

### FEATURES

- Monolithic 40 MSPS Converter
- 175 mW Power Dissipation
- On-Chip Track-and-Hold
- Single +5 V Power Supply
- TTL/CMOS Outputs
- 5 pF Input Capacitance
- Low Cost
- Tri-State Output Buffers
- High ESD Protection: 3,500 V Minimum
- Selectable +3 V or +5 V Logic I/O

### GENERAL DESCRIPTION

The SPT7734 is a 8-bit monolithic, low cost, ultralow power analog-to-digital converter capable of minimum word rates of 40 MSPS. The on-chip track-and-hold function assures very good dynamic performance without the need for external components. The input drive requirements are minimized due to the SPT7734's low input capacitance of only 5 pF.

Power dissipation is extremely low at only 175 mW typical at 40 MSPS with a power supply of +5.0 V. The digital outputs

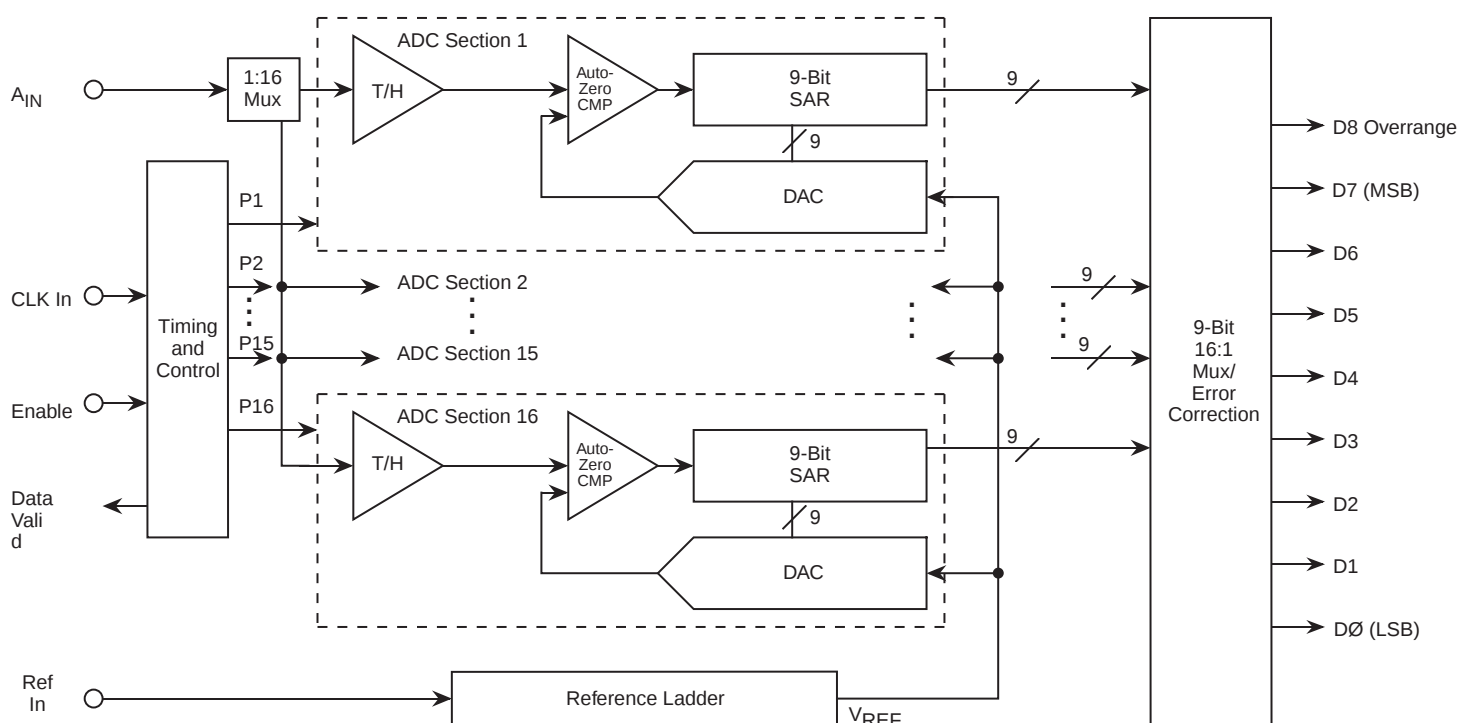
### APPLICATIONS

- All High-Speed Applications Where Low Power Dissipation is Required
- Video Imaging
- Medical Imaging
- Radar Receivers
- IR Imaging
- Digital Communications

are +3 V or +5 V, and are user selectable. The SPT7734 has incorporated proprietary circuit design and CMOS processing technologies to achieve its advanced performance. Inputs and outputs are TTL/CMOS compatible to interface with TTL/CMOS logic systems. Output data format is straight binary.

The SPT7734 is available in 28-lead SOIC and 32-lead small (7 mm square) TQFP packages over the commercial temperature range.

