

## FEATURES

- 16-Bit 250ksps ADCs in MSOP Package
- Single 5V Supply
- Low Supply Current: 850µA (Typ)
- Auto Shutdown Reduces Supply Current to 2µA at 1ksps
- True Differential Inputs
- 1-Channel (LTC1864) or 2-Channel (LTC1865) Versions
- SPI/MICROWIRE™ Compatible Serial I/O
- 16-Bit Upgrade to 12-Bit LTC1286/LTC1298
- Pin Compatible with 12-Bit LTC1860/LTC1861
- Guaranteed Operation to +125°C (MSOP Package)

## APPLICATIONS

- High Speed Data Acquisition
- Portable or Compact Instrumentation
- Low Power Battery-Operated Instrumentation
- Isolated and/or Remote Data Acquisition

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## DESCRIPTION

The LTC®1864/LTC1865 are 16-bit A/D converters that are offered in MSOP and SO-8 packages and operate on a single 5V supply. At 250ksps, the supply current is only 850µA. The supply current drops at lower speeds because the LTC1864/LTC1865 automatically power down between conversions. These 16-bit switched capacitor successive approximation ADCs include sample-and-holds. The LTC1864 has a differential analog input with an adjustable reference pin. The LTC1865 offers a software-selectable 2-channel MUX and an adjustable reference pin on the MSOP version.

The 3-wire, serial I/O, small MSOP or SO-8 package and extremely high sample rate-to-power ratio make these ADCs ideal choices for compact, low power, high speed systems.

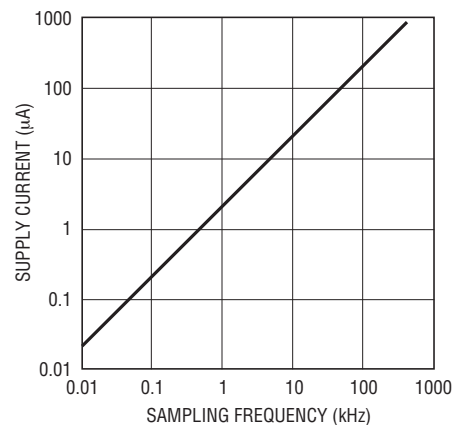
These ADCs can be used in ratiometric applications or with external references. The high impedance analog inputs and the ability to operate with reduced spans down to 1V full scale, allow direct connection to signal sources in many applications, eliminating the need for external gain stages.

## TYPICAL APPLICATION

Single 5V Supply, 250ksps, 16-Bit Sampling ADC



Supply Current vs Sampling Frequency



# LTC1864/LTC1865

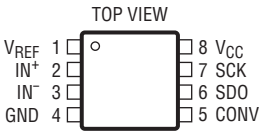
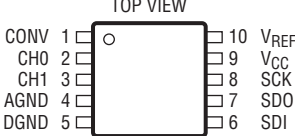
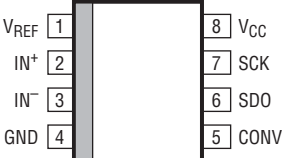
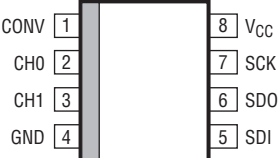
## ABSOLUTE MAXIMUM RATINGS

(Notes 1, 2)

Supply Voltage ( $V_{CC}$ ) .....7V  
 Ground Voltage Difference  
     AGND, DGND LTC1865 MSOP Package .....  $\pm 0.3V$   
 Analog Input ..... (GND – 0.3V) to ( $V_{CC} + 0.3V$ )  
 Digital Input ..... (GND – 0.3V) to 7V  
 Digital Output ..... (GND – 0.3V) to ( $V_{CC} + 0.3V$ )  
 Power Dissipation ..... 400mW

Operating Temperature Range  
 LTC1864C/LTC1865C/  
 LTC1864AC/LTC1865AC ..... 0°C to 70°C  
 LTC1864I/LTC1865I/  
 LTC1864AI/LTC1865AI ..... –40°C to 85°C  
 LTC1864H/LTC1865H  
 LTC1864AH/LTC1865AH ..... –40°C to 125°C  
 Storage Temperature Range ..... –65°C to 150°C  
 Lead Temperature (Soldering, 10 sec) ..... 300°C

## PIN CONFIGURATION

|                                                                                                                                                                                                      |                                                                                                                                                                                                        |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>LTC1864</b><br><br>MS8 PACKAGE<br>8-LEAD PLASTIC MSOP<br>$T_{JMAX} = 150^{\circ}C, \theta_{JA} = 210^{\circ}C/W$ | <b>LTC1865</b><br><br>MS PACKAGE<br>10-LEAD PLASTIC MSOP<br>$T_{JMAX} = 150^{\circ}C, \theta_{JA} = 210^{\circ}C/W$ |
| <b>LTC1864</b><br><br>S8 PACKAGE<br>8-LEAD PLASTIC SO<br>$T_{JMAX} = 150^{\circ}C, \theta_{JA} = 175^{\circ}C/W$  | <b>LTC1865</b><br><br>S8 PACKAGE<br>8-LEAD PLASTIC SO<br>$T_{JMAX} = 150^{\circ}C, \theta_{JA} = 175^{\circ}C/W$  |

## ORDER INFORMATION

| LEAD FREE FINISH | TAPE AND REEL      | PART MARKING | PACKAGE DESCRIPTION  | TEMPERATURE RANGE |
|------------------|--------------------|--------------|----------------------|-------------------|
| LTC1864CMS8#PBF  | LTC1864CMS8#TRPBF  | LTHQ         | 8-Lead Plastic MSOP  | 0°C to 70°C       |
| LTC1864IMS8#PBF  | LTC1864IMS8#TRPBF  | LTHQ         | 8-Lead Plastic MSOP  | –40°C to 85°C     |
| LTC1864HMS8#PBF  | LTC1864HMS8#TRPBF  | LTHQ         | 8-Lead Plastic MSOP  | –40°C to 125°C    |
| LTC1864ACMS8#PBF | LTC1864ACMS8#TRPBF | LTHQ         | 8-Lead Plastic MSOP  | 0°C to 70°C       |
| LTC1864AIMS8#PBF | LTC1864AIMS8#TRPBF | LTHQ         | 8-Lead Plastic MSOP  | –40°C to 85°C     |
| LTC1864AHMS8#PBF | LTC1864AHMS8#TRPBF | LTHQ         | 8-Lead Plastic MSOP  | –40°C to 125°C    |
| LTC1864CS8#PBF   | LTC1864CS8#TRPBF   | 1864         | 8-Lead Plastic SO    | 0°C to 70°C       |
| LTC1864IS8#PBF   | LTC1864IS8#TRPBF   | 1864I        | 8-Lead Plastic SO    | –40°C to 85°C     |
| LTC1864ACS8#PBF  | LTC1864ACS8#TRPBF  | 1864A        | 8-Lead Plastic SO    | 0°C to 70°C       |
| LTC1864AIS8#PBF  | LTC1864AIS8#TRPBF  | 1864AI       | 8-Lead Plastic SO    | –40°C to 85°C     |
| LTC1865CMS#PBF   | LTC1865CMS#TRPBF   | LTHS         | 10-Lead Plastic MSOP | 0°C to 70°C       |
| LTC1865IMS#PBF   | LTC1865IMS#TRPBF   | LTHS         | 10-Lead Plastic MSOP | –40°C to 85°C     |

