII				
Low, Deterministic Delay	•	•	•	•	•
Smart Power Up/Down	•	•	•	•	•
LEDs	1	2	2	1	1
Packaging	LLP-40				
Package Size (mm)	6 x 6 x 0.8				

[E] Evaluation board

DP83849 – Dual PHYTER® 10/100 Ethernet PHY Transceiver for Commercial, Industrial, and Fiber Applications

Features

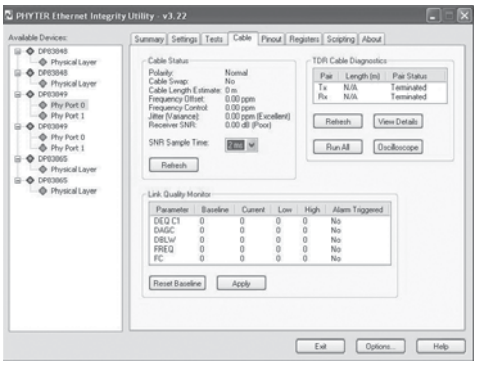
- Flexible port switching and chaining
  - MII port assignment
  - MDI chaining
- Industry's lowest deterministic latency
- Enhanced cable diagnostics
- Two fully independent 10/100 ports
  - Selectable 100Base-Tx/100Base-Fx
  - MII/RMII/SNI
- Controlled I/O during power up
- Built-in Self-Test (Packet BIST)
- Industrial temperature range
- Fully IEEE 802.3u compliant
- Available in TQFP-80 packaging (12 x 12 mm)
- Low power consumption: < 300 mW per port



Unique Flexible Switching Capability

Applications

Ideal for use in industrial automation, test and measurement, telecom, military, and aerospace applications



Enhanced Cable Diagnostics

Dual PHYTER Transceiver

Product ID	DP83849C [E]	DP83849I [E]	DP83849ID	DP83849IF
Parameter	Commercial	Industrial	Industrial	Industrial
Temp Range (°C)	0 to 70	-40 to 85	-40 to 85	-40 to 85
Number of Ports	Dual			
Interface	MII/RMII			
Low, Deterministic Delay	•	•	•	•
Fiber Support			•	•
Flexible Port Switching		•		•
Cable Health Diagnostics	•	•	•	•
IEEE 1149.1 (JTAG)		•	•	•
Packaging	TQFP-80			
Package Size (mm)	12 x 12 x 1.0			

[E] Evaluation board

Serializer/Deserializers

World's Most Robust Serial Interface Solutions for Industrial Imaging, Display, and Control Applications

Features

- Wider operating frequency
- Broad portfolio
- Integrated signal conditioning
- FPGA friendly
- Easy to use
- Low EMI, high ESD protection

Serializers and Deserializers

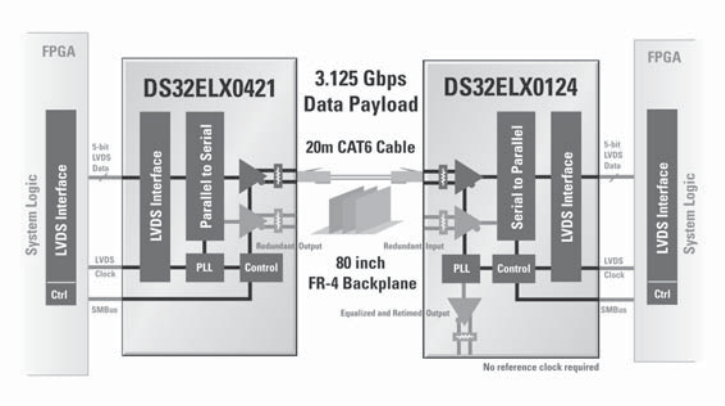
Product ID	MUX Ratio	Function	Clock Min (MHz)	Clock Max (MHz)	Max Payload (Mbps)	Temp Range °C	Packaging	Eval Kit
Embedded Clock FPGA-Link								
NEW **DS32ELX0421** [E]	5:1 DDR LVDS	SER +1:2 Fanout	125	312.5	3.125 Gbps	-40 to 85	LLP-48	AES-EXP-HPSER-G (Avnet)
NEW **DS32ELX0124** [E]	1:5 DDR LVDS	DES+Reclocker	125	312.5	3.125 Gbps	-40 to 85	LLP-48	AES-EXP-HPSER-G (Avnet)
NEW **DS32EL0421** [E]	5:1 DDR LVDS	SER	125	312.5	3.125 Gbps	-40 to 85	LLP-48	AES-EXP-HPSER-G (Avnet)
NEW **DS32EL0124** [E]	1:5 DDR LVDS	DES	125	312.5	3.125 Gbps	-40 to 85	LLP-48	AES-EXP-HPSER-G (Avnet)
Embedded Clock Start/Stop Bit								
SCAN921025H [E]	10:1	SER	20	80	800	-40 to 125	FBGA-49	—
SCAN921226H [E]	1:10	DES	20	80	800	-40 to 125	FBGA-49	—
DS92LV16 [E]	16:1	SERDES	25	80	1280	-40 to 85	LQFP-80	BLVDS16EVK
DS92LV18 [E]	18:1	SERDES	15	66	1188	-40 to 85	LQFP-80	LVDS-18B-EVK
DS90C241 [E]	24:1	SER	5.0	35	840	-40 to 105	TQFP-48	SERDES24-35USB
DS90C124 [E]	1:24	DES	5.0	35	840	-40 to 105	TQFP-48	SERDES24-35USB
DS99R103 [E]	24:1	SER	3.0	40	960	- 40 to 85	LLP-48	SERDES03-40USB
DS99R104 [E]	24:1	DES	3.0	40	960	- 40 to 85	LLP-48	SERDES03-40USB
Parallel Clock Channel Link								
DS90CR217 [E]	21:3	SER	20	85	595/1785	-10 to 70	TSSOP-48	CLINK3V28BT-85
DS90CR218A [E]	3:21	DES	12	85	595/1785	-10 to 70	TSSOP-48	CLINK3V28BT-85
DS90CR287 [E]	28:4	SER	20	85	595/2380	-10 to 70	TSSOP-56	CLINK3V28BT-85
DS90CR288A [E]	4:28	DES	20	85	595/2380	-10 to 70	TSSOP-56	CLINK3V28BT-85

[E] Evaluation board

DS32EL(X)0421/DS32EL(X)0124 – 3.125 Gbps FPGA-Link Serializers and Deserializers

Features

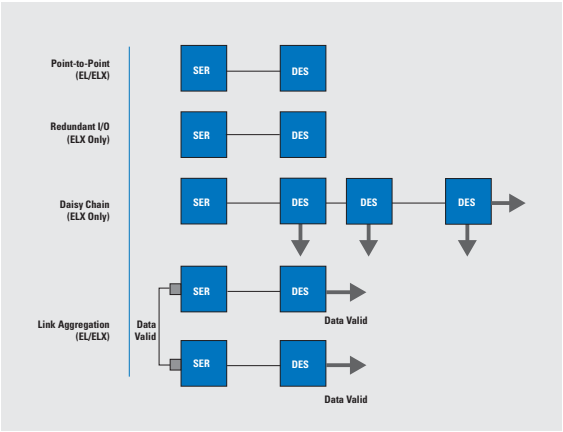
- Wide serial data rate – 1.25 Gbps to 3.125 Gbps
- Tx de-emphasis, RX equalizer, DC balancing, scrambler
- Supports – CAT5e/6/7, FR-4, coax (50Ω, 75Ω) interconnects
- FPGA-friendly interface – 5-bit DDR LVDS data
- "Remote sense" back-channel enables self-healing link
- 35 ps_{pp} (typical) Tx jitter, 0.9 UI (typical) Rx jitter tolerance
- Low power – auto standby and configurable sleep modes
- ELX version features – retimed output and redundant I/O
- Sample FPGA IP for Ser/Des interfacing included