### BLOCK DIAGRAM



## ABSOLUTE MAXIMUM RATINGS (Beyond which damage may occur)<sup>1</sup> 25 °C

### Supply Voltages

AV<sub>DD</sub> ..... +6 V  
DV<sub>DD</sub> ..... +6 V

### Input Voltages

Analog Input ..... -0.5 V to AV<sub>DD</sub> +0.5 V  
V<sub>REF</sub> ..... 0 to AV<sub>DD</sub>  
CLK Input ..... V<sub>DD</sub>  
AV<sub>DD</sub> - DV<sub>DD</sub> ..... ±100 mV  
AGND - DGND ..... ±100 mV

### Output

Digital Outputs ..... 10 mA

### Temperature

Operating Temperature ..... 0 to +70 °C  
Junction Temperature ..... +175 °C  
Lead Temperature, (soldering 10 seconds) ..... +300 °C  
Storage Temperature ..... -65 to +150 °C

**Note:** 1. Operation at any Absolute Maximum Rating is not implied. See Electrical Specifications for proper nominal applied conditions in typical applications.

## ELECTRICAL SPECIFICATIONS

T<sub>A</sub>=T<sub>MAX</sub> to T<sub>MAX</sub>, AV<sub>DD</sub>=DV<sub>DD</sub>=+5.0 V, V<sub>IN</sub>=0 to 4 V, f<sub>S</sub>=40 MSPS, V<sub>RHS</sub>=4.0 V, V<sub>RLS</sub>=0.0 V, unless otherwise specified.

| PARAMETERS                              | TEST CONDITIONS | TEST LEVEL | MIN              | SPT7734<br>TYP | MAX              | UNITS        |
|-----------------------------------------|-----------------|------------|------------------|----------------|------------------|--------------|
| Resolution                              |                 |            | 8                |                |                  | Bits         |
| DC Accuracy                             |                 |            |                  |                |                  |              |
| Integral Nonlinearity                   |                 | IV         |                  | ±1.0           |                  | LSB          |
| Differential Nonlinearity               |                 | IV         |                  | ±0.5           |                  | LSB          |
| No Missing Codes                        |                 | VI         |                  | Guaranteed     |                  |              |
| Analog Input                            |                 |            |                  |                |                  |              |
| Input Voltage Range                     |                 | VI         | V <sub>RLS</sub> |                | V <sub>RHS</sub> | V            |
| Input Resistance                        |                 | IV         | 50               |                |                  | kΩ           |
| Input Capacitance                       |                 | V          |                  | 5.0            |                  | pF           |
| Input Bandwidth                         | (Small Signal)  | V          | 250              |                |                  | MHz          |
| Offset                                  |                 | V          |                  | ±2.0           |                  | LSB          |
| Gain Error                              |                 | V          |                  | ±2.0           |                  | LSB          |
| Reference Input                         |                 |            |                  |                |                  |              |
| Resistance                              |                 | VI         | 300              | 500            | 600              | Ω            |
| Bandwidth                               |                 | V          | 100              | 150            |                  | MHz          |
| Voltage Range                           |                 |            |                  |                |                  |              |
| V <sub>RLS</sub>                        |                 | IV         | 0                | -              | 2.0              | V            |
| V <sub>RHS</sub>                        |                 | IV         | 3.0              | -              | AV <sub>DD</sub> | V            |
| V <sub>RHS</sub> - V <sub>RLS</sub>     |                 | V          | 1.0              | 4.0            | 5.0              | V            |
| Δ(V <sub>RHF</sub> - V <sub>RHS</sub> ) |                 | V          |                  | 90             |                  | mV           |
| Δ(V <sub>RLS</sub> - V <sub>RLE</sub> ) |                 | V          |                  | 75             |                  | mV           |
| Reference Settling Time                 |                 |            |                  |                |                  |              |
| V <sub>RHS</sub>                        |                 | V          |                  | 15             |                  | Clock Cycles |
| V <sub>RLS</sub>                        |                 | V          |                  | 20             |                  | Clock Cycles |
| Conversion Characteristics              |                 |            |                  |                |                  |              |
| Maximum Conversion Rate                 |                 | VI         | 40               |                |                  | MHz          |
| Minimum Conversion Rate                 |                 | IV         | 2                |                |                  | MHz          |
| Pipeline Delay (Latency)                |                 | IV         |                  |                | 12               | Clock Cycles |
| Aperture Delay Time                     |                 | V          |                  | 4.0            |                  | ns           |
| Aperture Jitter Time                    |                 | V          |                  | 30             |                  | ps(p-p)      |
| Dynamic Performance                     |                 |            |                  |                |                  |              |
| Effective Number of Bits                |                 |            |                  |                |                  |              |
| f <sub>IN</sub> =3.58 MHz               |                 | VI         | 7.3              | 7.8            |                  | Bits         |
| f <sub>IN</sub> =10.3 MHz               |                 | VI         | 7.2              | 7.7            |                  | Bits         |

## ELECTRICAL SPECIFICATIONS

$T_A = T_{MAX}$  to  $T_{MAX}$ ,  $AV_{DD} = DV_{DD} = +5.0$  V,  $V_{IN} = 0$  to 4 V,  $f_S = 40$  MSPS,  $V_{RHS} = 4.0$  V,  $V_{RLS} = 0.0$  V, unless otherwise specified.

