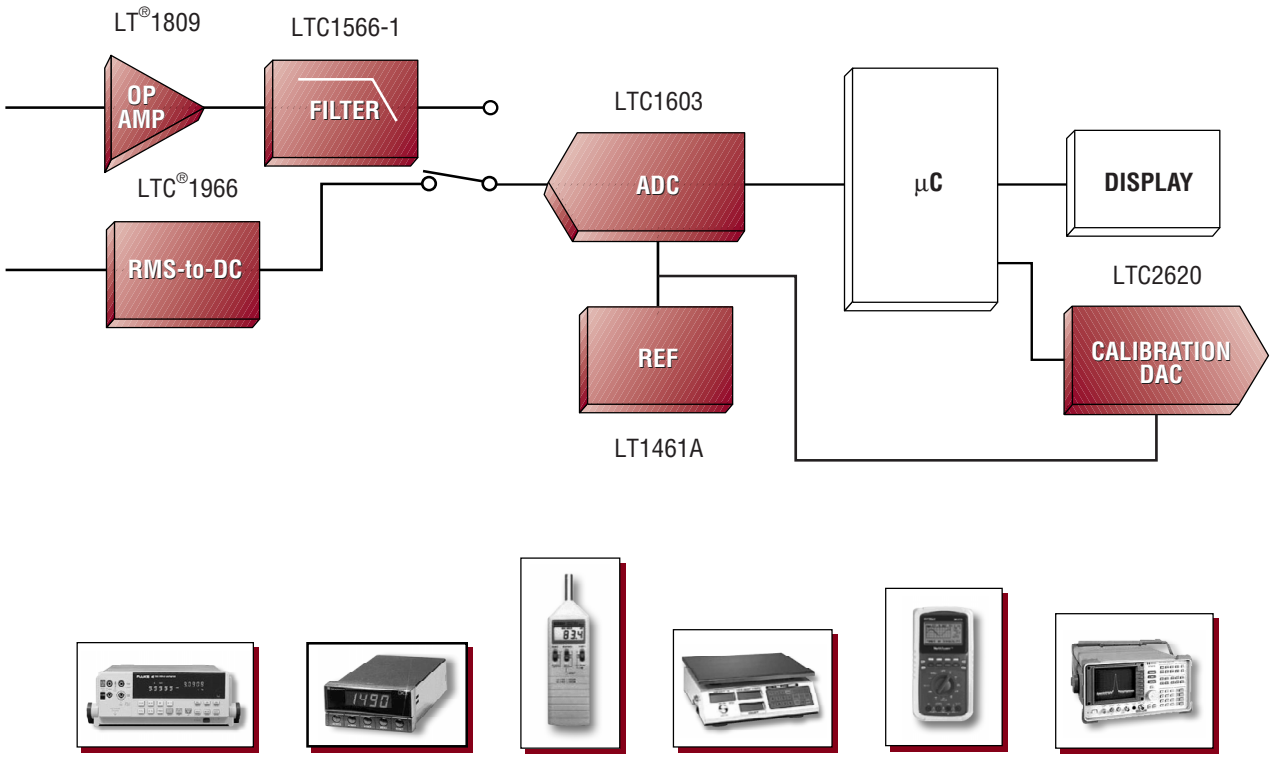
# Linear Technology Chronicle

*High Performance Analog Solutions from Linear Technology* Vol. 12 No. 7

*Focus...*

## Test and Measurement






## Inside This Issue:



Test and measurement instruments must keep pace with technological advances, as well as exceed the accuracy of the equipment under test to provide an accurate measure of performance. Frequency requirements range from DC signals up into the gigahertz range depending on the application. Performance and functionality are the drivers of component selection for instruments ranging from industrial calibrators and temperature measurements to communications test instruments, network analyzers and oscilloscopes.

For handheld devices, power and small package size are also key factors. Maximizing battery life while maintaining performance is imperative. Additionally, keeping the instruments form factor down enhances its "portability."

The following pages highlight Linear Technology integrated circuits that provide the performance needed in many of today's leading edge high performance test and measurement devices.