High-Performance SerDes Module Enables Multiple Application Scenarios

Features

- 1.25 to 3.125 Gbps serial data rate
- 125 to 312.5 MHz DDR parallel clock
- Typical power consumption (at 3.125 Gbps)
- DS32EL0421: 470 mW (typical)
- DS32EL0124: 525 mW (typical)
- Deserializer jitter tolerance 0.9 UI (typical)
- Serializer output jitter 35 ps_{pp} (typical)
- FPGA-friendly LVDS parallel interface

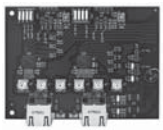


Applications

Ideal for use in industrial imaging, medical imaging, communications infrastructure, commercial displays, test and measurement, printers, and security infrastructure

FPGA IP package includes:

- Sample FPGA firmware to kick-start a design
- BERT engine for test pattern generation and validation
- 5-bit LVDS serialization/deserialization
- Link aggregation
- Failover/redundancy



AES-EXP-HPSER-G

To order the evaluation package, visit:
national.com/serdes

LVDS and CML PHYs

Signal Conditioning—Extend Your Reach

National offers an array of signal conditioning solutions, covering data rates from DC to 10 Gbps and topologies ranging from point-to-point to 32 multidrop loads.

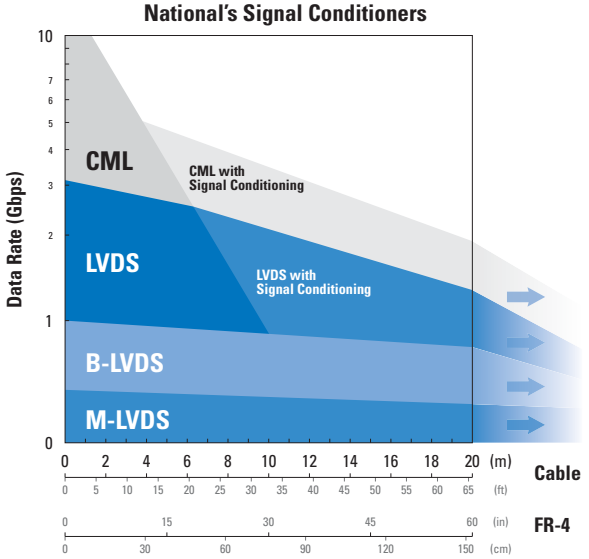
LVDS is the most widespread high-speed signaling technology and generally requires the least amount of power while supporting data rates from DC to 3.125 Gbps.

CML supports data rates as high as 10 Gbps while generally maintaining the lowest jitter.

Signal conditioning using equalization and pre-emphasis (for CML, de-emphasis) enables both technologies to significantly extend cable and backplane reach by compensating for media loss.

B-LVDS and M-LVDS are lower-speed technologies that use controlled edge rates to improve signal integrity when driving multiple loads in multi-drop or multi-point configurations.

National's Signal Conditioners

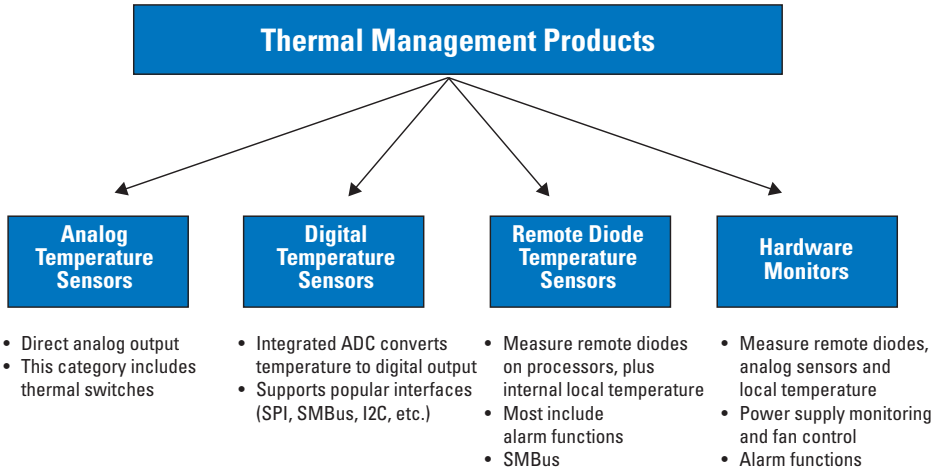


Select Signal Conditioning Products

Product ID	Function	Transmit Equalization (dB)	Receive Equalization (dB)	Max Speed/Ch (Mbps)	Packaging	Eval Kit
Buffers						
DS15BA101	Adjustable output buffer	—	—	1500	LLP-8	DriveCable02EVK
DS10BR150	Single LVDS buffer	—	—	1000	LLP-8	DS10BR150EVK
NEW **DS50PCI401**	Quad PCIe transceiver	0/3/6/9/12	0/9/15/21/26	5000	LLP-54	DS50PCI401EVK
DS91D176	Single M-LVDS transceiver	—	—	200	SOIC-8	DS91D176EVK
DS91M047	Quad M-LVDS driver	—	—	250	SOIC-16	DS91M047EVK
DS92001	Single B-LVDS buffer	—	—	400	SOIC/LLP-8	—
DS92LV040A	Quad B-LVDS buffer	—	—	155	LLP-44	—
Equalizers						
DS15EA101	Adaptive cable equalizer	—	Adaptive	1500	LLP-16	DriveCable02EVK
DS25BR110	Single LVDS equalizer	—	0/3/6/9	3125	LLP-8	DS25BR100EVK
DS38EP100	Power-saver equalizer	—	7	5000	LLP-6	DS38EP100-EVK
Multiplexers and Mux-Buffers						
DS25MB100	2:1/1:2 mux/buffer	0/-3/-6/-9	0/5	2500	LLP-36	DS25MB100-EVK
DS15MB200	Dual 2:1/1:2 mux/buffer	0/6	—	1500	LLP-48	SCAN15MB200EVK
DS42MB200	Dual 2:1/1:2 mux/buffer	0/-3/-6/-9	0/5	4250	LLP-48	—
Crosspoint Switches						
DS25CP102	2 x 2 crosspoint	0/3/6/9	0/3/6/9	3125	LLP-16	DS25CP102EVK
DS10CP154A	4 X 4 crosspoint	—	—	1500	LLP-40	DS10CP154EVK
DS25CP104A	4 X 4 crosspoint	0/3/6/9	0/3/6/9	3125	LLP-40	DS25CP104EVK
1:n Repeaters						
DS90LV110A	1:10 LVDS repeater	—	—	400	TSSOP-28	—
DS10BR254	1:4 LVDS repeater	—	—	1500	LLP-40	—
DS25BR204	1:4 LVDS repeater	0/6	0/6	3125	LLP-40	DS25BR204EVK

PowerWise® product

Temperature Sensors
Analog and Digital



Analog Temperature Sensors

Product ID	Key Features	Operating Temp (°C)	Accuracy (°C)	Operating Supply Voltage Range (V)	Temp Coefficient (mV/C)	Supply Current (µA)	Packaging
LM19/20 [E]	Low power consumption	-55 to 130	±1.5, ±2.5	2.4 to 5.5	-11.7	4.0	SC-70, TO-92
LM45	No trim or external calibration required	-40 to 125	±3, ±4.0	4 to 10	10	120	SOT23-3
LM50	Negative temperature support	-40 to 150	±3, ±4.0	4.5 to 10	10	130	SOT23-3
LM60	Low voltage support	-40 to 125	±3, ±4.0	2.7 to 10	6.25	82	SOT23-3, TO-92-3
LM61	Low voltage support	-30 to 100	±3, ±4.0	2.7 to 10	10	82	SOT23-3, TO-92-3
LM62	Low voltage support	0 to 90	±3, ±4.0	2.7 to 10	15.6	155	SOT23-3
LM94022	Low 1.5V operation	-50 to 150	±2.4	1.5 to 5.5	-5.5/-8.2/10.9/-13.6	5.4	SC70-5