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## ORDER INFORMATION

| LEAD FREE FINISH  | TAPE AND REEL     | PART MARKING | PACKAGE DESCRIPTION  | TEMPERATURE RANGE |
|-------------------|-------------------|--------------|----------------------|-------------------|
| LTC1865HMS#PBF    | LTC1865HMS#TRPBF  | LTHS         | 10-Lead Plastic MSOP | –40°C to 125°C    |
| LTC1865ACMS#PBF   | LTC1865ACMS#TRPBF | LTHS         | 10-Lead Plastic MSOP | 0°C to 70°C       |
| LTC1865AIMS#PBF   | LTC1865AIMS#TRPBF | LTHS         | 10-Lead Plastic MSOP | –40°C to 85°C     |
| LTC1865AHMS#PBF   | LTC1865AHMS#TRPBF | LTHS         | 10-Lead Plastic MSOP | –40°C to 125°C    |
| LTC1865CS8#PBF    | LTC1865CS8#TRPBF  | 1865         | 8-Lead Plastic SO    | 0°C to 70°C       |
| LTC1865IS8#PBF    | LTC1865IS8#TRPBF  | 1865I        | 8-Lead Plastic SO    | –40°C to 85°C     |
| LTC1865ACS8#PBF   | LTC1865ACS8#TRPBF | 1865A        | 8-Lead Plastic SO    | 0°C to 70°C       |
| LTC1865AIS8#PBF   | LTC1865AIS8#TRPBF | 1865AI       | 8-Lead Plastic SO    | –40°C to 85°C     |
| LEAD BASED FINISH | TAPE AND REEL     | PART MARKING | PACKAGE DESCRIPTION  | TEMPERATURE RANGE |
| LTC1864CMS8       | LTC1864CMS8#TR    | LTHQ         | 8-Lead Plastic MSOP  | 0°C to 70°C       |
| LTC1864IMS8       | LTC1864IMS8#TR    | LTHQ         | 8-Lead Plastic MSOP  | –40°C to 85°C     |
| LTC1864HMS8       | LTC1864HMS8#TR    | LTHQ         | 8-Lead Plastic MSOP  | –40°C to 125°C    |
| LTC1864ACMS8      | LTC1864ACMS8#TR   | LTHQ         | 8-Lead Plastic MSOP  | 0°C to 70°C       |
| LTC1864AIMS8      | LTC1864AIMS8#TR   | LTHQ         | 8-Lead Plastic MSOP  | –40°C to 85°C     |
| LTC1864AHMS8      | LTC1864AHMS8#TR   | LTHQ         | 8-Lead Plastic MSOP  | –40°C to 125°C    |
| LTC1864CS8        | LTC1864CS8#TR     | 1864         | 8-Lead Plastic SO    | 0°C to 70°C       |
| LTC1864IS8        | LTC1864IS8#TR     | 1864I        | 8-Lead Plastic SO    | –40°C to 85°C     |
| LTC1864ACS8       | LTC1864ACS8#TR    | 1864A        | 8-Lead Plastic SO    | 0°C to 70°C       |
| LTC1684AIS8       | LTC1684AIS8#TR    | 1864AI       | 8-Lead Plastic SO    | –40°C to 85°C     |
| LTC1865CMS        | LTC1865CMS#TR     | LTHS         | 10-Lead Plastic MSOP | 0°C to 70°C       |
| LTC1865IMS        | LTC1865IMS#TR     | LTHS         | 10-Lead Plastic MSOP | –40°C to 85°C     |
| LTC1865HMS        | LTC1865HMS#TR     | LTHS         | 10-Lead Plastic MSOP | –40°C to 125°C    |
| LTC1865ACMS       | LTC1865ACMS#TR    | LTHS         | 10-Lead Plastic MSOP | 0°C to 70°C       |
| LTC1865AIMS       | LTC1865AIMS#TR    | LTHS         | 10-Lead Plastic MSOP | –40°C to 85°C     |
| LTC1865AHMS       | LTC1865AHMS#TR    | LTHS         | 10-Lead Plastic MSOP | –40°C to 125°C    |
| LTC1865CS8        | LTC1865CS8#TR     | 1865         | 8-Lead Plastic SO    | 0°C to 70°C       |
| LTC1865IS8        | LTC1865IS8#TR     | 1865I        | 8-Lead Plastic SO    | –40°C to 85°C     |
| LTC1865ACS8       | LTC1865ACS8#TR    | 1865A        | 8-Lead Plastic SO    | 0°C to 70°C       |
| LTC1865AIS8       | LTC1865AIS8#TR    | 1865AI       | 8-Lead Plastic SO    | –40°C to 85°C     |

Consult LTC Marketing for parts specified with wider operating temperature ranges.

For more information on lead free part marking, go to: <http://www.linear.com/leadfree/>

For more information on tape and reel specifications, go to: <http://www.linear.com/tapeandreel/>

# LTC1864/LTC1865

## CONVERTER AND MULTIPLEXER CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ\text{C}$ .  $V_{CC} = 5\text{V}$ ,  $V_{REF} = 5\text{V}$ ,  $f_{SCK} = f_{SCK}(\text{MAX})$  as defined in Recommended Operating Conditions, unless otherwise noted.

| PARAMETER                        | CONDITIONS                                          |        | LTC1864/LTC1865 |                    |                               | LTC1864A/LTC1865A |                    |                               | UNITS                     |
|----------------------------------|-----------------------------------------------------|--------|-----------------|--------------------|-------------------------------|-------------------|--------------------|-------------------------------|---------------------------|
|                                  |                                                     |        | MIN             | TYP                | MAX                           | MIN               | TYP                | MAX                           |                           |
| Resolution                       |                                                     | ●      | 16              |                    |                               | 16                |                    |                               | Bits                      |
| No Missing Codes Resolution      |                                                     | ●      | 14              |                    |                               | 15                |                    |                               | Bits                      |
| INL                              | (Note 3)<br>H-Grade (Note 3)                        | ●<br>● |                 |                    | $\pm 8$<br>$\pm 8.5$          |                   |                    | $\pm 6$<br>$\pm 6.5$          | LSB<br>LSB                |
| Transition Noise                 |                                                     |        |                 | 1.1                |                               |                   | 1.1                |                               | $\text{LSB}_{\text{RMS}}$ |
| Gain Error                       |                                                     | ●      |                 |                    | $\pm 20$                      |                   |                    | $\pm 20$                      | mV                        |
| Offset Error                     | LTC1864 SO-8 and MSOP, LTC1865 MSOP<br>LTC1865 SO-8 | ●<br>● |                 | $\pm 2$<br>$\pm 3$ | $\pm 5$<br>$\pm 7$            |                   | $\pm 2$<br>$\pm 3$ | $\pm 5$<br>$\pm 7$            | mV<br>mV                  |
| Input Differential Voltage Range | $V_{IN} = IN^+ - IN^-$                              | ●      | 0               |                    | $V_{REF}$                     | 0                 |                    | $V_{REF}$                     | V                         |
| Absolute Input Range             | $IN^+$ Input<br>$IN^-$ Input                        |        | -0.05<br>-0.05  |                    | $V_{CC} + 0.05$<br>$V_{CC}/2$ | -0.05<br>-0.05    |                    | $V_{CC} + 0.05$<br>$V_{CC}/2$ | V<br>V                    |
| $V_{REF}$ Input Range            | LTC1864 SO-8 and MSOP,<br>LTC1865 MSOP              |        | 1               |                    | $V_{CC}$                      | 1                 |                    | $V_{CC}$                      | V                         |
| Analog Input Leakage Current     | (Note 4)                                            | ●      |                 |                    | $\pm 1$                       |                   |                    | $\pm 1$                       | $\mu\text{A}$             |
| $C_{IN}$ Input Capacitance       | In Sample Mode<br>During Conversion                 |        |                 | 12<br>5            |                               |                   | 12<br>5            |                               | pF<br>pF                  |

## DYNAMIC ACCURACY

$T_A = 25^\circ\text{C}$ .  $V_{CC} = 5\text{V}$ ,  $V_{REF} = 5\text{V}$ ,  $f_{\text{SAMPLE}} = 250\text{kHz}$ , unless otherwise noted.

| SYMBOL    | PARAMETER                                    | CONDITIONS                 | LTC1864/LTC1865 |     |     | UNITS |
|-----------|----------------------------------------------|----------------------------|-----------------|-----|-----|-------|
|           |                                              |                            | MIN             | TYP | MAX |       |
| SNR       | Signal-to-Noise Ratio                        |                            |                 | 87  |     | dB    |
| S/(N + D) | Signal-to-Noise Plus Distortion Ratio        | 10kHz Input Signal         |                 | 83  |     | dB    |
|           |                                              | 100kHz Input Signal        |                 | 76  |     | dB    |
| THD       | Total Harmonic Distortion Up to 5th Harmonic | 10kHz Input Signal         |                 | 88  |     | dB    |
|           |                                              | 100kHz Input Signal        |                 | 77  |     | dB    |
|           | Full Power Bandwidth                         |                            |                 | 20  |     | MHz   |
|           | Full Linear Bandwidth                        | $S/(N+D) \geq 75\text{dB}$ |                 | 125 |     | kHz   |

## DIGITAL AND DC ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are  $T_A = 25^\circ\text{C}$ .  $V_{CC} = 5\text{V}$ ,  $V_{REF} = 5\text{V}$ , unless otherwise noted.

| SYMBOL       | PARAMETER                                               | CONDITIONS                                                                                                  | LTC1864/LTC1865 |                        |               | UNITS                                |
|--------------|---------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|-----------------|------------------------|---------------|--------------------------------------|
|              |                                                         |                                                                                                             | MIN             | TYP                    | MAX           |                                      |
| $V_{IH}$     | High Level Input Voltage                                | $V_{CC} = 5.25\text{V}$                                                                                     | ●               | 2.4                    |               | V                                    |
| $V_{IL}$     | Low Level Input Voltage                                 | $V_{CC} = 4.75\text{V}$                                                                                     | ●               |                        | 0.8           | V                                    |
| $I_{IH}$     | High Level Input Current                                | $V_{IN} = V_{CC}$                                                                                           | ●               |                        | 2.5           | $\mu\text{A}$                        |
| $I_{IL}$     | Low Level Input Current                                 | $V_{IN} = 0\text{V}$                                                                                        | ●               |                        | -2.5          | $\mu\text{A}$                        |
| $V_{OH}$     | High Level Output Voltage                               | $V_{CC} = 4.75\text{V}$ , $I_O = 10\mu\text{A}$<br>$V_{CC} = 4.75\text{V}$ , $I_O = 360\mu\text{A}$         | ●<br>●          | 4.5<br>2.4             | 4.74<br>4.72  | V<br>V                               |
| $V_{OL}$     | Low Level Output Voltage                                | $V_{CC} = 4.75\text{V}$ , $I_O = 1.6\text{mA}$                                                              | ●               |                        | 0.4           | V                                    |
| $I_{OZ}$     | Hi-Z Output Leakage                                     | $CONV = V_{CC}$                                                                                             | ●               |                        | $\pm 3$       | $\mu\text{A}$                        |
| $I_{SOURCE}$ | Output Source Current                                   | $V_{OUT} = 0\text{V}$                                                                                       |                 | -25                    |               | mA                                   |
| $I_{SINK}$   | Output Sink Current                                     | $V_{OUT} = V_{CC}$                                                                                          |                 | 20                     |               | mA                                   |
| $I_{REF}$    | Reference Current (LTC1864 SO-8 and MSOP, LTC1865 MSOP) | $CONV = V_{CC}$<br>$f_{SMPL} = f_{SMPL(MAX)}$                                                               | ●<br>●          | 0.001<br>0.05          | 3<br>0.1      | $\mu\text{A}$<br>mA                  |
| $I_{CC}$     | Supply Current                                          | $CONV = V_{CC}$ After Conversion<br>$CONV = V_{CC}$ After Conversion, H-Grade<br>$f_{SMPL} = f_{SMPL(MAX)}$ | ●<br>●<br>●     | 0.001<br>0.001<br>0.85 | 3<br>5<br>1.3 | $\mu\text{A}$<br>$\mu\text{A}$<br>mA |
| $P_D$        | Power Dissipation                                       | $f_{SMPL} = f_{SMPL(MAX)}$                                                                                  |                 | 4.25                   |               | mW                                   |

