



10-Bit, 20Msps, TTL-Output ADC

MAX1160

General Description

The MAX1160 10-bit, monolithic analog-to-digital converter (ADC) is capable of 20Msps minimum word rates. An on-board track/hold ensures excellent dynamic performance without the need for external components. A 5pF input capacitance minimizes drive requirement problems.

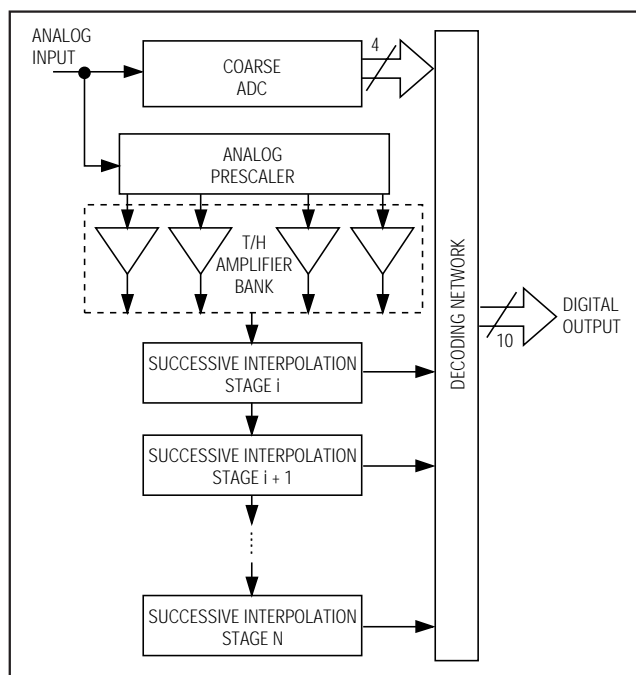
Inputs and outputs are TTL compatible. An overrange output is provided to indicate overflow conditions. Output data format is straight binary. Power dissipation is low at only 1W with +5V and -5.2V power-supply voltages. The MAX1160 also accepts wide $\pm 2V$ input voltages.

The MAX1160 is available in 28-pin DIP and SO packages in the commercial temperature range.

Applications

- Medical Imaging
- Professional Video
- Radar Receivers
- Instrumentation
- Digital Communications

Functional Diagram



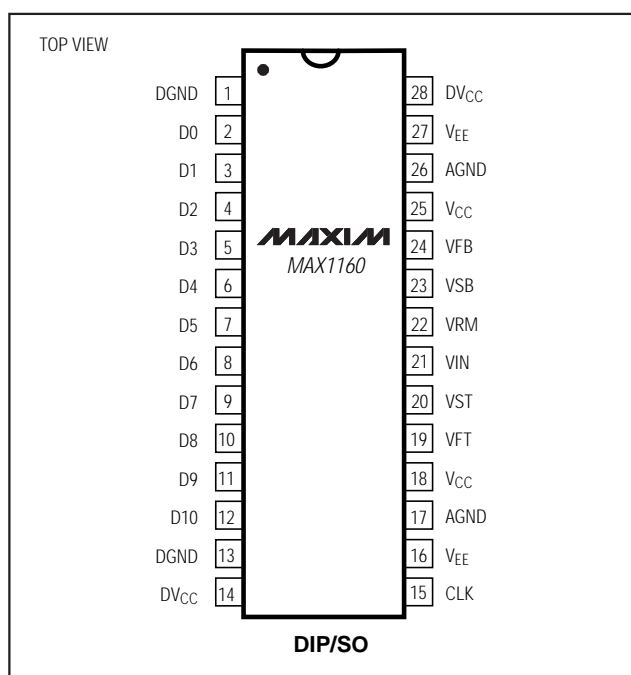
Features

- ◆ Monolithic 20Msps Converter
- ◆ On-Chip Track/Hold
- ◆ Bipolar, $\pm 2V$ Analog Input
- ◆ 60dB SNR at 1MHz Input
- ◆ 5pF Input Capacitance
- ◆ TTL Outputs

Ordering Information

| PART | TEMP. RANGE | PIN-PACKAGE |
|-------------|--------------|---------------------|
| MAX1160ACPI | 0°C to +70°C | 28 Wide Plastic DIP |
| MAX1160BCPI | 0°C to +70°C | 28 Wide Plastic DIP |
| MAX1160ACWI | 0°C to +70°C | 28 SO |
| MAX1160BCWI | 0°C to +70°C | 28 SO |