Digital Temperature Sensors

Product ID	Key Features	Temp Range (°C)	Temp Accuracy	Interface	Operating Supply Voltage (V)	Temp Resolutions (°C/LSB)	No. of Interrupts	No. of Available Addresses	Packaging
LM70 [E]	Low precision version of LM74	-10 to 85	1.5/-2	Microwire/SPI	2.85 to 5.5	0.125	—	—	MSOP-8, LLP-8
LM74	Industrial	-10 to 85/100	±1.25, 2.1	Microwire/SPI	3.0 to 5.5	0.0625	—	—	SOP-8
LM95071	High-precision version of LM74	0 to 70	±1.0	Microwire/SPI	2.4 to 5.5	0.03125	—	—	SOT23-5
LM73	Precision	-10 to 110	±1.0, 1.5	I²C/SMBus2.0	2.7 to 5.5	0.03125	1	6	SOT23-6
LM75A	Industry standard	25 to 100	±2.0	I²C BUS	3.0 to 5.5	0.5	1	8	SOP-8, MSOP-8
LM76	Precision	-10 to 100	±.5, 1.0, 2.5	I²C BUS	3.0 to 5.5	0.0625	2	4	SOP-8
LM77	Separate open-drain outputs	-10 to 100	±1.5, 2	I²C BUS	3.0 to 5.5	0.25	2	4	SOP-8, MSOP-8
LM92	Centralized thermal control system precision	-25 to 150	±.33 to 1.5	I²C BUS	2.7 to 5.5	0.0625	2	4	SOP-8

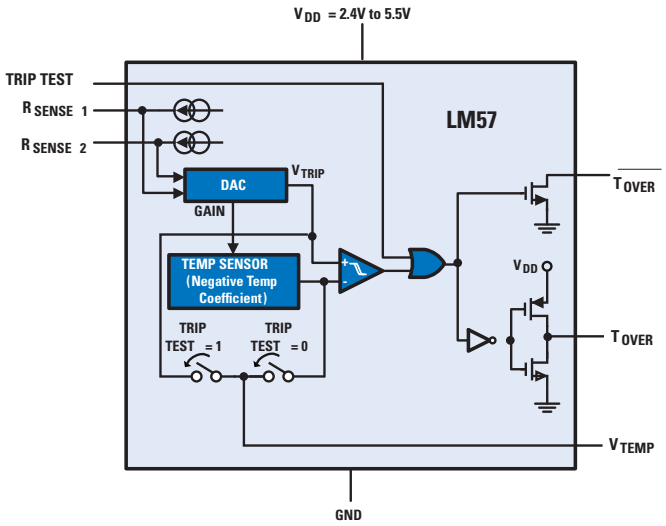
PowerWise® product [E] Evaluation board

Temperature Sensors
Switches and Remote Diode

LM26/27 and LM56/57 – Low-Power Temperature Switches with Single or Dual Output

Features

- Combines window comparator output and analog voltage output
- Alarm output temperature is set at the factory (LM26 and LM27)
- Low supply current: 20 µA to 230 µA (typ)
- Operating supply voltage range: +2.7V to +5.5V
- Detection temperature accuracy:
  - LM26 ±3°C (max) (-55°C to 110°C), ±4°C (max) (+120°C)
  - LM27 ±3°C (max) (-120°C to 150°C)
  - LM56BIM ±2°C (max) (-25°C to 85°C)
  - LM57B ±1.5°C (max) (-50°C to 150°C)



Temperature Switches

Product ID	Temp Range (°C)	Accuracy (°C)	Supply Range (V)	No. of Interrupt Outputs	Interrupt Temp Setting	Packaging
LM26 [E]	-55 to 125	+-3	2.7 to 5.5	1	Factory set	SOT 23-5
LM27	+120 to 150	+-3	2.7 to 5.5	1	Factory set	SOT 23-5
LM56	-40 to 125	±2, 3, 4	2.7 to 10	2	User specified	SOP-8, MSOP-8
LM26LV	0 to 150	±2.2	1.6 to 5.5	2	Factory set	LLP-6
NEW! LM57	-50 to 150	±1.5, 2.3	2.4 to 5.5	2	User specified	LLP-8

Remote Diode Temperature Sensors

Product ID	Description	Pin-Compatible	Processor Supported	Measurement Method	No. of Remote Channels	T_{CRIT}	Selectable Addresses
LM86/89/99 [E]	±0.75°C, MSOP-8		P4 and AMD	Traditional	1	1	Factory set
LM95235 [E]	±0.75°C, MSOP-8		65 nm	TruTherm®	1	1	✔
LM95245	±0.75°C, MSOP-8		45 nm	TruTherm	1	1	✔
LM95231	±1.25°C, MSOP-8		90 nm	TruTherm	2	—	Factory set
LM95241	±1.25°C, MSOP-8		65 nm	TruTherm	2	—	Factory set
LM95213 [E]	±1.1°C, LLP-14		—	Traditional	0 to 2	3	✔
LM95233 [E]	± 0.875°C, LLP-14		65 nm	TruTherm	0 to 2	3	✔
LM95214 [E]	±1.1°C, LLP-14		—	Traditional	0 to 4	3	✔
LM95234 [E]	±0.875°C, LLP-14		65 nm	TruTherm	0 to 4	3	✔
LM96194	±2.5°C, LLP-48		65 nm	TruTherm	2 to 4	—	Full PI hardware monitor
LM87	±4°C, TSSOP-24		—	Traditional	2	1	DAC hardware monitor
LM93	±3°C, TSSOP-56		—	Traditional	2	—	Full LUT hardware monitor
LM94	±2.5°C, TSSOP-56		65 nm	TruTherm	2 to 4	—	Full PI and LUT hardware monitor
LM96163 [E]	±0.75°C, LLP-10		45 nm	TruTherm	1	1	LUT fan control

PowerWise® product [E] Evaluation board

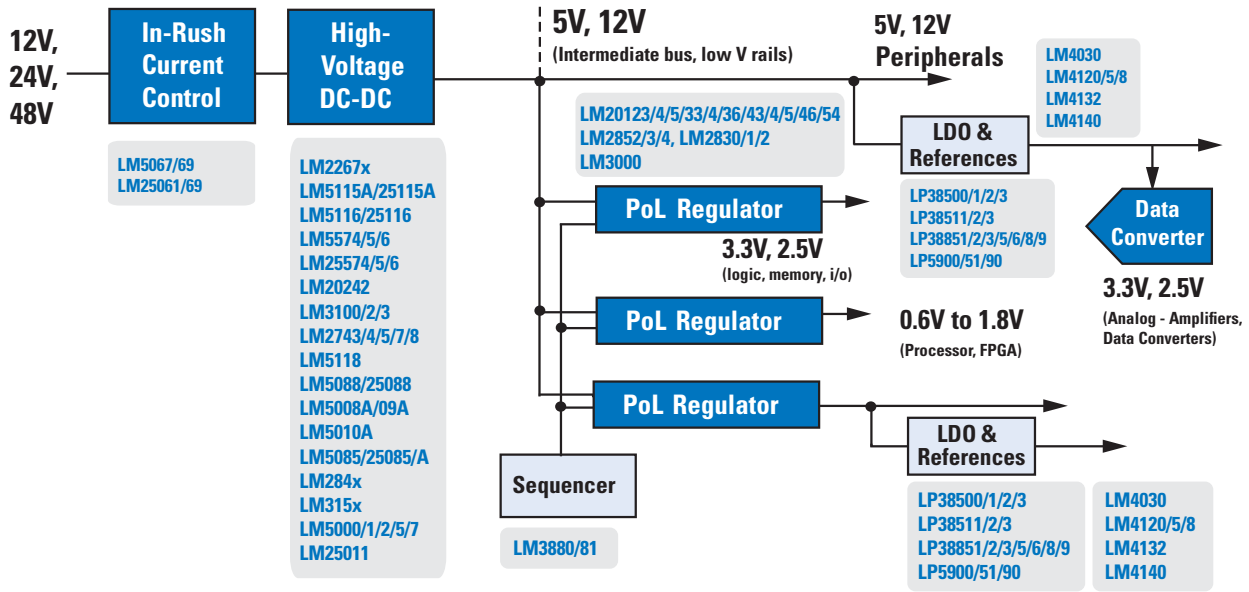
National Provides Highly Reliable Power Management Solutions for Your Industrial Applications

In-Rush Current Control
Limits in-rush current with both power AND current limiting to increase system robustness in high-power industrial applications where reliability is critical.