# LTC1864/LTC1865

## RECOMMENDED OPERATING CONDITIONS

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are  $T_A = 25^\circ\text{C}$ .

| SYMBOL       | PARAMETER                                            | CONDITIONS                           | LTC1864/LTC1865           |          |            | UNITS         |
|--------------|------------------------------------------------------|--------------------------------------|---------------------------|----------|------------|---------------|
|              |                                                      |                                      | MIN                       | TYP      | MAX        |               |
| $V_{CC}$     | Supply Voltage                                       |                                      | 4.75                      |          | 5.25       | V             |
| $f_{SCK}$    | Clock Frequency                                      | H-Grade ●                            |                           |          | 20<br>16.7 | MHz<br>MHz    |
| $t_{CYC}$    | Total Cycle Time                                     |                                      | $16 \cdot SCK + t_{CONV}$ |          |            | $\mu\text{s}$ |
| $t_{SMPL}$   | Analog Input Sampling Time                           | LTC1864 (Note 5)<br>LTC1865 (Note 5) | 16<br>14                  |          |            | SCK<br>SCK    |
| $t_{suCONV}$ | Setup Time CONV↓ Before First SCK↑<br>(See Figure 1) | H-Grade                              | 60<br>65                  | 30<br>30 |            | ns<br>ns      |
| $t_{hDI}$    | Hold Time SDI After SCK↑                             | LTC1865                              | 15                        |          |            | ns            |
| $t_{suDI}$   | Setup Time SSDI Stable Before SCK↑                   | LTC1865                              | 15                        |          |            | ns            |
| $t_{WHCLK}$  | SCK High Time                                        | $f_{SCK} = f_{SCK(MAX)}$             | 40%                       |          |            | $1/f_{SCK}$   |
| $t_{WLCLK}$  | SCK Low Time                                         | $f_{SCK} = f_{SCK(MAX)}$             | 40%                       |          |            | $1/f_{SCK}$   |
| $t_{WHCONV}$ | CONV High Time Between Data Transfer Cycles          | (Note 5)                             | $t_{CONV}$                |          |            | $\mu\text{s}$ |
| $t_{WLCONV}$ | CONV Low Time During Data Transfer                   | (Note 5)                             | 16                        |          |            | SCK           |
| $t_{hCONV}$  | Hold Time CONV Low After Last SCK↑                   |                                      |                           | 13       |            | ns            |

**TIMING CHARACTERISTICS**

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are  $T_A = 25^\circ\text{C}$ .  $V_{CC} = 5\text{V}$ ,  $V_{REF} = 5\text{V}$ ,  $f_{SCK} = f_{SCK(MAX)}$  as defined in Recommended Operating Conditions, unless otherwise noted.

| SYMBOL          | PARAMETER                                            | CONDITIONS                                                                                 |             | LTC1864/LTC1865 |              |                | UNITS                                     |
|-----------------|------------------------------------------------------|--------------------------------------------------------------------------------------------|-------------|-----------------|--------------|----------------|-------------------------------------------|
|                 |                                                      |                                                                                            |             | MIN             | TYP          | MAX            |                                           |
| $t_{CONV}$      | Conversion Time (See Figure 1)                       | H-Grade                                                                                    | ●<br>●      |                 | 2.75<br>2.75 | 3.2<br>3.3     | $\mu\text{s}$<br>$\mu\text{s}$            |
| $f_{SMPL(MAX)}$ | Maximum Sampling Frequency                           | H-Grade                                                                                    | ●<br>●      | 250<br>234      |              |                | $\text{kHz}$<br>$\text{kHz}$              |
| $t_{dDO}$       | Delay Time, $SCK\downarrow$ to SDO Data Valid        | $C_{LOAD} = 20\text{pF}$<br>$C_{LOAD} = 20\text{pF}$<br>$C_{LOAD} = 20\text{pF}$ , H-Grade | ●<br>●<br>● |                 | 15           | 20<br>25<br>30 | $\text{ns}$<br>$\text{ns}$<br>$\text{ns}$ |
| $t_{dis}$       | Delay Time, $CONV\uparrow$ to SDO Hi-Z               | H-Grade                                                                                    | ●<br>●      |                 | 30<br>30     | 60<br>65       | $\text{ns}$<br>$\text{ns}$                |
| $t_{en}$        | Delay Time, $CONV\downarrow$ to SDO Enabled          | $C_{LOAD} = 20\text{pF}$<br>$C_{LOAD} = 20\text{pF}$ , H-Grade                             | ●<br>●      |                 | 30<br>30     | 60<br>65       | $\text{ns}$<br>$\text{ns}$                |
| $t_{hDO}$       | Time Output Data Remains Valid After $SCK\downarrow$ | $C_{LOAD} = 20\text{pF}$                                                                   | ●           | 5               | 10           |                | $\text{ns}$                               |
| $t_r$           | SDO Rise Time                                        | $C_{LOAD} = 20\text{pF}$                                                                   |             |                 | 8            |                | $\text{ns}$                               |
| $t_f$           | SDO Fall Time                                        | $C_{LOAD} = 20\text{pF}$                                                                   |             |                 | 4            |                | $\text{ns}$                               |

**Note 1:** Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

**Note 2:** All voltage values are with respect to GND.

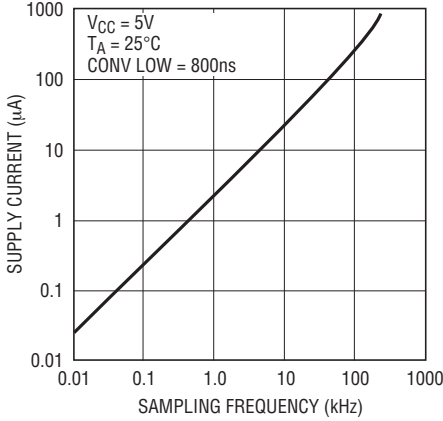
**Note 3:** Integral nonlinearity is defined as deviation of a code from a straight line passing through the actual endpoints of the transfer curve. The deviation is measured from the center of the quantization band.