# Precision DC Measurements

## *Transducer Amplifiers*

Many precision measurement instruments use front-end bridge circuits to measure such parameters as weight, force, torque and pressure. Transducer amplifiers for low level, low impedance (350Ω typical) sensor outputs require:

- **High common mode rejection**
- **Low input offset voltage drift over temperature and time**
- **Low voltage noise**
- **Excitation from either a precision current or voltage source**

Bridge transducers with higher impedances (1kΩ and above) such as piezoresistive pressure sensors, piezoresistive accelerometers or high impedance capacitive sensors require amplifiers with:

- **A combination of low voltage noise and low current noise**
- **Low input bias current**
- **True high impedance inputs, such as those provided by an instrumentation amplifier**

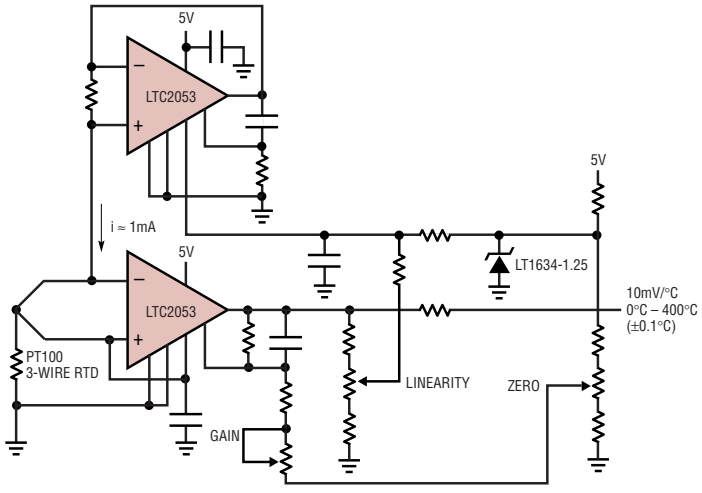
Thermocouples and Resistive Temperature Devices (RTDs) provide two ways of accurately monitoring temperature. Both have very low impedance (100Ω range) and very low sensitivity (20µV/°C for thermocouples and 0.385Ω/°C for RTDs). They have similar requirements to bridge amplifiers but also require:

- **Cold junction compensation (thermocouples)**
- **Precise current source excitation (RTDs)**

### Representative Sample of Transducer Amplifiers

| Part Number | Offset Voltage 25°C (µV) | $I_{BIAS}$ at 25°C (pA) | Voltage Noise (nV/√Hz) | Gain Bandwidth Min (MHz) | Supply Voltage (V) |
|---|---|---|---|---|---|
| **Low Noise** | | | | | |
| LT1001A | 25 | 2nA | 10.3 | 0.4 | ±3 to ±18 |
| LT1007 | 25 | 35 | 4.5 | 5 | 8 to 44 |
| LT1792 | 600 | 800 | 4.2 | 4 | 9 to 40 |
| **DC Precision** | | | | | |
| LTC2050 | 3 | 75 | $1.5\mu V_{P-P}$ | 3 (typ) | 2.7 to ±5.5 |
| LTC1050 | 5 | 30 | $1.6\mu V_{P-P}$ | 2.5 (typ) | 5 to ±8 |
| **Precision, Low Power** | | | | | |
| LT6011A | 60 | 900 | 14 | 0.25 | 2.7 to ±18 |
| LT1880 | 150 | 900 | 13 | 0.8 | 2.7 to 40 |
| **Instrumentation** | | | | | |
| LTC2053 | 10 | 10nA | $2.5\mu V_{P-P}$ | 0.0004 | 2.7 to 11 |
| LT1167A | 40 | 350 | 7.5 | 1 | ±2.3 to ±18 |
| LT1168A | 40 | 250 | 10 | 0.4 | ±2.3 to ±18 |
| LT1789-1 | 100 | 40nA | $1\mu V_{P-P}$ | 0.06 | 2.2 to 36 |
| LTC6800 | 100 | 10nA | $2.5\mu V_{P-P}$ | 0.0004 | 2.7 to 11 |