High-Voltage DC-DC and Point-of-Load (PoL) Regulators
National offers a wide selection of DC-DC converters and PoL regulators to convert wide voltage ranges found in industrial applications down to PoL. Our PowerWise® products enable energy-efficient systems while WEBENCH® tools allow for a simple design process which can be optimized for cost, efficiency, or size.

LDOs and References
National offers a wide portfolio of low-noise and precision LDOs and references to drive sensitive analog and digital loads for industrial applications.

Power Architecture for Industrial Applications

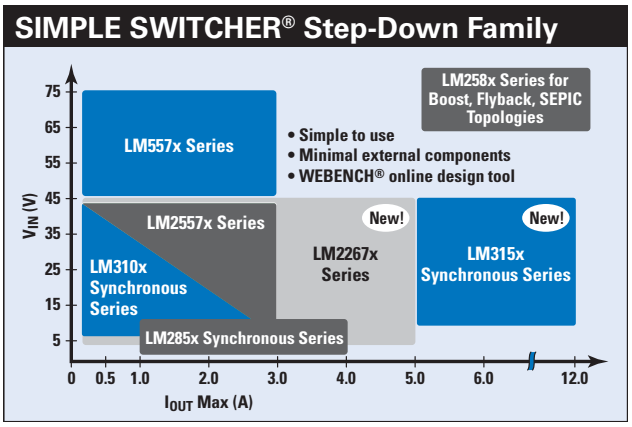


Integrated FET Switching Regulators

Integrated FET switching regulators are ideal for applications where:
Total current is low (<6A)
Low Bill of Materials (BOM) count is critical

National has several families of switching regulators:

- LM20xxx PowerWise® family of high-efficiency, synchronous step-down regulators for Point-of-Load (PoL) applications.
- LM500x wide input voltage regulators support input rails up to 75V with transients up to 100V
- LM3491x and LM248x - Small form factor non-synchronous bucks in ultra-small packages. Internal compensation allows for smaller board space by reducing the number of external components
- SIMPLE SWITCHER® regulators with WEBENCH® online support for maximum ease of use
  - LM310x - Synchronous buck converters regulate outputs down to 0.6V and require no loop compensation
  - LM557x - Emulated Current-Mode buck converters support up to 75V input and offers high performance and design flexibility
  - LM2267x – Non-synchronous regulators with adjustable switching frequency and frequency synchronization for reducing EMI



National's SIMPLE SWITCHER families of integrated regulators feature a full suite of online design tools including the WEBENCH software that allows designers to select, customize, simulate, and order an evaluation board that meets the needs of his or her specific application.

SIMPLE SWITCHER Non-Synchronous Buck Regulators

Product ID	Output Current (mA)	Input Max Voltage (V)	Input Min Voltage (V)	Output Min (V)	Output Max (V)	Frequency Range (kHz)	Sync	PWM Mode	Packaging
LM25574 E,W	500	42	6	1.23	40	50 to 1000	✔	Current	TSSOP-16
LM5574 E,W	500	75	6	1.23	70	50	✔	Current	TSSOP-16
LM25575 E,W	1500	42	6	1.23	40	50 to 1000	✔	Current	TSSOP-16EP
LM5575 E,W	1500	75	6	1.23	70	50	✔	Current	TSSOP-16EP
LM25576 E,W	3000	42	6	1.23	40	50 to 1000	✔	Current	TSSOP-20EP
LM5576 E,W	3000	75	6	1.23	70	50	✔	Current	TSSOP-20EP
LM22671/74 E, W	500	42	4.5	1.285	40	200 to 1000 Adj	✔/–	Voltage	PSOP-8
LM22672/75 E, W	1000	42	4.5	1.285	40	200 to 1000 Adj	✔/–	Voltage	PSOP-8
LM22680 E, W	2000	42	4.5	1.285	40	200 to 1000 Adj	✔	Voltage	PSOP-8
LM22670/73/76 E, W	3000	42	4.5	1.285	40	200 to 1000 Adj	✔/–/–	Voltage	TO263-7 Thin, PSOP-8
LM22677/78/79 E, W	5000	42	4.5	1.285	40	200 to 1000 Adj	✔/–/–	Voltage	TO263-7 Thin

SIMPLE SWITCHER® Synchronous Regulators

Product ID	Output Current (mA)	Input Max Voltage (V)	Input Min Voltage (V)	Output Min (V)	Output Max (V)	Frequency Range (kHz) and Sync (computed field)	PWM Mode	Packaging
LM3103 E,W	750	42	4.5	0.6	38	1000	COT	eTSSOP-16
LM3100 E,W	1500	36	4.5	0.8	32	1000	COT	eTSSOP-20
LM2852 E,W	2000	5.5	2.85	0.8	3.3	500, 1500	Voltage	eTSSOP-14
LM3102 E,W	2500	42	4.5	0.8	38	1000	COT	eTSSOP-20
LM2853 E,W	3000	5.5	3.0	0.8	3.3	550	Voltage	eTSSOP-14
LM2854 E,W	4000	5.5	2.95	0.8	5.0	500, 1000	Voltage	eTSSOP-16

PowerWise® product E Evaluation board W WEBENCH enabled

LM5000 Series Wide-Input-Range Regulators

Product ID	Switch Current (mA)	Input Min Voltage (V)	Input Max Voltage (V)	Frequency Range (kHz) and Sync	Output Min (V)	Output Max (V)	Topology	Packaging
LM5000/1/2 E, W	500/1000/2000	3.1	40/75	50 to 1500, Sync	1.26	Set by external feedback network	Boost	LLP-8/16, TSSOP-16, SOIC-8 Narrow
LM(2)5005 E, W	2500	7.0	(42) 75	50 to 1000, Sync	1.23	(40) 70	Buck	TSSOP-20
LM5009/9A/8/8A E, W	150/350	9.5, 6.0	95	50 to 600	2.5	85/75	Buck	LLP-8, MSOP-8
LM(2)5007 E, W	500	9.0	42/75	50 to 800	2.5	(37) 73	Buck	MSOP-8
LM25010/5010(A) E, W	1000	6.0	42/75	50 to 1000	2.5	37/70	Buck	LLP-10, TSSOP-14EP
NEW! **LM25011** E	2000	6.0	42	2000	2.5	37	Buck	eMSOP-10

LM284X and LM3491X Small Form Factor Non-Synchronous Buck Regulators

Product ID	Current (mA)	Input Max Voltage (V)	Input Min Voltage (V)	Output Min(V)	Output Max (V)	Frequency Range	PWM Mode	Package
LM2841 E	300	42	4.5	0.765	37	550 to 1250	Voltage	TSOT-6
LM2842 E	600	42	4.5	0.765	37	550 to 1250	Voltage	TSOT-6
LM34919 E	600	40	8.0	2.5	35	1600	Constant on-time	micro SMD-10
LM34930 E	1000	33	8.0	2.5	30	Up to 2000	Constant on-time	micro SMD-12
LM34917A E	1250	33	8.0	2.5	30	2000	Constant on-time	micro SMD-12
LM34910/C E, W	1250	36/50	8.0	2.5	33/45	1000	Constant on-time	LLP-10
LM34914 E	1250	40	8.0	2.5	37	1300	Constant on-time	LLP-10