**Note 4:** Channel leakage current is measured while the part is in sample mode.

**Note 5:** Guaranteed by design, not subject to test.

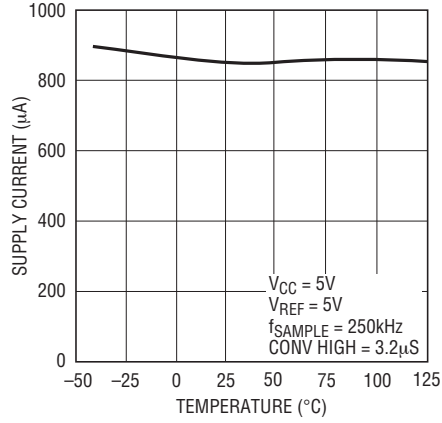
## TYPICAL PERFORMANCE CHARACTERISTICS

**Supply Current vs Sampling Frequency**



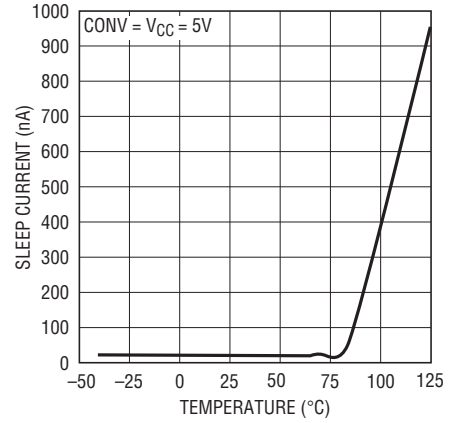
18645 G01

**Supply Current vs Temperature**



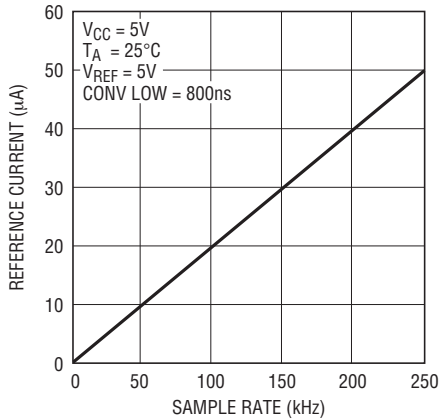
18645 G02

**Sleep Current vs Temperature**



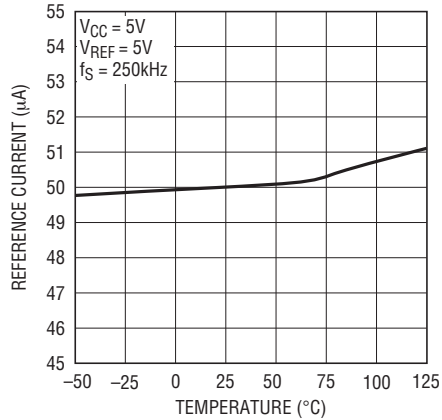
18645 G03

**Reference Current vs Sampling Rate**



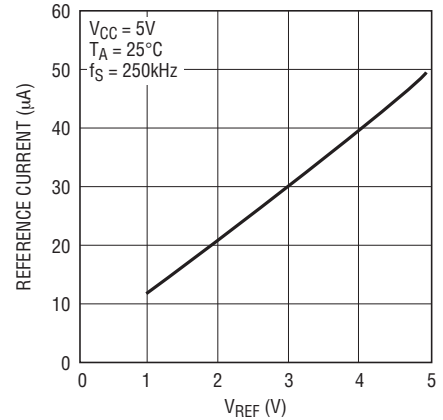
18645 G04

**Reference Current vs Temperature**



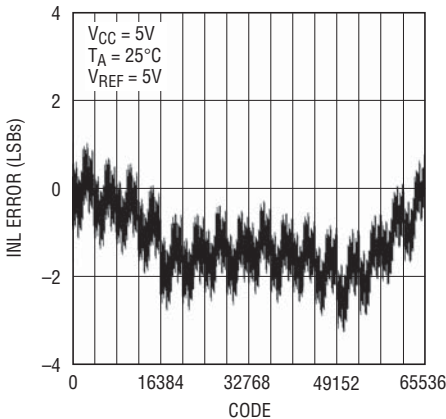
18645 G05

**Reference Current vs Reference Voltage**



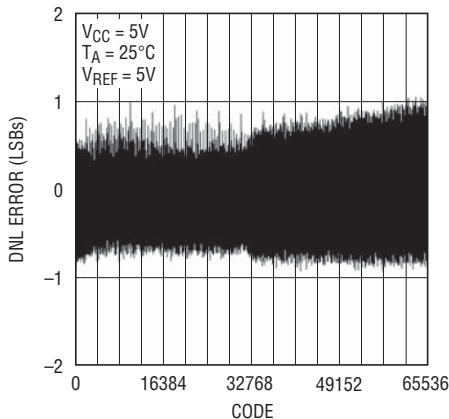
18645 G06

**Typical INL Curve**



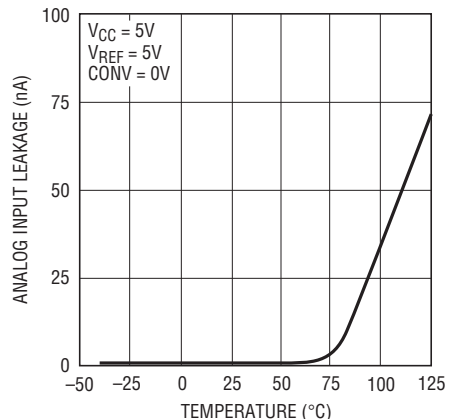
18645 G07

**Typical DNL Curve**



18645 G08

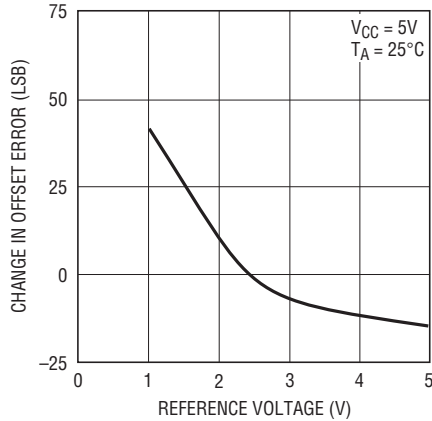
**Analog Input Leakage Current vs Temperature**



18645 G09

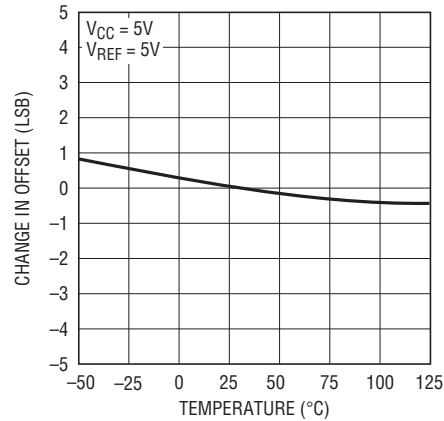
## TYPICAL PERFORMANCE CHARACTERISTICS

Change in Offset Error vs Reference Voltage



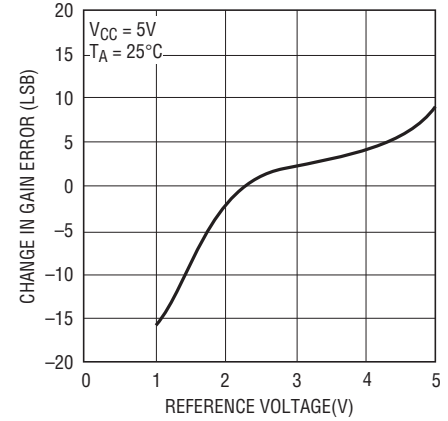
18645 G10

Change in Offset vs Temperature



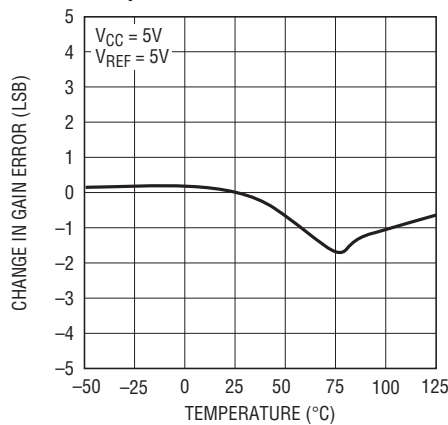
18645 G11

Change in Gain Error vs Reference Voltage



18645 G12

Change in Gain Error vs Temperature



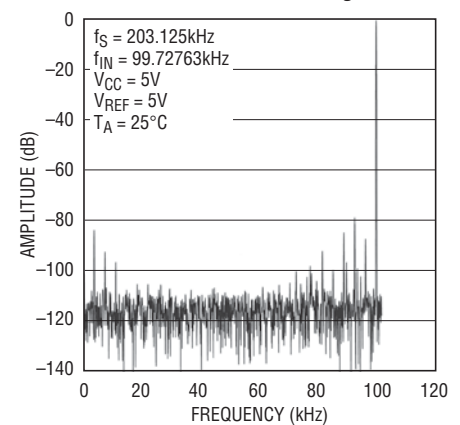
18645 G13

Histogram of 4096 Conversions of a DC Input Voltage



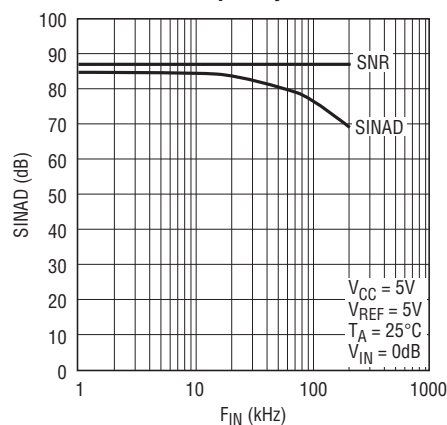
18645 G14

4096 Point FFT Nonaveraged



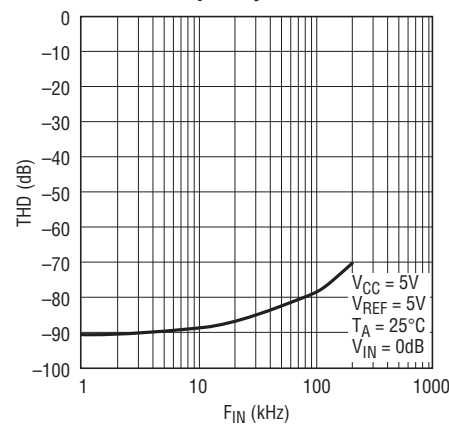
18645 G15

SINAD vs Frequency



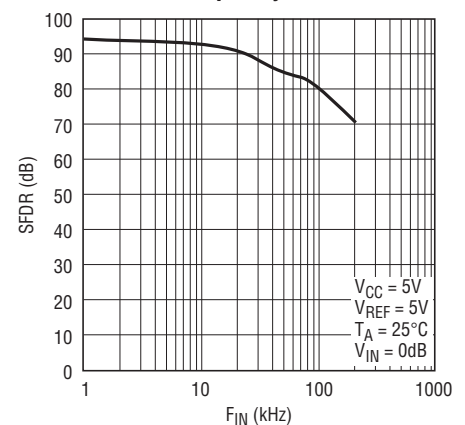
18645 G16

THD vs Frequency



18645 G17

SFDR vs Frequency



18645 G18

18645fb

## PIN FUNCTIONS

### LTC1864

**V<sub>REF</sub> (Pin 1):** Reference Input. The reference input defines the span of the A/D converter and must be kept free of noise with respect to GND.