| PARAMETERS                                | TEST CONDITIONS                    | TEST LEVEL | MIN  | SPT7734 TYP | MAX  | UNITS   |
|-------------------------------------------|------------------------------------|------------|------|-------------|------|---------|
| Dynamic Performance                       |                                    |            |      |             |      |         |
| Signal-to-Noise Ratio (without Harmonics) |                                    | VI         | 46   | 49          |      | dB      |
| $f_{IN} = 3.58$ MHz                       |                                    | VI         | 45   | 48          |      | dB      |
| Harmonic Distortion                       | 9 Distortion bins from 1024 pt FFT | VI         | 53   | 57          |      | dB      |
| $f_{IN} = 3.58$ MHz                       |                                    | VI         | 53   | 56          |      | dB      |
| $f_{IN} = 10.3$ MHz                       |                                    |            |      |             |      |         |
| Signal-to-Noise and Distortion (SINAD)    |                                    |            |      |             |      |         |
| $f_{IN} = 3.58$ MHz                       |                                    | VI         | 46   | 49          |      | dB      |
| $f_{IN} = 10.3$ MHz                       |                                    | VI         | 45   | 48          |      | dB      |
| Spurious Free Dynamic Range               | $f_{IN} = 1.0$ MHz                 | V          |      | 63          |      | dB      |
| Differential Phase                        |                                    | V          |      | $\pm 0.3$   |      | Degree  |
| Differential Gain                         |                                    | V          |      | $\pm 0.3$   |      | %       |
| Intermodulation Distortion                |                                    |            |      | TBD         |      | dB      |
| Inputs                                    |                                    |            |      |             |      |         |
| Logic 1 Voltage                           |                                    | VI         | 2.0  |             |      | V       |
| Logic 0 Voltage                           |                                    | VI         |      |             | 0.8  | V       |
| Maximum Input Current Low                 |                                    | VI         | -10  |             | +10  | $\mu$ A |
| Maximum Input Current High                |                                    | VI         | -10  |             | +10  | $\mu$ A |
| Input Capacitance                         |                                    | V          |      | +5          |      | pF      |
| Digital Outputs                           |                                    |            |      |             |      |         |
| Logic 1 Voltage                           | $I_{OH} = 0.5$ mA                  | VI         | 3.5  |             |      | V       |
| Logic 0 Voltage                           | $I_{OL} = 1.6$ mA                  | VI         |      |             | 0.4  | V       |
| $t_{RISE}$                                | 15 pF load                         | V          |      | 10          |      | ns      |
| $t_{FALL}$                                | 15 pF load                         | V          |      | 10          |      | ns      |
| Output Enable to Data Output Delay        | 20 pF load, $T_A = +25$ °C         | V          |      | 10          |      | ns      |
|                                           | 50 pF load over temp.              | V          |      | 22          |      | ns      |
| Power Supply Requirements                 |                                    |            |      |             |      |         |
| Voltages                                  | $OV_{DD}$                          | IV         | 3.0  |             | 5.0  | V       |
|                                           | $DV_{DD}$                          | IV         | 4.75 | 5.0         | 5.25 | V       |
|                                           | $AV_{DD}$                          | IV         | 4.75 | 5.0         | 5.25 | V       |
| Currents                                  | $AI_{DD}$                          | VI         |      | 17          | 22   | mA      |
|                                           | $DI_{DD}$                          | VI         |      | 18          | 23   | mA      |
| Power Dissipation                         |                                    | VI         |      | 175         | 225  | mW      |

### TEST LEVEL CODES

### TEST LEVEL

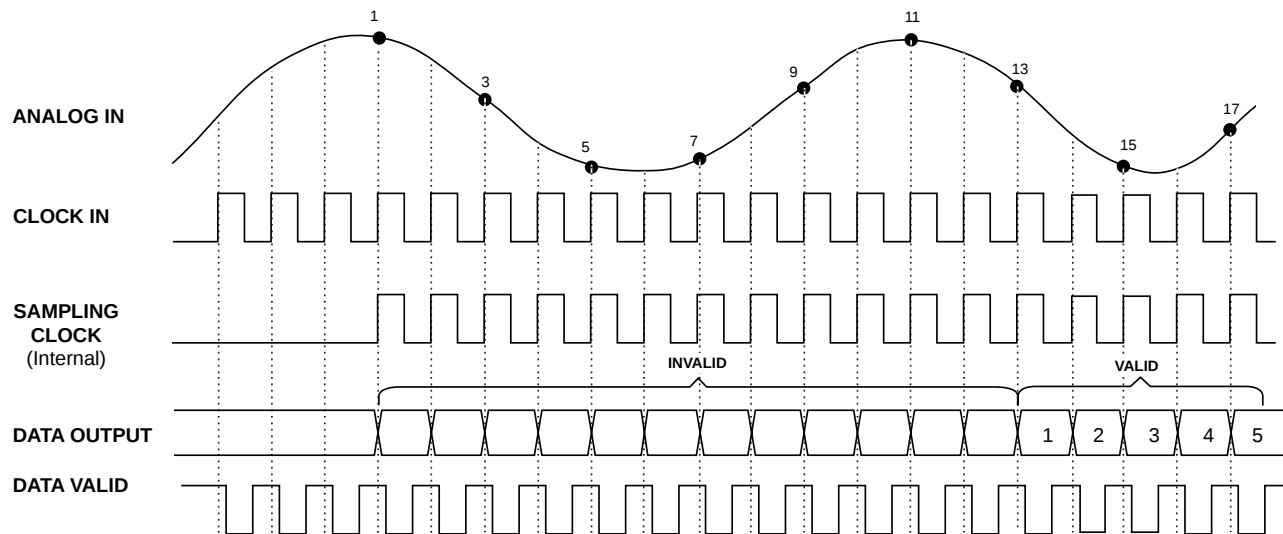
### TEST PROCEDURE

All electrical characteristics are subject to the following conditions:

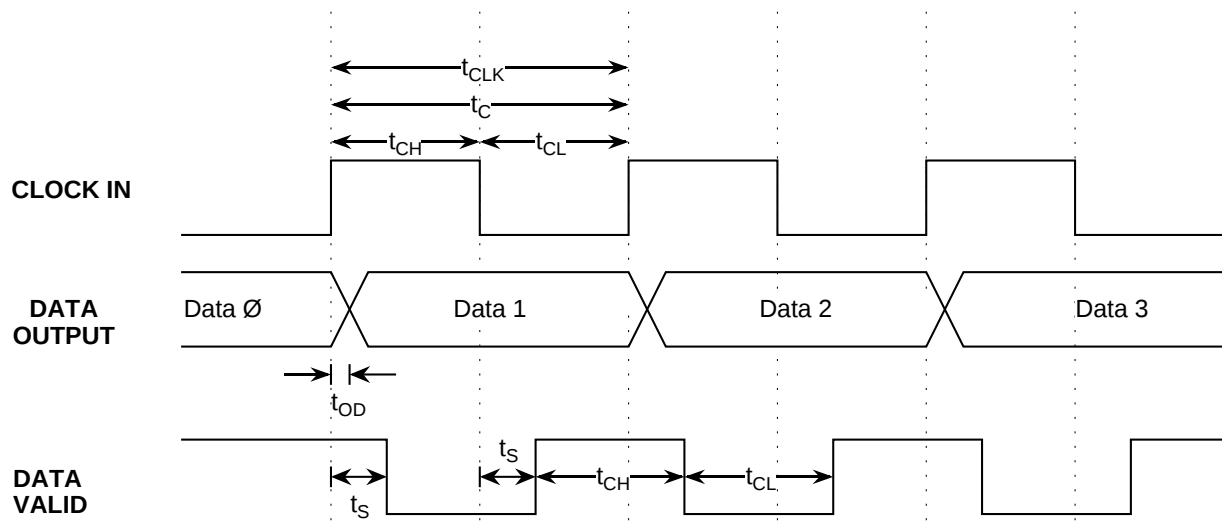
All parameters having min/max specifications are guaranteed. The Test Level column indicates the specific device testing actually performed during production and Quality Assurance inspection. Any blank section in the data column indicates that the specification is not tested at the specified condition.

|     |                                                                                                    |
|-----|----------------------------------------------------------------------------------------------------|
| I   | 100% production tested at the specified temperature.                                               |
| II  | 100% production tested at $T_A = 25$ °C, and sample tested at the specified temperatures.          |
| III | QA sample tested only at the specified temperatures.                                               |
| IV  | Parameter is guaranteed (but not tested) by design and characterization data.                      |
| V   | Parameter is a typical value for information purposes only.                                        |
| VI  | 100% production tested at $T_A = 25$ °C. Parameter is guaranteed over specified temperature range. |

**Figure 1A: Timing Diagram 1**



**Figure 1B: Timing Diagram 2**



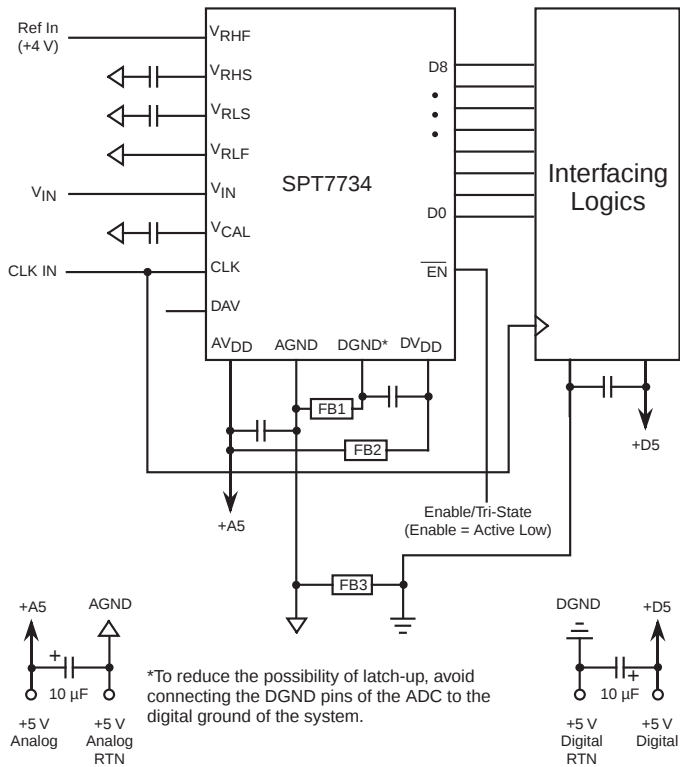
**Table I - Timing Parameters**

| DESCRIPTION                        | PARAMETERS | MIN       | TYP | MAX | UNITS |
|------------------------------------|------------|-----------|-----|-----|-------|
| Conversion Time                    | $t_C$      | $t_{CLK}$ |     |     | ns    |
| Clock Period                       | $t_{CLK}$  | 25        |     |     | ns    |
| Clock High Duty Cycle              | $t_{CH}$   | 40        | 50  | 60  | %     |
| Clock Low Duty Cycle               | $t_{CL}$   | 40        | 50  | 60  | %     |
| Clock to Output Delay (15 pF Load) | $t_{OD}$   |           | 17  |     | ns    |
| Clock to DAV                       | $t_S$      |           | 10  |     | ns    |

TYPICAL INTERFACE CIRCUIT

Very few external components are required to achieve the stated device performance. Figure 1 shows the typical interface requirements when using the SPT7734 in normal circuit operation. The following sections provide descriptions of the major functions and outline critical performance criteria to consider for achieving the optimal device performance.