LM20xxx PowerWise® Step-Down Synchronous Buck Regulators

Product ID	Output Current (A)	Input Max Voltage (V)	Input Min Voltage (V)	Output Min (V)	Output Max (V)	Frequency Range (kHz) & Sync (computed field)	On/Off Pin	PWM Mode	Packaging
LM20242 E, W	2.0	36	4.5	0.8	32	1000	✔	Current-mode control	eTSSOP-20
LM20123 E, W	3.0	5.5	2.95	0.8	5.0	1500	✔	Current-mode control	eTSSOP-16
LM20133 E, W	3.0	5.5	2.95	0.8	5.0	460 to 1.5 MHz, Sync-in	✔	Current-mode control	eTSSOP-16
LM20143 E, W	3.0	5.5	2.95	0.8	5.0	500 to 1500	✔	Current-mode control	eTSSOP-16
LM20323 E, W	3.0	36	4.5	0.8	32	500	✔	Current-mode control	eTSSOP-20
LM20333 E, W	3.0	36	4.5	0.8	32	250 to 1.5 MHz, Sync-in	✔	Current-mode control	eTSSOP-20
LM20343 E, W	3.0	36	4.5	0.8	32	250 to 1 MHz	✔	Current-mode control	eTSSOP-20
LM20124 E, W	4.0	5.5	2.95	0.8	5.0	1000	✔	Current-mode control	eTSSOP-16
LM20134 E, W	4.0	5.5	2.95	0.8	5.0	460 to 1.5 MHz, Sync-in	✔	Current-mode control	eTSSOP-16
LM20144 E, W	4.0	5.5	2.95	0.8	5.0	500 to 1000	✔	Current-mode control	eTSSOP-16
LM20154 E, W	4.0	5.5	2.95	0.8	5.0	1000, Sync-out	✔	Current-mode control	eTSSOP-16
LM20125 E, W	5.0	5.5	2.95	0.8	5.0	500	✔	Current-mode control	eTSSOP-16
LM20145 E, W	5.0	5.5	2.95	0.8	5.0	250 to 750	✔	Current-mode control	eTSSOP-16
NEW! **LM20136** E, W	6.0	5.5	2.95	0.8	5.0	460 to 1500, Sync-in	✔	Current-mode control	eTSSOP-16
NEW! **LM20146** E, W	6.0	5.5	2.95	0.8	5.0	250 to 750, Adj	✔	Current-mode control	eTSSOP-16

PowerWise® product E Evaluation board W WEBENCH enabled

Switching Controllers

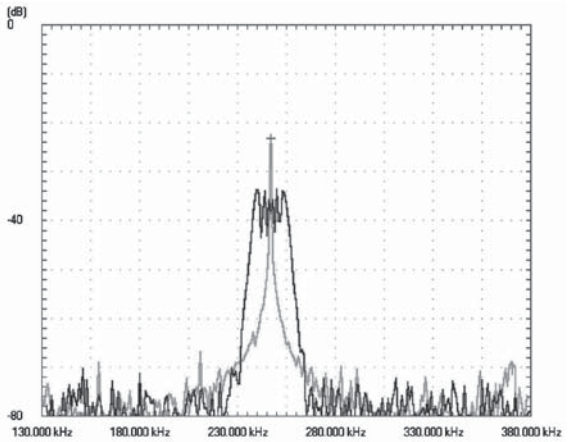
Switching controllers with external MOSFETs are ideal for applications where:

Currents up to 20A+
Design flexibility is important

National has several families of switching controllers:

- LM(2)5xxx Emulated Current Mode (ECM) family of high-efficiency step-down controllers support input rails to 100V
- LM5118 3V to 75V buck-boost controller that supports applications with an input voltage that varies both above and below the output voltage
- LM3000 dual output synchronous controller converts 12V rails to Point of Load (PoL) using separate error amp ground pins for accurate differential sensing of output voltage
- LM315x synchronous SIMPLE SWITCHER® controllers feature WEBENCH® support for a quick and easy design process

LM5088 Uses Spread-Spectrum Technique to Reduce EMI



National's LM5088 Emulated Current Mode (ECM) step-down controller features:

- Frequency dithering (+ 5%) to improve EMI
- Synchronizable frequency, settable to 750 kHz
- Robust 2A gate drivers for high current capability
- Optional voltage tracking through SS/TRK pin

Controllers: Single and Dual Channel

Product ID	Input Max Voltage (V)	Input Min Voltage (V)	Output Min (V)	Feedback Tolerance	Freq Range (kHz) and Sync	Error Flag	Channels	PWM Mode	Packaging	Comments
LM2642 E	30	4.5	1.238	2	300	✔	2	Current	TSSOP-28	Paralleled single output
LM2647 E	28	5.5	0.6	1.5	200 to 500	✔	2	Voltage with V_{IN} FF	LLP-28, TSSOP-28	Lossless current limiting
LM(2)5085/A E	(42) 75	4.5	1.25 / 0.9	2	1000	—	1	COT	MSOP-8, LLP-8	No loop comp required
LM(2)5088 E, W	(42) 75	4.5	1.2	1.5	50 to 1000, Sync	—	1	ECM	TSSOP-16EP	Spread-spectrum EMI reduction
LM(2)5116 E	(42) 100	6	1.2	1.5	50 to 1000	—	1	ECM	TSSOP-20EP	Low Iq SHDN
LM2742	16	1	0.6	1.5	50 to 2000	✔	1	Voltage	TSSOP-14	Adj soft start
LM2743 E, W	16	1	0.6	2	50 to 2000	✔	1	Voltage	TSSOP-14	Adj soft start, tracking
LM2744 E	16	1	0.5	Ext	50 to 2000	✔	1	Voltage	TSSOP-14	Adj external ref, soft start
LM2745/47/48 E	16	1	0.6	1.5/1/1.5	50 to 1000, Sync	✔	1	Voltage	TSSOP-14	Pre-bias operation, track
NEW! **LM3000** E	18.5	3.3	0.6	1	200 to 1000, Sync	✔	2	ECM	LLP-32	Clock out, diff remote sense
LM3150 E, W	42	6	0.6		Adj to 1000	—	1	COT	eTSSOP	No loop comp required
LM3151/52/53 E, W	42/33/18	6	3.3		250/500/700	—	1	COT	eTSSOP	No loop comp required
LM5118 E, W	75	13	1.23		50 to 500, Sync	✔	1	ECM	TSSOP-20	Buck-boost operation
LM5642 E, W	36	4.5	1.3	1.5	200 to 500, Sync	—	2	Current	TSSOP-28	Paralleled single output

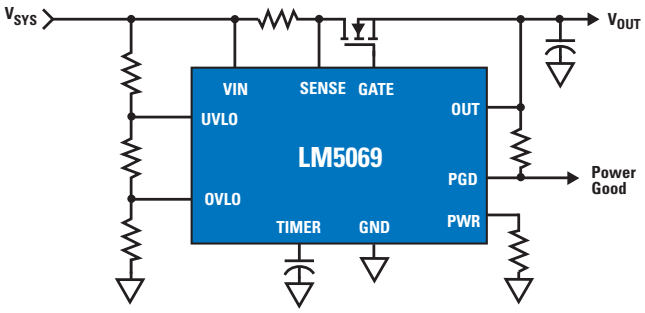
PowerWise® product E Evaluation board W WEBENCH enabled

LM(2)506x – Hot Swap/In-Rush Current Limit Controllers with Current and Power Limiting