### Linearized Platinum RTD Amplifier



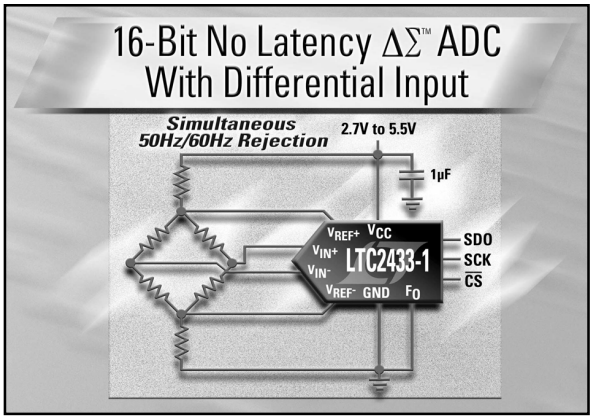
# Precision DC Measurements

## *ADCs*

Linear's high resolution delta-sigma converters provide many inherent benefits when measuring low level signals from load cells, pressure sensors, temperature sensors and gas analyzers. The delta-sigma's noise shaping and filtering improve noise performance and its ability to resolve full-scale signals as small as ±50mV reduces the amount of signal gain required. Pin-compatible 16-/20-/24-bit devices provide an easy migration path for upgraded or downgraded instruments.

For example, the new LTC2433-1 ADC is a true 16-bit high performance data converter with very low noise and a small footprint. The device has 20-bit (LTC2431) and 24-bit (LTC2411) upgrades. Features include:

- **Simultaneous 50/60Hz rejection — 87dB**
- **0.5LSB INL accuracy at 100sps**
- **Small MSOP-10 package**
- **Only 1.45$\mu V_{RMS}$ noise**
- **0.02$\mu$V/°C offset drift**




**Delta-Sigma ADCs**

| Part Number | Bits | MUX | Output Rate (Hz) | Noise ($\mu V_{RMS}$) | Power (mW) | Differential Input | Package |
|---|---|---|---|---|---|---|---|
| LTC2440 | 24 | | 3500 | 0.2 | 55 | YES | SSOP-16 |
| LTC2410 | 24 | | 7.5 | 0.8 | 1 | YES | SSOP-16 |
| LTC2413 | 24 | | 7.5 | 0.8 | 1 | YES | SSOP-16 |
| LTC2412 | 24 | 2 | 7.5 | 0.8 | 1 | YES | SSOP-16 |
| LTC2415 | 24 | | 15 | 1.1 | 1 | YES | SSOP-16 |
| LTC2411 | 24 | | 7.5 | 1.45 | 1 | YES | MSOP-10 |
| LTC2402 | 24 | 2 | 7.5 | 3 | 1 | | MSOP-10 |
| LTC2401 | 24 | | 7.5 | 3 | 1 | | MSOP-10 |
| LTC2435 | 20 | | 15 | 4 | 1 | YES | SSOP-16 |
| LTC2431 | 20 | | 7.5 | 2.8 | 1 | YES | MSOP-10 |
| LTC2430 | 20 | | 7.5 | 2.8 | 1 | YES | SSOP-16 |
| LTC2422 | 20 | 2 | 7.5 | 6 | 1 | | MSOP-10 |
| LTC2421 | 20 | | 7.5 | 6 | 1 | | MSOP-10 |
| LTC2420 | 20 | | 7.5 | 6 | 1 | | SO-8 |
| LTC2433-1 | 16 | | 6.8 | 1.45 | 1 | YES | MSOP-10 |
| LTC2436-1 | 16 | 2 | 6.8 | 0.8 | 1 | YES | SSOP-16 |

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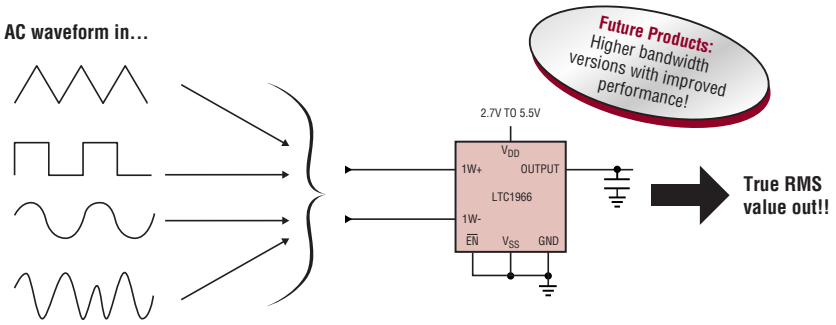
# RMS-to-DC Measurements