**IN<sup>+</sup>, IN<sup>-</sup> (Pins 2, 3):** Analog Inputs. These inputs must be free of noise with respect to GND.

**GND (Pin 4):** Analog Ground. GND should be tied directly to an analog ground plane.

**CONV (Pin 5):** Convert Input. A logic high on this input starts the A/D conversion process. If the CONV input is left high after the A/D conversion is finished, the part

powers down. A logic low on this input enables the SDO pin, allowing the data to be shifted out.

**SDO (Pin 6):** Digital Data Output. The A/D conversion result is shifted out of this pin.

**SCK (Pin 7):** Shift Clock Input. This clock synchronizes the serial data transfer.

**V<sub>CC</sub> (Pin 8):** Positive Supply. This supply must be kept free of noise and ripple by bypassing directly to the analog ground plane.

### LTC1865 (MSOP Package)

**CONV (Pin 1):** Convert Input. A logic high on this input starts the A/D conversion process. If the CONV input is left high after the A/D conversion is finished, the part powers down. A logic low on this input enables the SDO pin, allowing the data to be shifted out.

**CH0, CH1 (Pins 2, 3):** Analog Inputs. These inputs must be free of noise with respect to AGND.

**AGND (Pin 4):** Analog Ground. AGND should be tied directly to an analog ground plane.

**DGND (Pin 5):** Digital Ground. DGND should be tied directly to an analog ground plane.

**SDI (Pin 6):** Digital Data Input. The A/D configuration word is shifted into this input.

**SDO (Pin 7):** Digital Data Output. The A/D conversion result is shifted out of this output.

**SCK (Pin 8):** Shift Clock Input. This clock synchronizes the serial data transfer.

**V<sub>CC</sub> (Pin 9):** Positive Supply. This supply must be kept free of noise and ripple by bypassing directly to the analog ground plane.

**V<sub>REF</sub> (Pin 10):** Reference Input. The reference input defines the span of the A/D converter and must be kept free of noise with respect to AGND.

### LTC1865 (SO-8 Package)

**CONV (Pin 1):** Convert Input. A logic high on this input starts the A/D conversion process. If the CONV input is left high after the A/D conversion is finished, the part powers down. A logic low on this input enables the SDO pin, allowing the data to be shifted out.

**CH0, CH1 (Pins 2, 3):** Analog Inputs. These inputs must be free of noise with respect to GND.

**GND (Pin 4):** Analog Ground. GND should be tied directly to an analog ground plane.

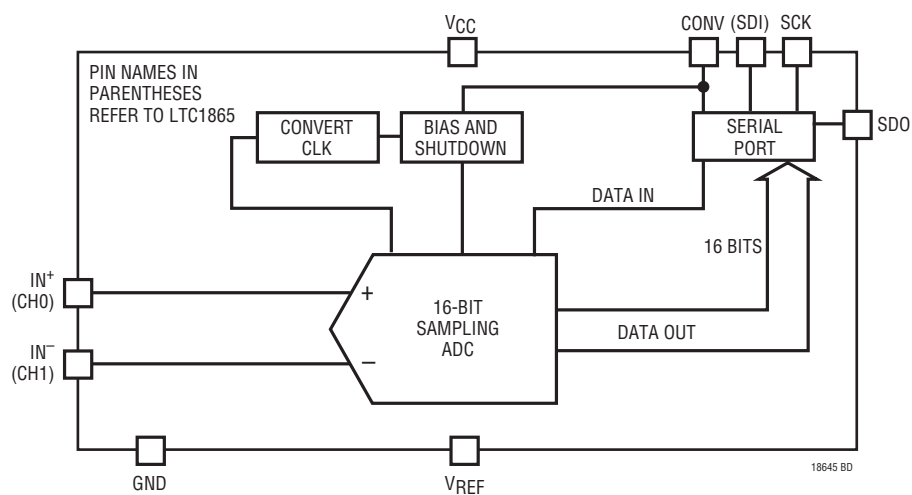
**SDI (Pin 5):** Digital Data Input. The A/D configuration word is shifted into this input.

**SDO (Pin 6):** Digital Data Output. The A/D conversion result is shifted out of this output.

**SCK (Pin 7):** Shift Clock Input. This clock synchronizes the serial data transfer.

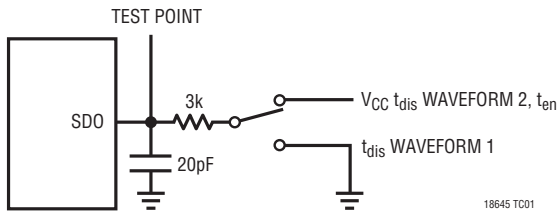
**V<sub>CC</sub> (Pin 8):** Positive Supply. This supply must be kept free of noise and ripple by bypassing directly to the analog ground plane. V<sub>REF</sub> is tied internally to this pin.

## FUNCTIONAL BLOCK DIAGRAM

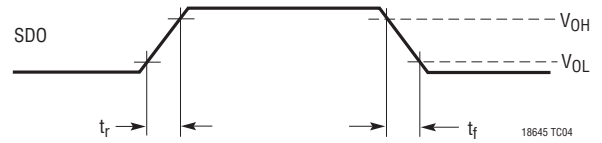


## TEST CIRCUITS

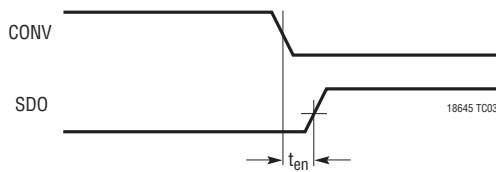
Load Circuit for  $t_{dDO}$ ,  $t_r$ ,  $t_f$ ,  $t_{dis}$  and  $t_{en}$



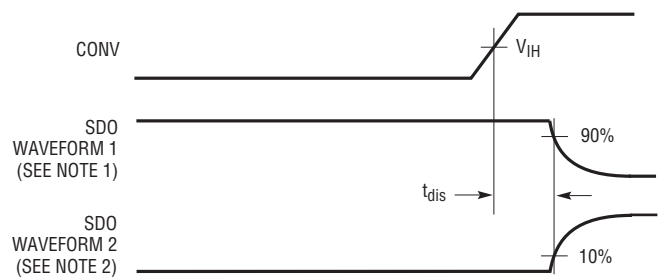
Voltage Waveforms for SDO Rise and Fall Times,  $t_r$ ,  $t_f$



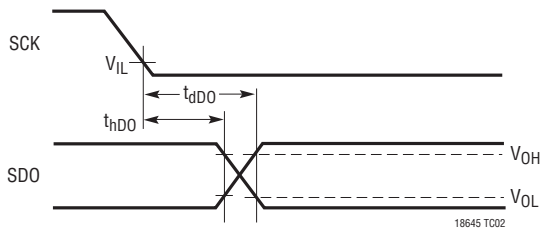
Voltage Waveforms for  $t_{en}$



Voltage Waveforms for  $t_{dis}$



Voltage Waveforms for SDO Delay Times,  $t_{dDO}$  and  $t_{hDO}$



NOTE 1: WAVEFORM 1 IS FOR AN OUTPUT WITH INTERNAL CONDITIONS SUCH THAT THE OUTPUT IS HIGH UNLESS DISABLED BY THE OUTPUT CONTROL  
NOTE 2: WAVEFORM 2 IS FOR AN OUTPUT WITH INTERNAL CONDITIONS SUCH THAT THE OUTPUT IS LOW UNLESS DISABLED BY THE OUTPUT CONTROL

18645 TC05

# APPLICATIONS INFORMATION

## LTC1864 OPERATION

### Operating Sequence

The LTC1864 conversion cycle begins with the rising edge of CONV. After a period equal to  $t_{CONV}$ , the conversion is finished. If CONV is left high after this time, the LTC1864 goes into sleep mode drawing only leakage current. On the falling edge of CONV, the LTC1864 goes into sample mode and SDO is enabled. SCK synchronizes the data transfer with each bit being transmitted from SDO on the falling edge of SCK. The receiving system should capture the data from SDO on the rising edge of SCK. After completing the data transfer, if further SCK clocks are applied with CONV low, SDO will output zeros indefinitely. See Figure 1.

### Analog Inputs

The LTC1864 has a unipolar differential analog input. The converter will measure the voltage between the "IN+" and "IN-" inputs. A zero code will occur when  $IN^+$  minus  $IN^-$  equals zero. Full scale occurs when  $IN^+$  minus  $IN^-$  equals  $V_{REF}$  minus 1LSB. See Figure 2. Both the "IN+" and "IN-" inputs are sampled at the same time, so common mode noise on the inputs is rejected by the ADC. If "IN-" is grounded and  $V_{REF}$  is tied to  $V_{CC}$ , a rail-to-rail input span will result on "IN+" as shown in Figure 3.

### Reference Input

The voltage on the reference input of the LTC1864 defines the full-scale range of the A/D converter. The LTC1864 can operate with reference voltages from  $V_{CC}$  to 1V.