Features

- Adjustable in-rush current limit and circuit breaker protect system from over-current/short-circuit events and module insertion/removal from live power sources
- Adjustable power limit sets maximum power dissipation in the external pass device
  - Ensures MOSFET stays in safe operating area (SOA)
  - Reduces MOSFET size
- Adjustable features for design flexibility:
  - Input UVLO/OVLO and hysteresis
  - Multifunction timer to prevent nuisance trips
  - Power GOOD flag output using FB pin (LM25061)
- Internal high-side charge pump and gate driver for external N-channel MOSFET
- Available in latched fault and automatic restart versions

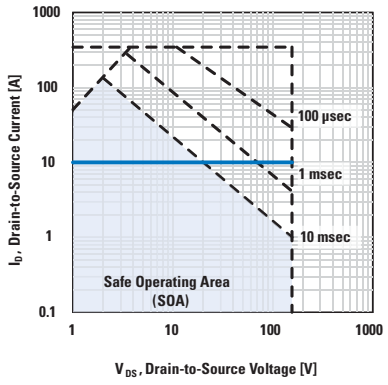
LM5069 Typical Application Circuit



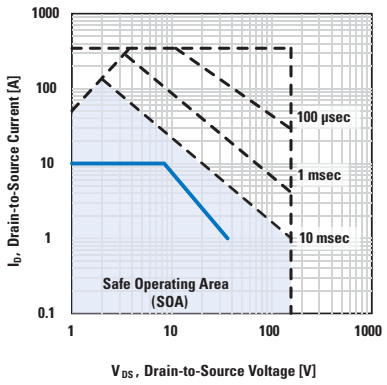
Power Limiting Protects External Pass Device for Improved System Reliability

To ensure system reliability, any MOSFET must operate within its Safe Operating Area (SOA) in order to avoid FET failure. National's LM(2)506x hot swap controllers provide both current and power limiting to dynamically adjust the current limit at large V_{DS} and ensure the MOSFET stays in the SOA at all conditions – maximizing long-term system reliability and robustness.

Conventional Hot Swap: Current Limit Only
MOSFET Out of SOA at Large V_{DS}



LM(2)506x: Current Limit AND Power Limit
Optimal Circuit and MOSFET Protection for All V_{DS}



Hot Swap/In-Rush Current Controllers

Product ID	V_{IN} Range (V)	Power GOOD	Adjustable UVLO	Adjustable OVLO	Active In-Rush Current Limit	Active Current Limiting	Active Power Limiting	Fault Latch-Off/Auto Retry	Packaging
LM5067 [E]	+9 to -80	V_{DS}	✔	✔	✔	✔	✔	Both	MSOP-10, LLP-10
LM5069 [E]	+9 to +80	V_{DS}	✔	✔	✔	✔	✔	Both	MSOP-10
NEW! **LM25061** [E]	+2.9 to +17	V_{OUT} (Adj)	✔		✔	✔	✔	Both	MSOP-10
NEW! **LM25069** [E]	+2.9 to +17	V_{DS}	✔	✔	✔	✔	✔	Both	MSOP-10

[E] Evaluation board

Low Dropout (LDO) Linear Regulators

LP38xxx Family of High-Performance CMOS LDOs Power Digital ICs

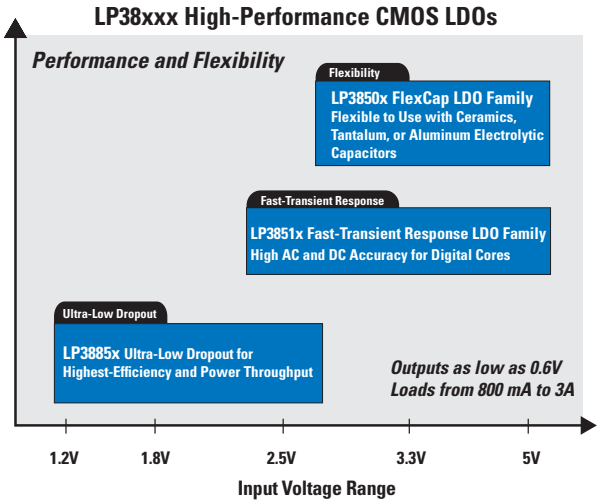
Performance and Flexibility

The LP38xxx family offers performance:

- Ultra-low dropout as low as 115 mV
- Fast-transient response with high AC and DC accuracy for powering digital cores
- High efficiency of 80% for 1.5V to 1.2V conversions

The LP38xxx family offers flexibility:

- Flexible to use with ceramics, tantalum, and aluminum electrolytic capacitors
- Supports input voltages from 1.2V, 1.5V, 1.8V, 2.5V, 3.3V, and 5V rails
- Load currents from 800 mA to 3A with the same pin-out



Fast Transient Response LDOs

Product ID	Load Current (A)	V_{IN} Min (V)	V_{IN} Max (V)	V_{OUT} (V)	Error Flag	Enable	Packaging
LP38511 [E]	0.8	2.25	5.5	1.8, Adj down to 0.8V	✔	✔	TO263-5
LP38512 [E]	1.5	2.25	5.5	1.8, Adj down to 0.8V	✔	✔	TO263-5, LLP-8
LP38513 [E]	3.0	2.25	5.5	1.8, Adj down to 0.8V	✔	✔	TO263-5

Low Input Voltage and High-Efficiency LDOs

Product ID	Load Current (A)	V_{OUT} Options (V)	Adj. Output	Enable Pin	Soft-Start Pin	Typical Dropout (mV)	Packaging
LP38851 PowerWise®	0.8	Adj 0.8 to 1.8	✔	✔	✔	115	PSOP-8, TO263-7
LP38852 [E] PowerWise®	1.5	Adj 0.8 to 1.8	✔	✔	✔	180	PSOP-8, TO263-7
LP38855 PowerWise®	1.5	0.8V, 1.2	—	✔	—	180	TO263-5, TO220-5
LP38858 PowerWise®	1.5	0.8V, 1.2	—	—	✔	180	TO263-5, TO220-5
LP38853 [E] PowerWise®	3.0	Adj 0.8 to 1.8	✔	✔	✔	450	PSOP-8, TO263-7
LP38856 [E] PowerWise®	3.0	0.8V, 1.2	—	✔	—	450	TO263-5, TO220-5
LP38859 [E] PowerWise®	3.0	0.8V, 1.2	—	—	✔	450	TO263-5, TO220-5

FlexCap LDOs

Product ID	Load Current (A)	V_{IN} Min (V)	V_{IN} Max (V)	V_{OUT} (V)	Typical Dropout (mV)	Enable	Packaging
LP38500	1.5	2.7	5.5	Adj down to 0.6	220	—	TO263-5, LLP-8
LP38502 [E]	1.5	2.7	5.5	Adj down to 0.6	220	✔	TO263-5, LLP-8
LP38501 [E]	3.0	2.7	5.5	Adj down to 0.6	450	✔	TO263-5
LP38503	3.0	2.7	5.5	Adj down to 0.6	450	—	TO263-5

PowerWise® product [E] Evaluation board

To see a more complete list and to learn more about LDOs, visit:

national.com/LDO

Low Dropout CMOS Linear Regulator Family

Product ID	V_{IN} Min	V_{IN} Max	V_{OUT}	Maximum Dropout (mV)	Load (mA)	Enable Pin	Packaging
LP38690	2.7	10	ADJ (1.25 - 9) or 1.8, 2.5, 3.3, 5	1600	1000	—	TO252-3, SOT223-5 or LLP-6
LP38691	2.7	10	ADJ (1.25 - 9) or 1.8, 2.5, 3.3, 5	725	500	—	TO252-3 or LLP-6
LP38692 [E]	2.7	10	ADJ (1.25 - 9) or 1.8, 2.5, 3.3, 5	1600	1000	✔	SOT223-5 or LLP-6
LP38693 [E]	2.7	10	ADJ (1.25 - 9) or 1.8, 2.5, 3.3, 5	725	500	✔	SOT223-5 or LLP-6