Ideal for panel meters, digital multimeters, power meters, AC mains monitoring and acoustic transducers, the LTC1966 uses a patented delta-sigma technique to provide the highest performance for true RMS measurements (compared with analog techniques). It is also simple to use and only requires a single capacitor. The LTC1966 features include:

- **High 0.02% linearity**
- **Low 170µA maximum supply current**
- **0.25% total error out to 1kHz**
- **Small MSOP-8 package**
- **Supports input signals with crest factors up to 4**

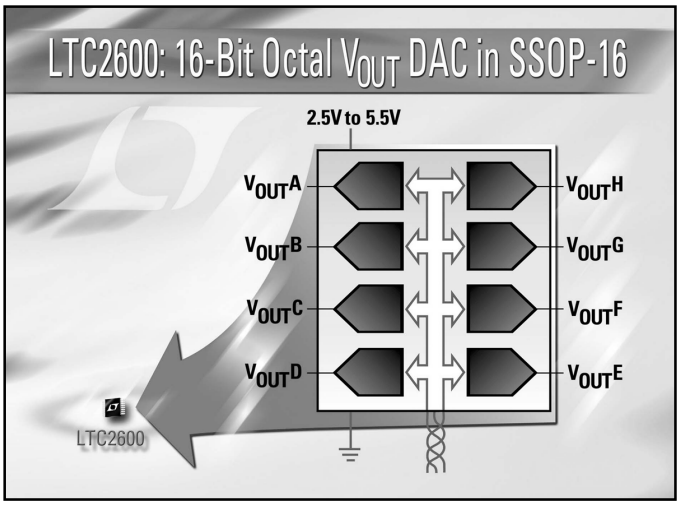
**Precision Patented RMS-to-DC Conversion**




# System Calibration DACs

For system calibration of offset and gain, Linear Technology's LTC2600 family of data converters is ideal. The devices are available in different packages (singles, duals, quads and octals) and have 12- to 16-bit resolution. In addition to low power and small size, these devices feature:

- **2.7V to 5.5V single supply operation**
- **Guaranteed monotonicity**
- **Rail-to-rail outputs**
- **Very small packages — ThinSOT™ single DACs, MSOP dual DACs, SSOP-16 octal DACs**




## DACs for Offset and Gain Adjustments

| Part Number | Resolution | No. of DACs | Supply Current/DAC (µA) | Package |
|---|---|---|---|---|
| LTC1665 | 8 | 8 | 60 | SSOP-16 |
| LTC1663 | 10 | 1 | 60 | ThinSOT |
| LTC1661 | 10 | 2 | 60 | MSOP-8 |
| LTC1662 | 10 | 2 | 1.5 | MSOP-8 |
| LTC1664 | 10 | 4 | 60 | SSOP-16 |
| LTC1660 | 10 | 8 | 60 | SSOP-16 |
| LTC2622 | 12 | 2 | 250 | MSOP-8 |
| LTC2620 | 12 | 8 | 250 | SSOP-16 |
| LTC2612 | 14 | 2 | 250 | MSOP-8 |
| LTC2610 | 14 | 8 | 250 | SSOP-16 |
| LTC2602 | 16 | 2 | 250 | MSOP-8 |
| LTC2600 | 16 | 8 | 250 | SSOP-16 |

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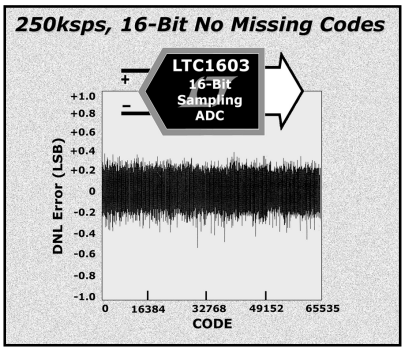
# ADCs for kHz Sensor Signals

In many test and measurement applications, the signal is in the kilohertz range where fast ADCs are needed. A few examples of this include gyroscope measurements, vibration analysis, data loggers, sonar measurements, precision micrometer measurements and x-ray inspection, which require sample rates higher than most delta-sigma converters provide.

Linear Technology's LTC1603, 250ksps analog-to-digital converter, provides many features that ease the design process and maximize performance when fast moving signals are monitored. These include automatic shutdown, user-control of the sampling instant and excellent AC and DC specifications.