Figure 1 - Typical Interface Circuit



- NOTES: 1) FB3 is to be located as closely to the device as possible.  
2) There should be no additional connections to the right of FB1 and FB2.  
3) All capacitors are 0.1  $\mu$ F surface-mount unless otherwise specified.  
4) FB1, FB2 and FB3 are 10  $\mu$ H inductors or ferrite beads.

POWER SUPPLIES AND GROUNDING

CADEKA suggests that both the digital and the analog supply voltages on the SPT7734 be derived from a single analog supply as shown in figure 1. A separate digital supply should be used for all interface circuitry. CADEKA suggests using this power supply configuration to prevent a possible latch-up condition on power up.

OPERATING DESCRIPTION

The general architecture for the CMOS ADC is shown in the block diagram. The design contains 16 identical successive approximation ADC sections, all operating in parallel, a 16-phase clock generator, an 9-bit 16:1 digital output multiplexer, correction logic, and a voltage reference generator which provides common reference levels for each ADC section.

The high sample rate is achieved by using multiple SAR ADC sections in parallel, each of which samples the input signal in sequence. Each ADC uses 16 clock cycles to complete a conversion. The clock cycles are allocated as follows:

Table II - Clock Cycles

| Clock | Operation                 |
|-------|---------------------------|
| 1     | Reference zero sampling   |
| 2     | Auto-zero comparison      |
| 3     | Auto-calibrate comparison |
| 4     | Input sample              |
| 5-15  | 9-bit SAR conversion      |
| 16    | Data transfer             |

The 16 phase clock, which is derived from the input clock, synchronizes these events. The timing signals for adjacent ADC sections are shifted by one clock cycle so that the analog input is sampled on every cycle of the input clock by exactly one ADC section. After 16 clock periods, the timing cycle repeats. The latency from analog input sample to the corresponding digital output is 12 clock cycles.

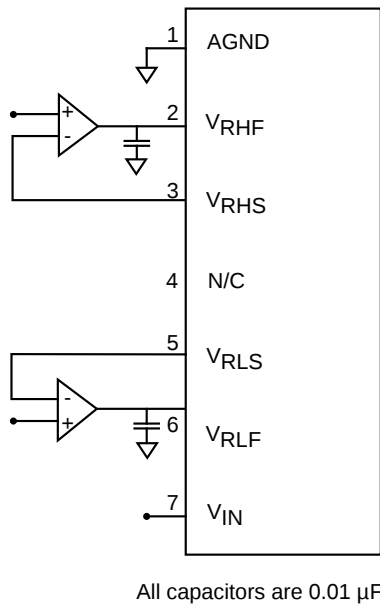
- Since only 16 comparators are used, a huge power savings is realized.
- The auto-zero operation is done using a closed loop system that uses multiple samples of the comparators response to a reference zero.
- The auto-calibrate operation, which calibrates the gain of the MSB reference and the LSB reference, is also done with a closed loop system. Multiple samples of the gain error are integrated to produce a calibration voltage for each ADC section.
- Capacitive displacement currents, which can induce sampling error, are minimized since only one comparator samples the input during a clock cycle.
- The total input capacitance is very low since sections of the converter which are not sampling the signal are isolated from the input by transmission gates.

VOLTAGE REFERENCE

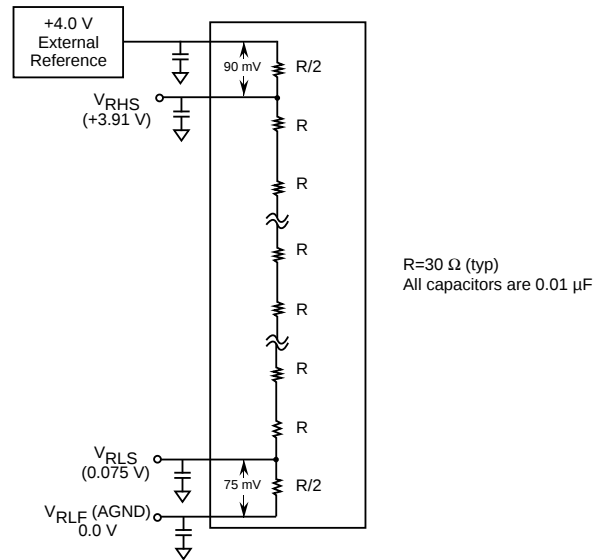
The SPT7734 requires the use of a single external voltage reference for driving the high side of the reference ladder. It must be within the range of 3 V to 5 V. The lower side of the ladder is typically tied to AGND (0.0 V), but can be run up to 2.0 V with a second reference. The analog input voltage range will track the total voltage difference measured between the ladder sense lines, V\_RHS and V\_RLS.