Low-Input/Low-Output LDOs for Powering Digital ICs

Product ID	Input Max Voltage (V)	Input Min Voltage (V)	Output Current (mA)	Dropout Voltage (V)	Output Voltage (V)	Adjustable Output	On/Off Pin	Quiescent Current (mA)	PSRR (dB)	Voltage Noise (rms)	Packaging
LP3990	6.0	2.0	150	0.06	1.5, 3.8, 1.8, 2.5, 0.8, 1.35, 2.8, 1.2, 3.3	—	✔	0.043	55	125	SOT23-5, micro SMD-4, LLP-6
LP3991 [E]	3.6	1.65	300	0.075	1.5, 1.3, 2.8, 1.2	—	✔	0.05	65	280	micro SMD-4
LP5951 [E]	5.5	1.8	150	0.2	2.0, 1.5, 3.0, 1.8, 1.3, 2.5, 2.8, 3.3	—	✔	0.029	60	125	SOT23-5, SC70-5
LP5952 [E]	4.5	0.9	350	0.088, 0.128	2.0, 1.6, 1.5, 0.7, 1.8, 1.3, 1.0, 1.2, 1.2, 1.4	—	✔	0.011	95	100	micro SMD-5

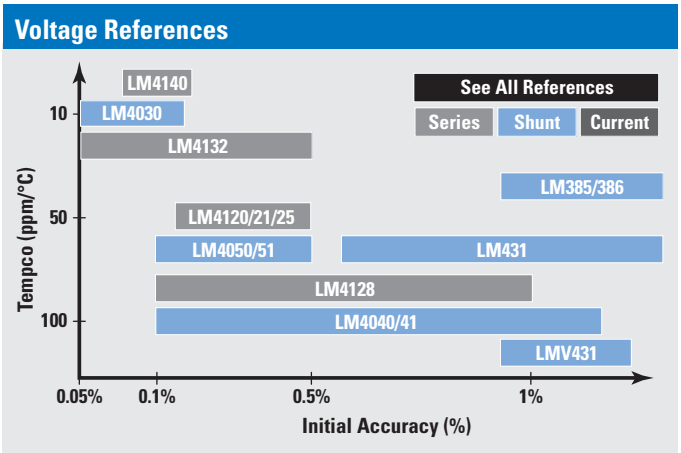
Low-Noise LDOs for Low-Power, Space-Constrained Applications

Product ID	Input Max Voltage (V)	Input Min Voltage (V)	Output Current (mA)	Dropout Voltage (V)	Output Voltage (V)	Adjustable Output	On/Off Pin	Quiescent Current (mA)	PSRR (dB)	Voltage Noise (rms)	Packaging
LP3995	6	2.5	150	0.06	3, 2.8, 1.9	—	✔	0.085	60	25	micro SMD-5; LLP-6
LP3997	6	2	250	0.14	3.3	—	✔	0.055	61	100	MSOP-8
LP3999	6	2.5	150	0.06	1.5, 2.4, 1.8, 2.5, 2.8, 3.3	—	✔	0.085	60	30	micro SMD-5
LP5900 [E]	5.5	2.5	150	0.08	1.5, 2.8, 3.3	—	✔	0.025	75	6.5	micro SMD-4
LP5990 [E]	5.5	2.2	200	0.15	0.8 to 3.6	—	✔	0.03	55	60	micro SMD-4

PowerWise® product [E] Evaluation board

High-Precision Voltage References

National's reference portfolio features low temperature coefficients and precise initial accuracy voltage references. Both series references and shunt references are available for a wide variety of industrial applications including instrumentation, test equipment, data acquisition, basestations, servo systems, battery chargers, and portable battery-powered equipment.



Voltage References

Product ID	Type	Input Max (V)	Input Min (V)	Reference (V)	Initial Accuracy (+/-) Max	Tempco, max (ppm/C)	Output Current (mA)	Quiescent Current (mA)	Long Term Stability (ppm/1000hr)	Voltage Noise (μV_{P-P})	Packaging
LM4120	Series	14	3.3	3, 3.3, 4.096, 2.048, 5, 1.8, 2.5	0.2, 0.5	50	5.0	0.16	100	20	SOT23-5
LM4125	Series	6.0	3.3	4.096, 2.048, 2.5	0.2, 0.5	50	5.0	0.16	100	20	SOT23-5
LM4128	Series	5.5	2.2	3, 3.3, 4.096, 2.048, 1.8, 2.5	0.1, 0.2, 0.5, 1	75, 100	20	0.06	50	170	SOT23-5
LM4132	Series	5.5	2.2	4.096, 2.048, 2.5	0.05, 0.1, 0.2, 0.4, 0.5	10-30	20	0.06	50	170	SOT23-5
LM4140	Series	5.5	1.8	1.25, 4.096, 2.048, 1.024, 2.5	0.1	3.0	8.0	0.23	60	2.2	SOIC-8 Narrow
LM4030	Shunt	NA	NA	2.5, 4.096, 5.0	0.05, 0.10, 0.15	10, 20, 30	30	0.12	50	100	SOT23-5

PowerWise® product

Machinery downtime during normal shift operations is very costly due to lost production, but it is also avoidable. Preventative maintenance systems improve the operating efficiency of machinery used in factories, power plants, mining, and many other operations.

Diagnostic electronics, monitor the operating parameters of the machine. For example, a roller mill may have several large electric motors and rollers, all of which have bearings, a hydraulic pump, and a variety of hydraulic actuators. A preventative maintenance system for this type of equipment could include electronic monitoring equipment to measure bearing vibration and temperature, hydraulic fluid pressure and temperature, and motor temperature.

Vibration analysis, the measurement of vibrations generated by moving parts in the frequency range of 50 Hz to 10 kHz, can be used to monitor the condition of bearings and other moving components. Ultrasonic analysis, an extension of vibration analysis, uses higher frequencies in the 15 kHz to 40 kHz range. Changes are detected through spectral analysis of the generated frequencies in the moving components due to wear or damage. As parts wear, the magnitude of vibrations and ultrasonic noise will increase. An increase of about 12 dB indicates possible impending failure.

This type of monitoring allows repairs to be made before the component fails. In many cases, vibration analysis and ultrasonic require two different pieces of equipment. A single, cost-effective instrument that can monitor the complete frequency range would be useful. (***Figure 1***)

The piezoelectric sensor senses the vibrations and ultrasonic noise generated by the bearings. The piezoelectric element is buffered internally by a MOSFET, which is driven by a constant current source, amplifier A5, and is internally AC coupled to the filter. Amplifiers A1, A2, and A3 implement a gain of 41.9 dB in conjunction with a 6-pole lowpass filter. Amplifier A4 has a gain of 1 with a 2-pole filter. The ADC121S021 Analog-to-Digital Converter (ADC), which operates at a 200 kHz sampling rate, digitizes the amplified and filtered signal. The microprocessor's software performs a FFT (Fast Fourier Transform) on the data to obtain the frequency and magnitude information. The pass-band of the circuitry shown is about 40 kHz. A typical wide band vibration sensor has a transfer function in the form of ***Figure 2***.