- **No pipeline delay**
- **5MHz full power bandwidth**
- **90dB SINAD (typ)**
- **16-bit wide parallel data bus**
- **Pin-compatible upgrades — (LTC1604 - 333ksps and LTC1608 - 500ksps)**




## 16-Bit Successive Approximation Register ADCs

| Part Number | Supply Voltage (V) | Resolution (Bits) | Sample Rate (sps) | INL Error (LSB) | DNL Error (LSB) | Interface | Package | Input Range (V) |
|---|---|---|---|---|---|---|---|---|
| LTC1609 | 5 | 16 | 200k | 2 | 1 | Serial | SSOP-28 | 5,10,±10 |
| LTC1603 | ±5 | 16 | 250k | 3 | 1 | Parallel | SSOP-36 | ±2.5 |
| LTC1604 | ±5 | 16 | 333k | 2 | 1 | Parallel | SSOP-36 | ±2.5 |
| LTC1608 | ±5 | 16 | 500k | 2 | 1 | Parallel | SSOP-36 | ±2.5 |
| LTC1864L | 3 | 16 | 150k | 6 | 2 | Serial | MSOP-8 | $V_{REF}$ |
| LTC1865L | 3 | 16 | 150k | 6 | 2 | Serial | MSOP-10 | $V_{REF}$ |
| LTC1864 | 5 | 16 | 250k | 6 | 2 | Serial | MSOP-8 | $V_{REF}$ |
| LTC1865 | 5 | 16 | 250k | 6 | 2 | Serial | MSOP-10 | $V_{REF}$ |

# Low Noise Amplifiers

Network/spectrum analyzers, optical test equipment, acoustics monitors and other noise-sensitive measurement instruments require high speed, low noise amplifiers. The LT6200 family of amplifiers is ideally suited for such applications. Features include:

- **Very low noise — 0.95nV/$\sqrt{Hz}$ at 100kHz**
- **Gain bandwidth to 1.6GHz (LT6200-10)**
- **Single 2.5V to 12.6V supply**
- **Rail-to-rail outputs**
- **Low distortion — – 80dBc at 1MHz**

## High Speed, Low Noise Amplifiers

| Part Number | Noise Voltage at 100kHz (nV/$\sqrt{Hz}$) | Gain Bandwidth (MHz) | Amplifiers |
|---|---|---|---|
| LT6200 | 0.95 | 165 | Single |
| LT6201 | 0.95 | 165 | Dual |
| LT6200-5 | 0.95 | 800 ($A_V$≥5) | Single |
| LT6200-10 | 0.95 | 1600 ($A_V$≥10) | Single |
| LT6202 | 1.9 | 100 | Single |
| LT6203 | 1.9 | 100 | Dual |
| LT6204 | 1.9 | 100 | Quad |

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# MHz Test and Measurement Signals

## *High Speed Amplifiers*

The push for more bandwidth in high speed communications networks has fueled the need for high performance, high speed signal path ICs. Not only are these ICs used in communications systems, but also in the test equipment that measures overall system performance. Examples include transient analysis instruments, waveform generators, automated test equipment, network analyzers and data acquisition boards.

For fast moving signals, adequate slew rate and gain-bandwidth product prevent the signal path amplifiers from distorting the signal to be measured. High speed buffers isolate the signal source from the data converter, minimizing interaction between the two. The table lists high speed op amps that work well with high speed converters.

### High Speed Op Amps

| Part Number | Gain Bandwidth Product (MHz) | Input Offset Voltage, 0°C to 70°C (µV) | Slew Rate (V/µs) | Power Supplies (V) | Rail-to-Rail |
|---|---|---|---|---|---|
| LT1124 (dual) | 12.5 | 120 | 3 | ±4 to 44 | No |
| LT1468 | 90 | 150 | 15 | ±4.5 to 36 | No |
| LT1800 | 80 | 500 | 11 | 2.3 to 12.6 | Input/Output |
| LT1806 | 325 | 700 | 100 | 2.5 to 12.6 | Input/Output |
| LT1807 (dual) | 325 | 700 | 100 | 2.5 to 12.6 | Input/Output |
| LT1809 | 320 | 3mV | 350 | 2.5 to 12.6 | Input/Output |
| LT6202 | 100 | 700 | 18 | 2.5 to 12.6 | No |