Force and sense taps are provided to ensure accurate and stable setting of the upper and lower ladder sense line voltages across part-to-part and temperature variations. By using the configuration shown in figure 2, offset and gain errors of less than  $\pm 2$  LSB can be obtained.

**Figure 2 - Ladder Force/Sense Circuit**



**Figure 3 - Simplified Reference Ladder Drive Circuit Without Force/Sense Circuit**



In cases where wider variations in offset and gain can be tolerated,  $V_{Ref}$  can be tied directly to  $V_{RHF}$  and AGND can be tied directly to  $V_{RLF}$  as shown in figure 3. Decouple force and sense lines to AGND with a .01  $\mu F$  capacitor (chip cap preferred) to minimize high-frequency noise injection. If this simplified configuration is used, the following considerations should be taken into account:

The reference ladder circuit shown in figure 3 is a simplified representation of the actual reference ladder with force and sense taps shown. Due to the actual internal structure of the ladder, the voltage drop from  $V_{RHF}$  to  $V_{RHS}$  is not equivalent to the voltage drop from  $V_{RLF}$  to  $V_{RLS}$ .

Typically, the top side voltage drop for  $V_{RHF}$  to  $V_{RHS}$  will equal:

$$V_{RHF} - V_{RHS} = 2.25 \% \text{ of } (V_{RHF} - V_{RLF}) \text{ (typical),}$$

and the bottom side voltage drop for  $V_{RLS}$  to  $V_{RLF}$  will equal:

$$V_{RLS} - V_{RLF} = 1.9 \% \text{ of } (V_{RHF} - V_{RLF}) \text{ (typical).}$$

Figure 3 shows an example of expected voltage drops for a specific case.  $V_{ref}$  of 4.0 V is applied to  $V_{RHF}$  and  $V_{RLF}$  is tied to AGND. A 90 mV drop is seen at  $V_{RHS}$  ( $\approx 3.91$  V) and a 75 mV increase is seen at  $V_{RLS}$  ( $\approx 0.075$  V).

## ANALOG INPUT

$V_{IN}$  is the analog input. The input voltage range is from  $V_{RLS}$  to  $V_{RHS}$  (typically 4.0 V) and will scale proportionally with respect to the voltage reference. (See voltage reference section.)

The drive requirements for the analog inputs are very minimal when compared to most other converters due to the SPT7734's extremely low input capacitance of only 5 pF and very high input resistance in excess of 50 k $\Omega$ .

The analog input should be protected through a series resistor and diode clamping circuit as shown in figure 4.

## CALIBRATION

The SPT7734 uses an auto calibration scheme to ensure 8-bit accuracy over time and temperature. Gain and offset errors are continually adjusted to 8-bit accuracy during device operation. This process is completely transparent to the user.

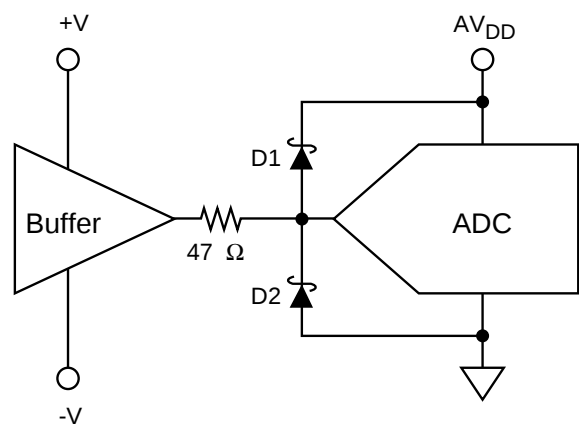
Upon power-up, the SPT7734 begins its calibration algorithm. In order to achieve the calibration accuracy required, the offset and gain adjustment step size is a fraction of a 8-bit LSB. Since the calibration algorithm is an oversampling process, a minimum of 10,000 clock cycles are required. This results in a minimum calibration time upon power-up of 250  $\mu sec$  (for a 40 MHz clock). Once calibrated, the SPT7734 remains calibrated over time and temperature.

Since the calibration cycles are initiated on the rising edge of the clock, the clock must be continuously applied for the SPT7734 to remain in calibration.

## INPUT PROTECTION

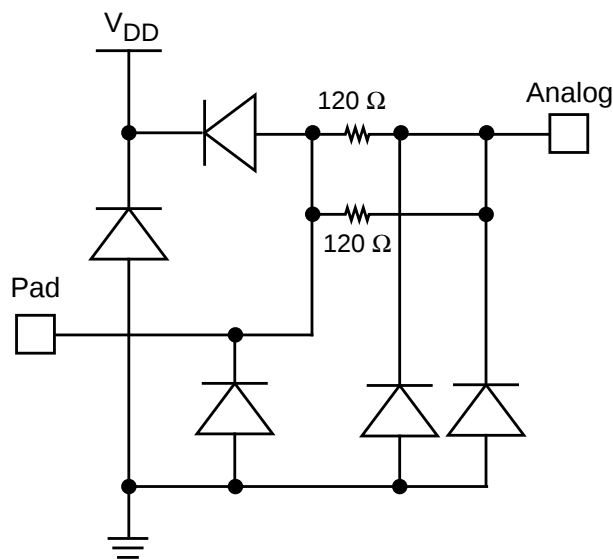
All I/O pads are protected with an on-chip protection circuit shown in figure 5. This circuit provides ESD robustness to 3.5 kV and prevents latch-up under severe discharge conditions without degrading analog transition times.