The low frequency will start to roll off around 30 Hz and will be relatively flat until a resonance frequency occurs at 65 kHz, after which the response falls rapidly. The peak-to-peak amplitude in

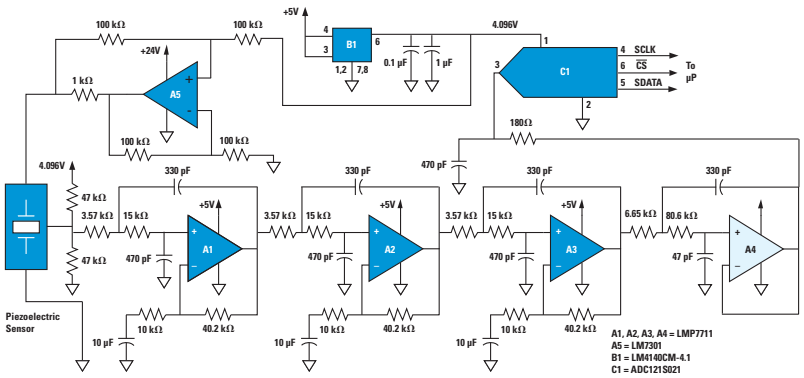


Figure 1. Vibration Analysis Signal Chain

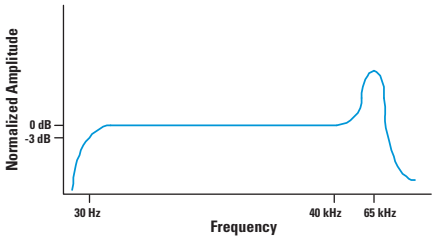


Figure 2. Sensor Transfer Function

the flat band is about 32 mV_{P-P} and will be amplified to 4 V_{P-P}. The gain will be:

$$\frac{4.096\,V}{0.032} = 128$$

A gain of 125 will be used to provide some margin. In relation to the maximum signal frequency of interest, 40 kHz in this case, the sampling rate is a concern. To avoid aliasing frequencies higher then the Nyquist rate, 1/2 the sampling frequency must be filtered and reduced in amplitude to less then 1 LSB of the ADC. In this example, a 12-bit ADC is being used with a 4.096V reference, which results in a resolution of 1 mV as follows:

$$\frac{4.096\,V}{4096} = 0.001V$$

To have a realizable filter in sampled data systems, there must be some separation between the highest frequency to be measured and the Nyquist frequency of the ADC. The result is over sampling the signal, but the filter can reduce or eliminate aliasing. ***Figure 1*** uses the ADC121S021, which is a 12-bit, 200k Samples Per Second (kSPS) ADC. When this ADC is converting at 200 kSPS, the Nyquist frequency will be 100 kHz. The output signal of the sensor is about 8 mVP-P at 100 kHz and the gain required to reduce this signal to less then 1 mV_{P-P} is:

$$20 \log \left(\frac{0.001\,V}{0.008\,V} \right) = -18\ dB$$

The difference between the 100 kHz and the 40 kHz signal is:

$$\log(100\ \text{kHz}) - \log(40\ \text{kHz}) = 5 - 4.60 = 0.40\ \text{decade}$$

At 40 kHz, the gain is:

$$20 \log \left(125\,V/V\right) = 41.9\ \text{dB}$$

The required filter roll off is:

$$\frac{\left(-41.9\ \text{dB} + \left(-18\ \text{dB}\right)\right)}{0.4\ \text{decade}} = -149.8\ \text{dB/decade}$$

Or at least an 8-pole filter:

$$\frac{-149.8\ \text{dB/decade}}{-20\ \text{dB/decade/pole}} = 7.5\ \text{poles}$$

An amplifier can easily implement a 2-pole filter with four amplifiers having a pass-band gain of five and another amplifier with a pass-band gain of one. The filter's pass-band characteristic is a result of the amplifier's gain bandwidth and the placement of the poles in the amplifier's feedback. Each filter stage can be considered as a non-inverting gain stage of 5V/V with two poles. The gain bandwidth of the amplifier required to keep the amplitude error less then 1 LSB at 40 kHz can be calculated as follows:

$$\frac{40\ \text{kHz} \times 5}{0.0156} = 12820\ \text{kHz} = 12.8\ \text{MHz}$$

The denominator, 0.0156, in the previous calculation is the effective bandwidth of an amplifier for 13-bit accuracy given its -3 dB point. The LMP7711 precision amplifier, with 17 MHz gain bandwidth and a typical offset voltage of 20 µV, is a good choice for this type of application. The output of amplifier A4 is isolated from the switched capacitor input of the ADC by the 180Ω resistor and the 470 pF capacitor which adds an additional pole to the antialias filter. ***Figure 3*** shows the estimated response of the low-pass filter.

The ADC121S021 is a single-ended input, 12-bit, 200 kSPS converter with a Serial Peripheral Interface (SPI). An LM4140ACM-4.1 precision voltage reference is the ADC's reference and biases the filter amplifiers to half of the ADC's input range. The sensor's output is an AC signal, and the mid-scale offset level shifts the signal to the center of the ADC's range. The LM4140 is also the reference voltage for the voltage-controlled current source using the LM7301, amplifier A5, a general- purpose 32V amplifier. Internal to the sensor, a MOSFET transistor buffers the piezoelectric sensor element. The current source drives the MOSFET, which is connected as a common source amplifier and is AC coupled to the output terminal.

Another aspect of machine monitoring is the measurement and analysis of hydraulic pressure transients in hydraulic control systems. For example, hydraulic hammer occurs when flow control valves have a fast shutoff and the fluid momentum causes a banging effect within the fluid system. Hydraulic hammer can damage and cause premature failure of hydraulic components and systems. These systems are designed to safely absorb the hydraulic energy. (***Figure 4***)

This signal chain monitor pressure fluctuations and conduct spectral analysis of the pressure fluctuations. As in ***Figure 1***, the frequency response of the sensor and amplifier must eliminate frequency components above the Nyquist frequency. In this case, the frequency response of the pressure sensor and the hydraulic system naturally band limit the pressure signals to about 3 kHz to 4 kHz. This reduces the

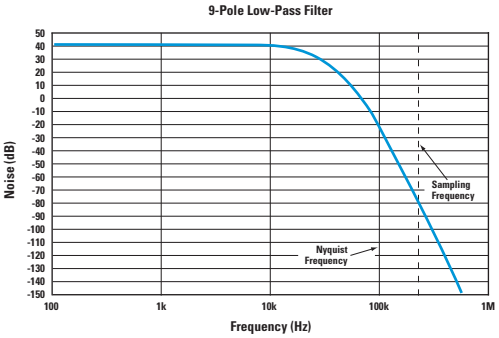
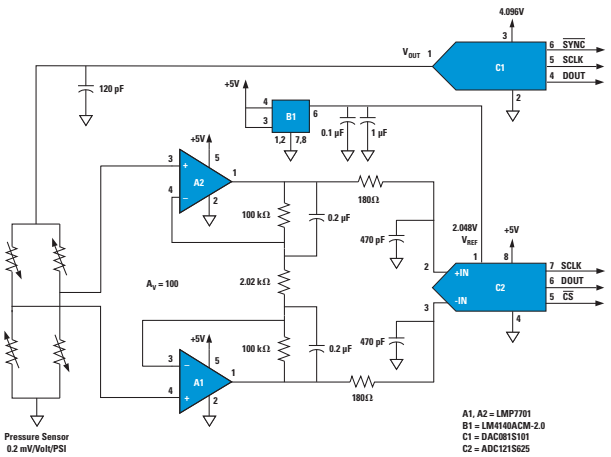


Figure 3. 9-Pole Low-Pass Filter

filter requirements of the amplifier circuits. This amplifier, made up of A1 and A2, is the input stage of an instrumentation amplifier and provides a differential input and a differential output with a gain of 100V/V. The 200 pF capacitors provide a pole at 8 kHz for additional filtering. The amplifiers' outputs are isolated from the switched capacitor inputs of the ADC by the 180Ω resistors and the 470 pF capacitors.

The pressure sensor in this example is a resistive bridge and the sensor's output is a function of the change in resistance and the voltage driving it. The sensor used in ***Figure 4*** has a sensitivity of 0.2 mV/V of bridge excitation voltage per PSI of pressure. The DAC081S101 is used to change the voltage driving the bridge which has the effect of a gain control for the pressure measurement circuit. For example, if the DAC's output is programmed to 4V, then the full-scale pressure is 25.6 PSI. With an output voltage of 1V, the full-scale pressure is 102 PSI.

Figure 4. Hydraulic Pressure Monitoring System



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