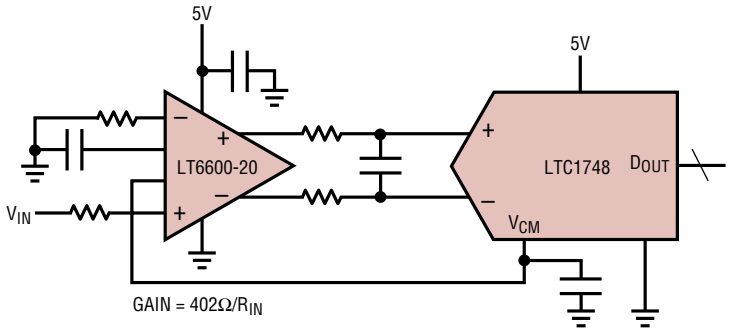
## *High Speed Filters*

As the available frequency spectrum continues to shrink and more complex modulation schemes cram more information into the allotted spectrum, the need for filters that block aliased signals and extract the desired information continues to grow. Off-the-shelf filters and filter building blocks combined with filter software packages like Linear Technology's FilterCAD™ provide a way to quickly exercise the filter to speed the design process and reduce time to market.

The LT6600-20 is a 20MHz lowpass filter for high speed communications and medical test equipment. Used as an ADC antialiasing filter or a post-DAC smoothing filter, this low noise, low distortion filter has 76dB SNR. Other features include:

- **4th order Chebyshev roll-off**
- **Differential input/output**
- **Programmable differential gain**
- **3V to ±5V supplies**

**LT6600 Differential Amplifier/Filter Drives High Speed ADCs**




### Filters for MHz Frequency Signals

| Part Number | Filter Order | Filters per Package | Configuration | Maximum Corner Frequency (MHz) | Package |
|---|---|---|---|---|---|
| LT6600-2.5 | 4 | 1 | Diff amp + Lowpass | Fixed 2.5 | SO-8 |
| LT6600-10 | 4 | 1 | Diff amp + Lowpass | Fixed 10 | SO-8 |
| LT6600-20 | 4 | 1 | Diff amp + Lowpass | Fixed 20 | SO-8 |
| LT1566-1 | 7 | 1 | Lowpass | Up to 2.3 | SO-8 |
| LT1567 | 2 | 1 | Universal | Up to 5 | MSOP-8 |
| LT1568 | 4 | 2 Matched Filters | Lowpass | Up to 5 | SSOP-16 |

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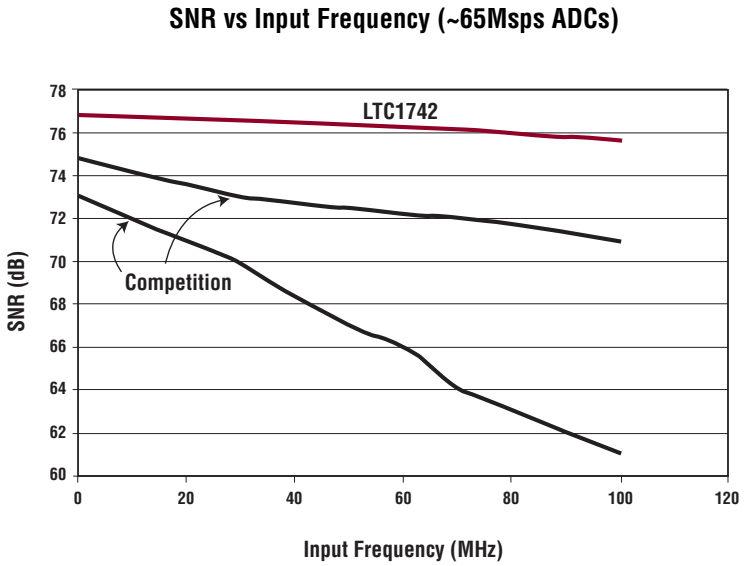
# MHz Test and Measurement Signals

## *High Speed ADCs*

It is imperative that test instruments operate well over the entire specified frequency band, rather than over a narrow frequency band. This reduces the number of test instruments required, thereby reducing the total system cost. The graphic shows how well the LTC1742 works over a wide frequency range vs 14-bit competition.

Ideal for communications and network test equipment, Linear Technology's high speed ADCs are offered in a range of resolutions and at various speeds. They also have AC and DC specifications that put them in the top echelon of high performance data converters.