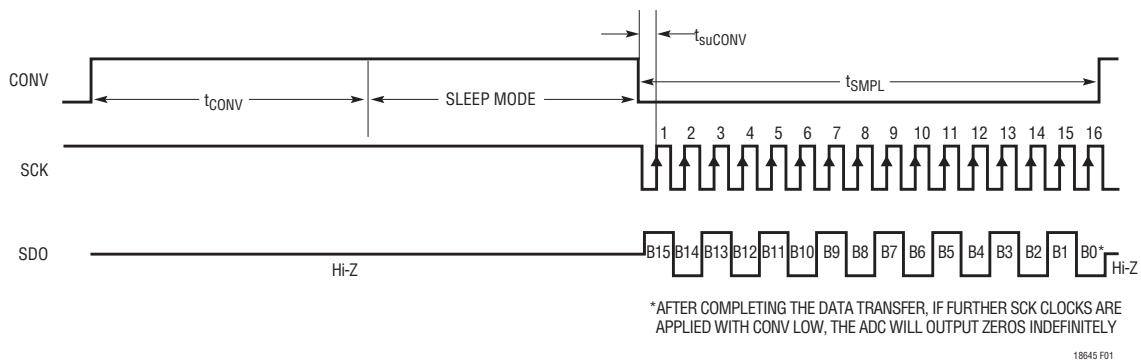


Figure 1. LTC1864 Operating Sequence

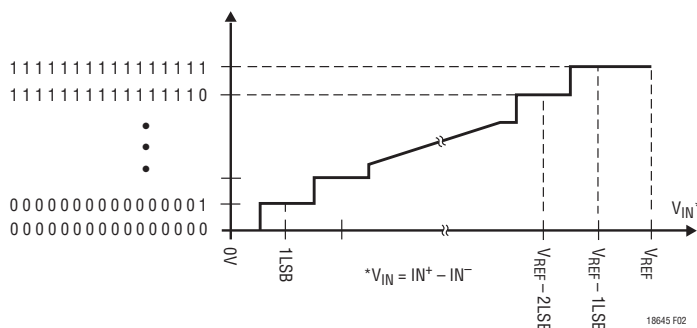


Figure 2. LTC1864 Transfer Curve

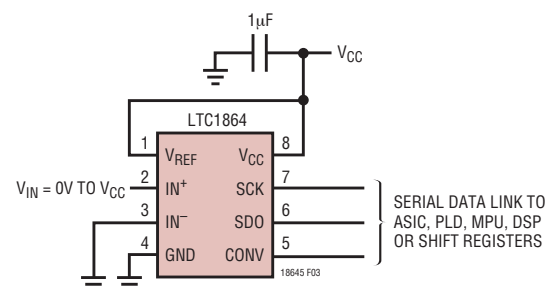


Figure 3. LTC1864 with Rail-to-Rail Input Span

## APPLICATIONS INFORMATION

### LTC1865 OPERATION

#### Operating Sequence

The LTC1865 conversion cycle begins with the rising edge of CONV. After a period equal to  $t_{\text{CONV}}$ , the conversion is finished. If CONV is left high after this time, the LTC1865 goes into sleep mode drawing only leakage current. The LTC1865's 2-bit data word is clocked into the SDI input on the rising edge of SCK after CONV goes low. Additional inputs on the SDI pin are then ignored until the next CONV cycle. The shift clock (SCK) synchronizes the data transfer with each bit being transmitted on the falling SCK edge and captured on the rising SCK edge in both transmitting and receiving systems. The data is transmitted and received simultaneously (full duplex). After completing the data transfer, if further SCK clocks are applied with CONV low, SDO will output zeros indefinitely. See Figure 4.

#### Analog Inputs

The two bits of the input word (SDI) assign the MUX configuration for the next requested conversion. For a given channel selection, the converter will measure the voltage between the two channels indicated by the "+" and "-" signs in the selected row of the following table. In

single-ended mode, all input channels are measured with respect to GND. A zero code will occur when the "+" input minus the "-" input equals zero. Full scale occurs when the "+" input minus the "-" input equals  $V_{\text{REF}}$  minus 1LSB. See Figure 5. Both the "+" and "-" inputs are sampled at the same time so common mode noise is rejected. The input span in the SO-8 package is fixed at  $V_{\text{REF}} = V_{\text{CC}}$ . If the "-" input in differential mode is grounded, a rail-to-rail input span will result on the "+" input.

#### Reference Input

The reference input of the LTC1865 SO-8 package is internally tied to  $V_{\text{CC}}$ . The span of the A/D converter is therefore equal to  $V_{\text{CC}}$ . The voltage on the reference input of the LTC1865 MSOP package defines the span of the A/D converter. The LTC1865 MSOP package can operate with reference voltages from 1V to  $V_{\text{CC}}$ .

**Table 1. Multiplexer Channel Selection**

|                          | MUX ADDRESS |          | CHANNEL # |   | GND |
|--------------------------|-------------|----------|-----------|---|-----|
|                          | SGL/DIFF    | ODD/SIGN | 0         | 1 |     |
| SINGLE-ENDED<br>MUX MODE | 1           | 0        | +         | — | —   |
|                          | 1           | 1        |           | + | —   |
| DIFFERENTIAL<br>MUX MODE | 0           | 0        | +         | — | —   |
|                          | 0           | 1        | —         | + | —   |

18645 TBL1



\*AFTER COMPLETING THE DATA TRANSFER, IF FURTHER SCK CLOCKS ARE APPLIED WITH CONV LOW, THE ADC WILL OUTPUT ZEROS INDEFINITELY

**Figure 4. LTC1865 Operating Sequence**

18645 F04

## APPLICATIONS INFORMATION

### GENERAL ANALOG CONSIDERATIONS

#### Grounding

The LTC1864/LTC1865 should be used with an analog ground plane and single point grounding techniques. Do not use wire wrapping techniques to breadboard and evaluate the device. To achieve the optimum performance, use a printed circuit board. The ground pins (AGND and DGND for the LTC1865 MSOP package and GND for the LTC1864 and LTC1865 SO-8 package) should be tied directly to the analog ground plane with minimum lead length.

#### Bypassing

For good performance, the  $V_{CC}$  and  $V_{REF}$  pins must be free of noise and ripple. Any changes in the  $V_{CC}/V_{REF}$  voltage with respect to ground during the conversion cycle can

induce errors or noise in the output code. Bypass the  $V_{CC}$  and  $V_{REF}$  pins directly to the analog ground plane with a minimum of 1 $\mu$ F tantalum. Keep the bypass capacitor leads as short as possible.

#### Analog Inputs

Because of the capacitive redistribution A/D conversion techniques used, the analog inputs of the LTC1864/LTC1865 have capacitive switching input current spikes. These current spikes settle quickly and do not cause a problem if source resistances are less than 200 $\Omega$  or high speed op amps are used (e.g., the LT<sup>®</sup>1211, LT1469, LT1807, LT1810, LT1630, LT1226 or LT1215). But if large source resistances are used, or if slow settling op amps drive the inputs, take care to ensure the transients caused by the current spikes settle completely before the conversion begins.

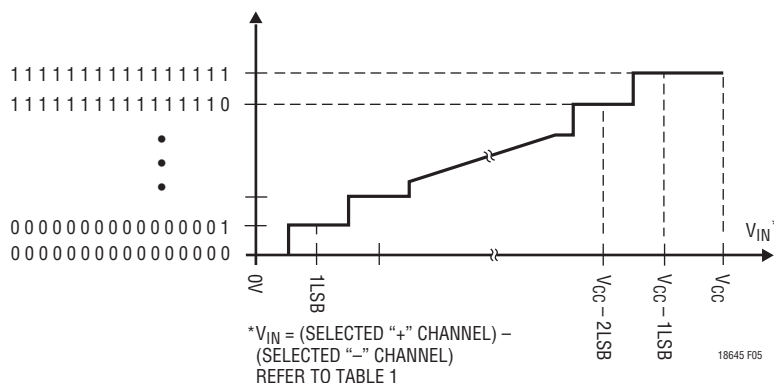
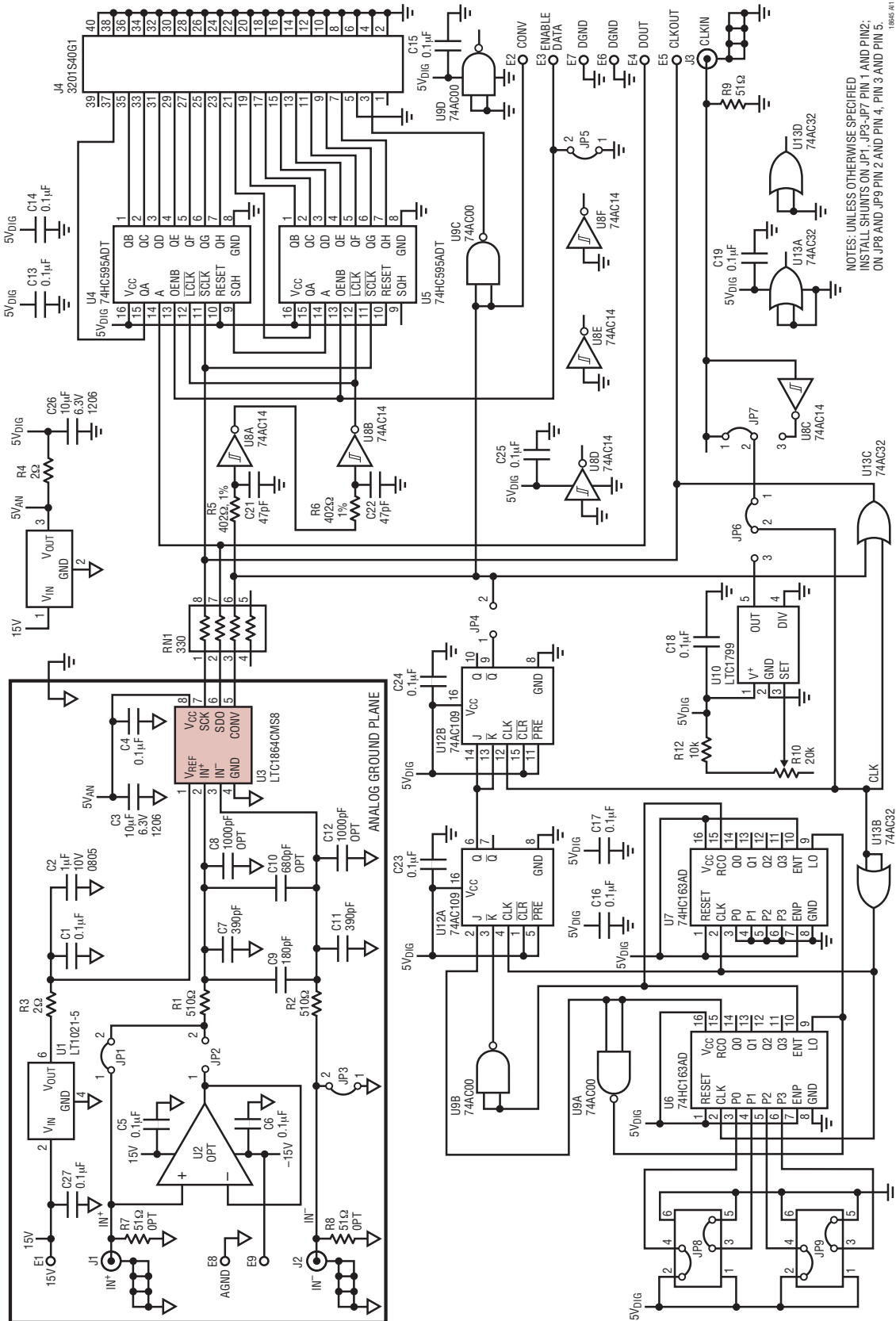