Figure 4 - Recommended Input Protection Circuit



D1 = D2 = Hewlett Packard HP5712 or equivalent

Figure 5 - On-Chip Protection Circuit



CLOCK INPUT

The SPT7734 is driven from a single-ended TTL-input clock. Because the pipelined architecture operates on the rising edge of the clock input, the device can operate over a wide range of input clock duty cycles without degrading the dynamic performance.

DIGITAL OUTPUTS

The digital outputs (D0-D8) are driven by a separate supply (OV<sub>DD</sub>) ranging from +3 V to +5 V. This feature makes it possible to drive the SPT7734's TTL/CMOS-compatible outputs with the user's logic system supply. The format of the output data (D0-D7) is straight binary. (See table III.) The outputs are latched on the rising edge of CLK. These outputs can be switched into a tri-state mode by bringing  $\overline{EN}$  high.

Table III - Output Data Information

| ANALOG INPUT    | OVERRANGE<br>D8 | OUTPUT CODE<br>D7-D0 |
|-----------------|-----------------|----------------------|
| +F.S. + 1/2 LSB | 1               | 1111 1111            |
| +F.S. -1/2 LSB  | 0               | 1111 111Ø            |
| +1/2 F.S.       | 0               | ØØØØ ØØØØ            |
| +1/2 LSB        | 0               | 0000 000Ø            |
| 0.0 V           | 0               | 0000 0000            |

(Ø indicates the flickering bit between logic 0 and 1).

DO NOT CONNECT PINS (DNC)

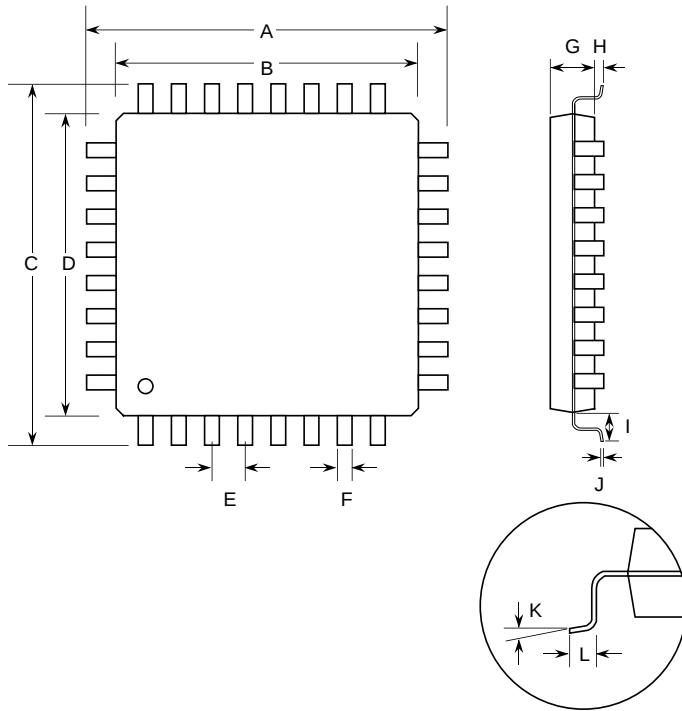
There are two pins designated as Do Not Connect (DNC). These pins must be left floating for proper operation of the device.

OVERRANGE OUTPUT

The OVERRANGE OUTPUT (D8) is an indication that the analog input signal has exceeded the positive full scale input voltage by 1 LSB. When this condition occurs, D8 will switch to logic 1. All other data outputs (D0 to D7) will remain at logic 1 as long as D8 remains at logic 1. This feature makes it possible to include the SPT7734 into higher resolution systems.