- **25Msps up to 80Msps ADCs**
- **14-bit and 12-bit pin compatible versions**
- **240MHz bandwidth track and hold**
- **Ideal for undersampling**
- **Industry-leading AC and DC performance**




## High Speed, 14-Bit and 12-Bit ADCs

| Part Number | Resolution (Bits) | Speed (Msps) | T/H Bandwidth (MHz) | SINAD (dB) | SFDR (dB) |
|---|---|---|---|---|---|
| LTC1748 | 14 | 80 | 240 | 76 | 90 |
| LTC1742 | 14 | 65 | 240 | 76 | 90 |
| LTC1744 | 14 | 50 | 150 | 77 | 87 |
| LTC1746 | 14 | 25 | 240 | 77.5 | 96 |
| LTC1747 | 12 | 80 | 240 | 72 | 87 |
| LTC1741 | 12 | 65 | 240 | 72 | 87 |
| LTC1743 | 12 | 50 | 150 | 72.2 | 90 |
| LTC1745 | 12 | 25 | 240 | 72.5 | 96 |

## *High Speed DACs*

The LTC1666/67/68 are 50M writes per second 12-, 14- and 16-bit DACs that are ideally suited for high speed communications and test equipment such as waveform generators and direct digital synthesizers (DDS). The devices feature:

- **20ns settling time**
- **87dB SFDR @ 1MHz output**
- **Low 5pV–s glitch energy**
- **Small 28-pin SSOP package**
- **Differential current output**

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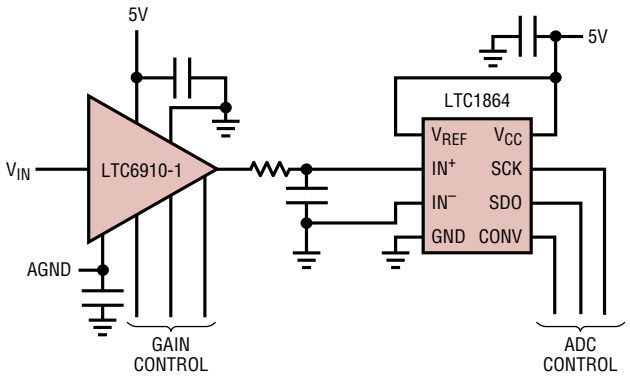
# LTC6910 General Purpose PGA

Measurement equipment often employs a Programmable Gain Amplifier (PGA) for increased dynamic range and automatic gain control. In these applications, using a discrete solution of transistors, matched resistors and additional components is both time consuming and difficult. The LTC6910 is a straightforward simple alternative solution. With matched components on-chip and a simple 3-pin gain control, the device provides a cost-effective easy-to-design-in solution. Features include:

- **Simple 3-bit control**
- **Small ThinSOT package**
- **11MHz gain-bandwidth product**
- **Linear, binary or exponential gain steps**
- **Rail-to-rail input and output**

**Expanding an ADC's Dynamic Range**




# Precision Voltage References

Ideal for system references and data converters, Linear Technology's voltage references provide good initial accuracy and tight drift specifications in a variety of output voltage options.

## Precision, Low Drift References

| Part Number | Initial Accuracy (%) | Drift (ppm/°C) | Output Voltage (V) | Typical RMS Noise, 10Hz to 1kHz (μV) | Package |
|---|---|---|---|---|---|
| LM399A | 2 | 1 | 6.95 | 7 | TO-46 |
| LTZ1000A | - | 2μV/kHr* | 7.2 | 1.2μ $V_{P-P}$, (0.1Hz<f<10Hz) | TO-5 |
| LT1019A | 0.05 | 5 | 2.5, 4.5, 5, 10 | 2.5 | SO-8 |
| LT1236A | 0.05 | 5 | 5, 10 | 2.2 | SO-8 |
| LT1460 | 0.075 | 10 | 2.5, 3, 3.3, 5, 10 | 20 | ThinSOT SO-8 |
| LT1461A | 0.04 | 3 | 2.5, 3, 3.3, 4.096, 5 | 24 to 48 | SO-8 |
| LT1790A | 0.05 | 10 | 1.25, 2.048, 2.5 3, 3.3, 4.096, 5 | 41 | ThinSOT |

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