Figure 5. LTC1865 Transfer Curve

## APPLICATIONS INFORMATION

LTC1864 Evaluation Circuit Schematic



NOTES: UNLESS OTHERWISE SPECIFIED  
INSTALL SHUNTS ON JP1, JP3-JP7 PIN 1 AND PIN2;  
ON JP8 AND JP9 PIN 2 AND PIN 4, PIN 3 AND PIN 5.



## APPLICATIONS INFORMATION



Figure 6. LTC1864 Manchester Transmitter

## APPLICATIONS INFORMATION

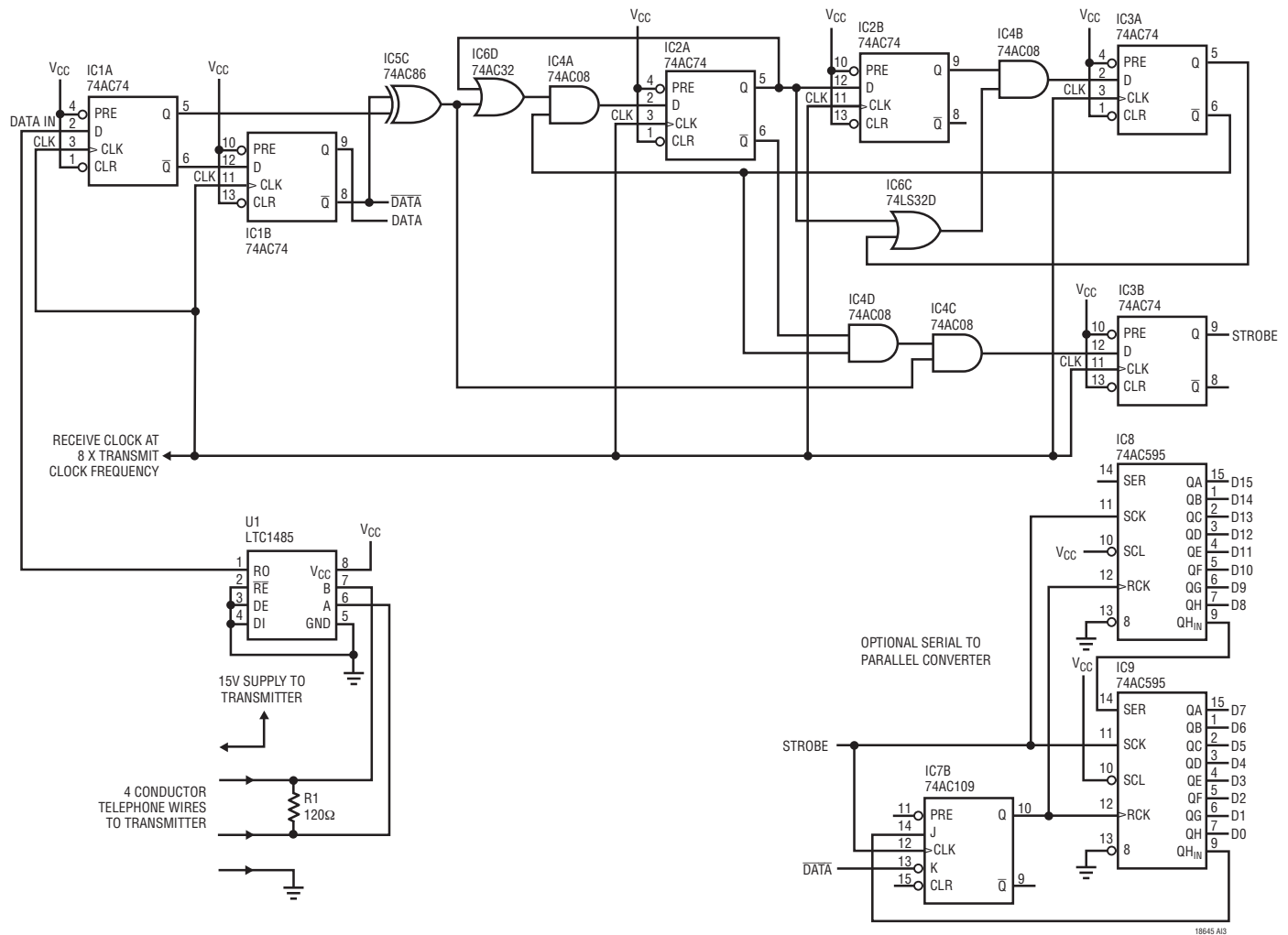


Figure 7. LTC1864 Manchester Receiver

## APPLICATIONS INFORMATION

### Transmit LTC1864 Data Over Modular Telephone Wire Using Simple Transmitter/Receiver

Figure 6 shows a simple Manchester encoder and differential transmitter suitable for use with the LTC1864. This circuit allows transmission of data over inexpensive telephone wire. This is useful for measuring a remote sensor, particularly when the cost of preserving the analog signal over a long distance is high.

Manchester encoding is a clock signal that is modulated by exclusive ORing with the data signal. The resulting signal contains both clock and data information and has an average duty cycle of 50%, that also allows transformer coupling. In practice, generating a Manchester encoded signal with an XOR gate will often produce glitches due to the skew between data and clock transitions. The D flip-flops in this encoder retime the clock and data such that the respective edges are closely aligned, effectively suppressing glitches. The retimed data and clock are then XORed to produce the Manchester encoded data, which is interfaced to telephone wire with an LTC1485 RS485 transceiver.

In order to synchronize to incoming data, the receiver needs a sequence to indicate the start of a data word. The transmitter schematic shows logic that will produce 31

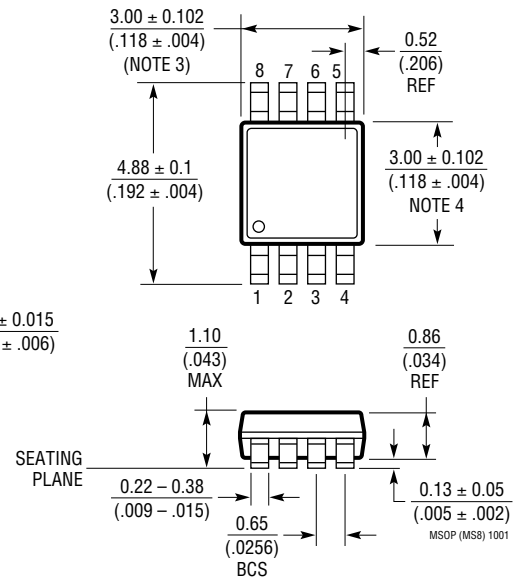
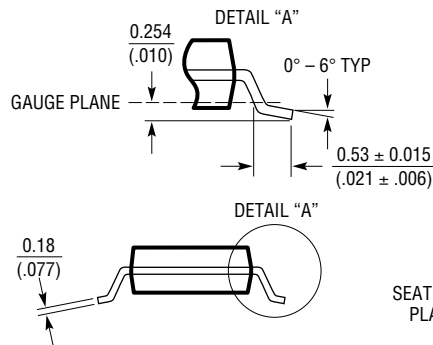
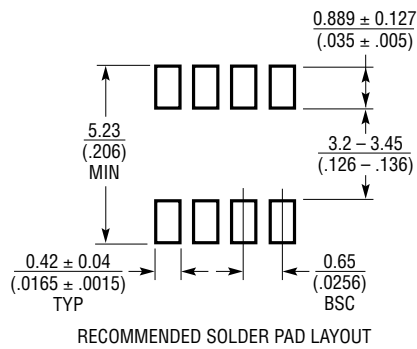
zeros, a start bit, followed by the 16 data bits (one sample every 48 clock cycles) at a clock frequency of 1MHz set by the LTC1799 oscillator. Sending at least 18 zeros before each start bit ensures that if synchronization is lost, the receiver can resynchronize to a start bit under all conditions. The serial to parallel converter shown in Figure 7 requires 18 zeros to avoid triggering on data bits.