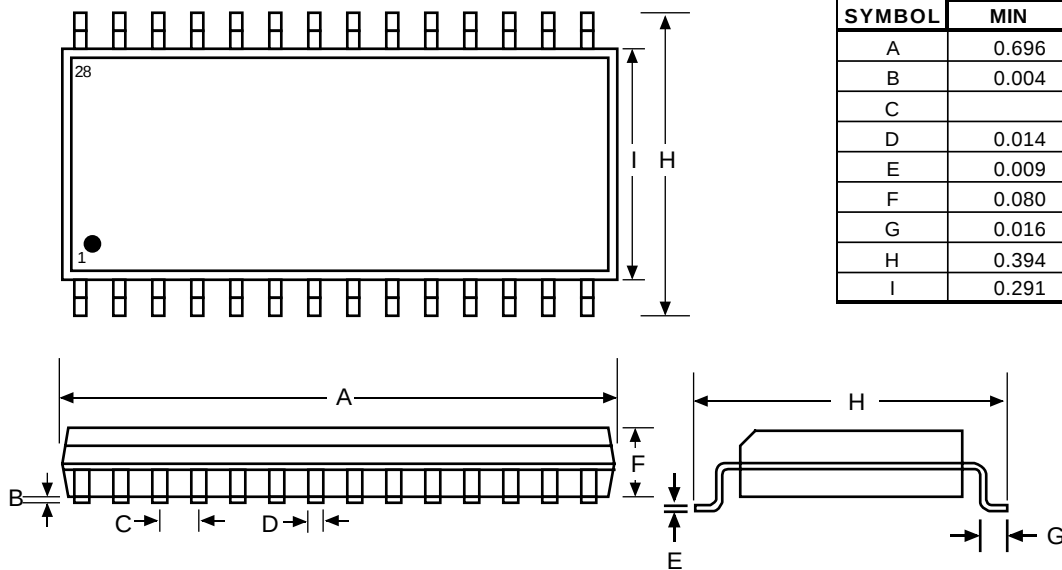
## PACKAGE OUTLINES

### 32-Lead TQFP



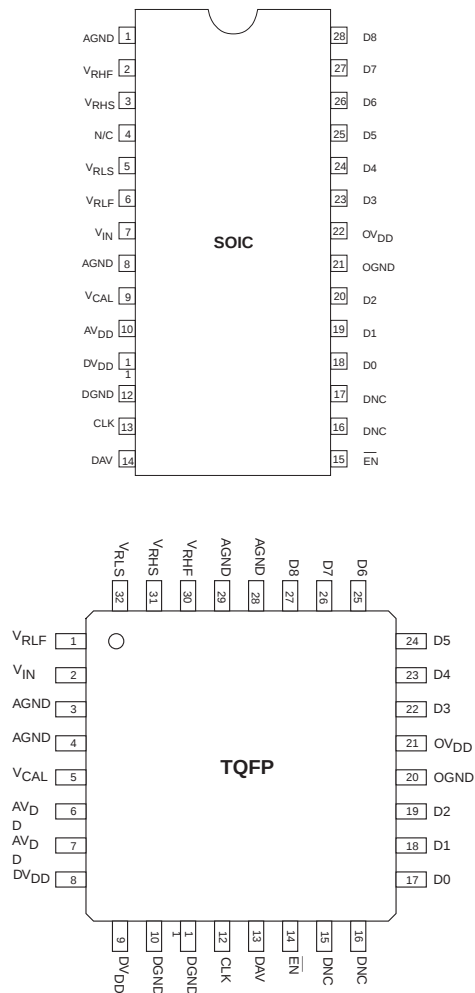
| SYMBOL | INCHES    |       | MILLIMETERS |      |
|--------|-----------|-------|-------------|------|
|        | MIN       | MAX   | MIN         | MAX  |
| A      | 0.347     | 0.355 | 8.90        | 9.10 |
| B      | 0.269     | 0.277 | 6.90        | 7.10 |
| C      | 0.347     | 0.355 | 8.90        | 9.10 |
| D      | 0.269     | 0.277 | 6.90        | 7.10 |
| E      | 0.027     | 0.035 | 0.68        | 0.89 |
| F      | 0.012     | 0.018 | 0.30        | 0.45 |
| G      | 0.053     | 0.057 | 1.35        | 1.45 |
| H      | 0.002     | 0.006 | 0.05        | 0.15 |
| I      | 0.039 typ |       | 1.00 typ    |      |
| J      | 0.004     | 0.008 | 0.09        | 0.20 |
| K      | 0°        | 7°    | 0°          | 7°   |
| L      | 0.018     | 0.029 | 0.45        | 0.75 |

### 28-Lead SOIC



| SYMBOL | INCHES |          | MILLIMETERS |       |
|--------|--------|----------|-------------|-------|
|        | MIN    | MAX      | MIN         | MAX   |
| A      | 0.696  | 0.712    | 17.68       | 18.08 |
| B      | 0.004  | 0.012    | 0.10        | 0.30  |
| C      |        | .050 typ | 0.00        | 1.27  |
| D      | 0.014  | 0.019    | 0.36        | 0.48  |
| E      | 0.009  | 0.012    | 0.23        | 0.30  |
| F      | 0.080  | 0.100    | 2.03        | 2.54  |
| G      | 0.016  | 0.050    | 0.41        | 1.27  |
| H      | 0.394  | 0.419    | 10.01       | 10.64 |
| I      | 0.291  | 0.299    | 7.39        | 7.59  |

PIN ASSIGNMENTS



PIN FUNCTIONS

| Name             | Function                               |
|------------------|----------------------------------------|
| AGND             | Analog Ground                          |
| V <sub>RHF</sub> | Reference High Force                   |
| V <sub>RHS</sub> | Reference High Sense                   |
| V <sub>RLS</sub> | Reference Low Sense                    |
| V <sub>RLF</sub> | Reference Low Force                    |
| V <sub>CAL</sub> | Calibration Reference                  |
| V <sub>IN</sub>  | Analog Input                           |
| AV <sub>DD</sub> | Analog V <sub>DD</sub>                 |
| DV <sub>DD</sub> | Digital V <sub>DD</sub>                |
| DGND             | Digital Ground                         |
| CLK              | Input Clock f <sub>CLK</sub> =fs (TTL) |
| EN               | Output Enable                          |
| D0-7             | Tri-State Data Output, (D0=LSB)        |
| D8               | Tri-State Output Overage               |
| DAV              | Data Valid Output                      |
| OV <sub>DD</sub> | Digital Output Supply                  |
| OGND             | Digital Output Ground                  |
| DNC              | Do Not Connect                         |

ORDERING INFORMATION

| PART NUMBER | TEMPERATURE RANGE | PACKAGE TYPE |
|-------------|-------------------|--------------|
| SPT7734SCS  | 0 to +70 °C       | 28L SOIC     |
| SPT7734SCT  | 0 to +70 °C       | 32L TQFP     |

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