The Manchester receiver shown in Figure 7 was adopted from Xilinx application note 17-30 and would typically be implemented in an FPGA. The decoder clock frequency is nominally 8 times the transmit clock frequency and is very tolerant of frequency errors. The outputs of the decoder are data and a strobe that indicates a valid data bit. The data can be deserialized using shift registers as shown. The start bit resets the J-K/flip-flop on its way into the first shift register. When it appears at the  $QH_{IN}$  output of the second shift register, it sets the flip-flop that loads the parallel data into the output register.

With AC family CMOS logic at 5V the receiver clock frequency is limited to 20MHz; the corresponding transmitter clock frequency is 2.5MHz. If the receiver is implemented in an FPGA that can be clocked at 160MHz, the LTC1864 can be clocked at its rated clock frequency of 20MHz.

## PACKAGE DESCRIPTION

**MS8 Package**  
**8-Lead Plastic MSOP**  
 (Reference LTC DWG # 05-08-1660)

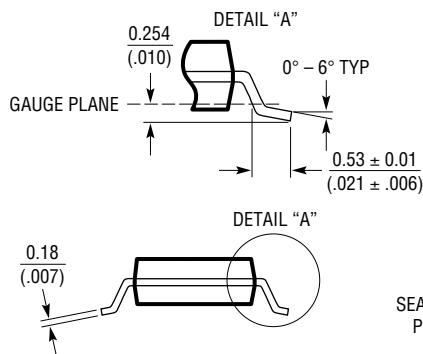
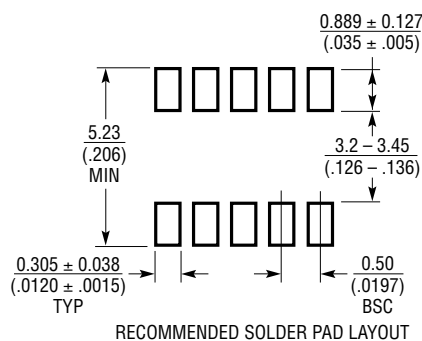


## NOTE:

1. DIMENSIONS IN MILLIMETER/(INCH)
2. DRAWING NOT TO SCALE
3. DIMENSION DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS.  
MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.152mm (.006") PER SIDE
4. DIMENSION DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSIONS.  
INTERLEAD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.152mm (.006") PER SIDE
5. LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.102mm (.004") MAX

## PACKAGE DESCRIPTION

**MS Package**  
**10-Lead Plastic MSOP**  
 (Reference LTC DWG # 05-08-1661)

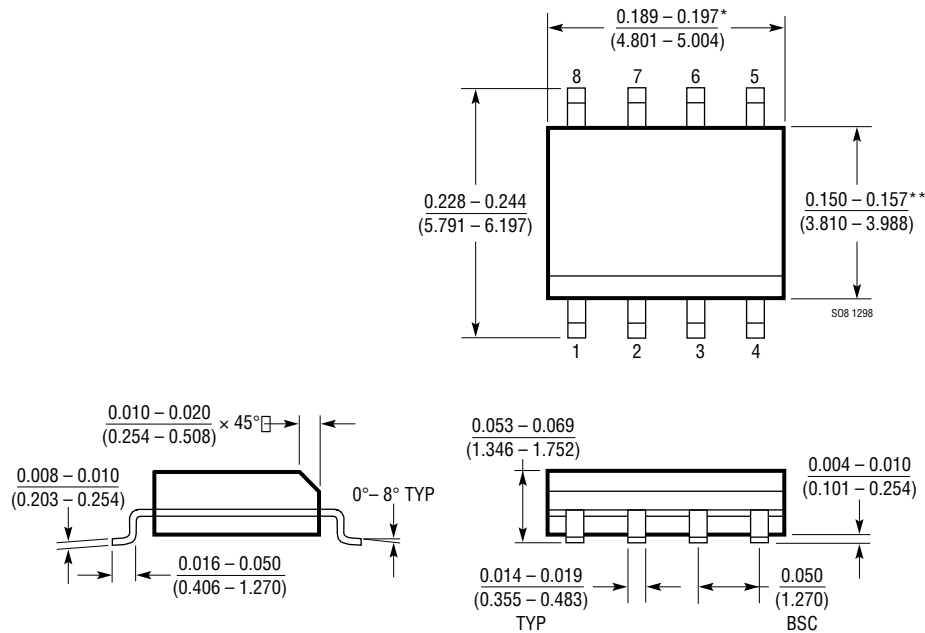


## NOTE:

1. DIMENSIONS IN MILLIMETER/(INCH)
2. DRAWING NOT TO SCALE
3. DIMENSION DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS.  
MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED  $0.152\text{mm}$  ( $.006$ ) PER SIDE
4. DIMENSION DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSIONS.  
INTERLEAD FLASH OR PROTRUSIONS SHALL NOT EXCEED  $0.152\text{mm}$  ( $.006$ ) PER SIDE
5. LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE  $0.102\text{mm}$  ( $.004$ ) MAX

## PACKAGE DESCRIPTION

### S8 Package 8-Lead Plastic Small Outline (Narrow .150 Inch) (Reference LTC DWG # 05-08-1610)



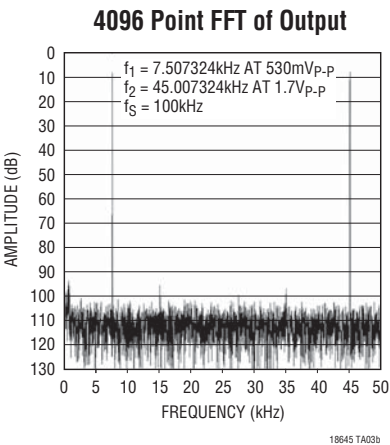
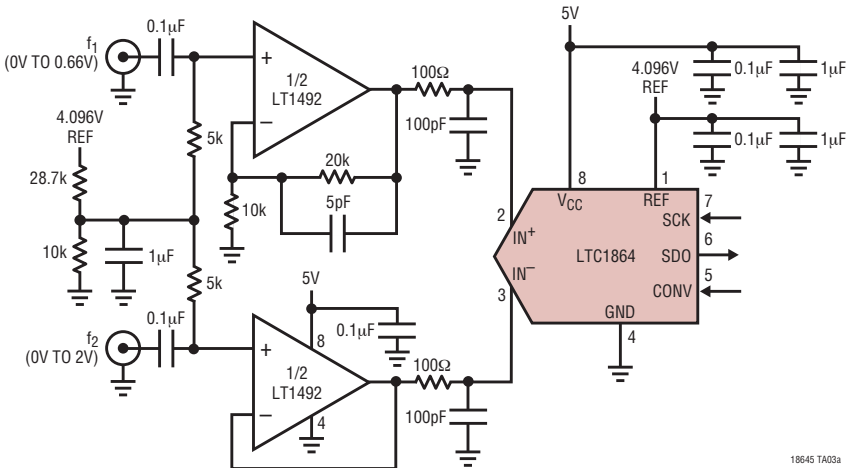
\*DIMENSION DOES NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

\*\*DIMENSION DOES NOT INCLUDE INTERLEAD FLASH. INTERLEAD FLASH SHALL NOT EXCEED 0.010" (0.254mm) PER SIDE

# LTC1864/LTC1865

## TYPICAL APPLICATION

### Sample Two Channels Simultaneously with a Single Input ADC



## RELATED PARTS

| PART NUMBER            | SAMPLE RATE                                | POWER DISSIPATION | DESCRIPTION                                                  |
|------------------------|--------------------------------------------|-------------------|--------------------------------------------------------------|
| 14-Bit Serial I/O ADCs |                                            |                   |                                                              |
| LTC1417                | 400ksps                                    | 20mW              | 16-Pin SSOP, Unipolar or Bipolar, Reference, 5V or ±5V       |
| LTC1418                | 200ksps                                    | 15mW              | Serial/Parallel I/O, Internal Reference, 5V or ±5V           |
| 16-Bit Serial I/O ADCs |                                            |                   |                                                              |
| LTC1609                | 200ksps                                    | 65mW              | Configurable Bipolar or Unipolar Input Ranges, 5V            |
| References             |                                            |                   |                                                              |
| LT1460                 | Micropower Precision Series Reference      |                   | Bandgap, 130µA Supply Current, 10ppm/°C, Available in SOT-23 |
| LT1790                 | Micropower Low Dropout Reference           |                   | 60µA Supply Current, 10ppm/°C, SOT-23                        |
| Op Amps                |                                            |                   |                                                              |
| LT1468/LT1469          | Single/Dual 90MHz, 16-Bit Accurate Op Amps |                   | 22V/µs Slew Rate, 75µV/125µV Offset                          |
| LT1806/LT1807          | Single/Dual 325MHz Low Noise Op Amps       |                   | 140V/µs Slew Rate, 3.5nV/√Hz Noise, −80dBc Distortion        |
| LT1809/LT1810          | Single/Dual 180MHz Low Distortion Op Amps  |                   | 350V/µs Slew Rate, −90dBc Distortion at 5MHz                 |