Pin Configuration



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ABSOLUTE MAXIMUM RATINGS

| | | | |
|---|---|---|-----------------|
| V _{CC} | 6V | Continuous Power Dissipation (T _A = +70°C) | |
| V _{EE} | -6V | Plastic DIP | 1.14W |
| Analog Input | V _{FB} ≤ V _{IN} ≤ V _{FT} | SO | 1W |
| V _{FT} , V _{FB} | 3V, -3V | Operating Temperature Range | 0°C to +70°C |
| Reference-Ladder Current | 12mA | Junction Temperature | +150°C |
| CLK Input | V _{CC} | Storage Temperature Range | -65°C to +150°C |
| Digital Outputs | 30mA to -30mA | Lead Temperature (soldering, 10sec) | +300°C |

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

(V_{CC} = +5.0V, V_{EE} = -5.2V, DV_{CC} = +5.0V, V_{IN} = ±2.0V, V_{SB} = -2.0V, V_{ST} = +2.0V, f_{CLK} = 20MHz, 50% clock duty cycle, T_A = T_{MIN} to T_{MAX}, unless otherwise noted.)

| PARAMETER | CONDITIONS | TEST LEVEL | MAX1160A | | | MAX1160B | | | UNITS |
|---|----------------------------------|----------------|----------|------------|-----|----------|------------|-----|-------------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Resolution | | | 10 | | | 10 | | | Bits |
| DC ACCURACY (± full scale, 250kHz sample rate, T _A = +25°C) | | | | | | | | | |
| Integral Nonlinearity | | I | | ±1.0 | | | ±1.5 | | LSB |
| Differential Nonlinearity | | I | | ±0.5 | | | ±0.75 | | LSB |
| No Missing Codes | | | | Guaranteed | | | Guaranteed | | |
| ANALOG INPUT | | | | | | | | | |
| Input Voltage Range | | V _I | | ±2.0 | | | ±2.0 | | V |
| Input Bias Current | V _{IN} = 0V | V _I | | 30 | 60 | | 30 | 60 | μA |
| Input Bias Current | T _A = -55°C to +125°C | V _I | | | 75 | | | 75 | μA |
| Input Resistance | | V _I | 100 | 300 | | 100 | 300 | | kΩ |
| Input Resistance | T _A = -55°C to +125°C | V _I | 75 | 300 | | 75 | 300 | | kΩ |
| Input Capacitance | | V | | 5 | | | 5 | | pF |
| Input Bandwidth | 3dB small signal | V | | 120 | | | 120 | | MHz |
| Positive Full-Scale Error | | V | | ±2.0 | | | ±2.0 | | LSB |
| Negative Full-Scale Error | | V | | ±2.0 | | | ±2.0 | | LSB |
| REFERENCE INPUT | | | | | | | | | |
| Reference-Ladder Resistance | | V _I | 500 | 800 | | 500 | 800 | | Ω |
| Reference-Ladder Tempco | | V | | 0.8 | | | 0.8 | | Ω/°C |
| TIMING CHARACTERISTICS | | | | | | | | | |
| Maximum Conversion Rate | | V _I | 20 | | | 20 | | | MHz |
| Overshoot Recovery Time | | V | | 20 | | | 20 | | ns |
| Pipeline Delay (Latency) | | V _I | | | 1 | | | 1 | Clock Cycle |
| Output Delay | T _A = +25°C | V | | 14 | 18 | | 14 | 18 | ns |
| Aperture Delay Time | T _A = +25°C | V | | 1 | | | 1 | | ns |
| Aperture Jitter Time | T _A = +25°C | V | | 5 | | | 5 | | ps-RMS |
| Acquisition Time | T _A = +25°C | V | | 20 | | | 20 | | ns |

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ELECTRICAL CHARACTERISTICS (continued)

(V_{CC} = +5.0V, V_{EE} = -5.2V, DV_{CC} = +5.0V, V_{IN} = ±2.0V, V_{SB} = -2.0V, V_{ST} = +2.0V, f_{CLK} = 20MHz, 50% clock duty cycle, T_A = T_{MIN} to T_{MAX}, unless otherwise noted.)

| PARAMETER | CONDITIONS | | TEST LEVEL | MAX1160A | | | MAX1160B | | | UNITS |
|---|---------------------------------------|--|------------|----------|-----|-----|----------|-----|-----|---------|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| DYNAMIC PERFORMANCE | | | | | | | | | | |
| Effective Number of Bits (ENOB) | f _{IN} = 1MHz | | | 9.2 | | | 8.7 | | | Bits |
| | f _{IN} = 3.58MHz | | | 8.8 | | | 8.3 | | | |
| | f _{IN} = 10MHz | | | 7.5 | | | 7.0 | | | |
| Signal-to-Noise Ratio (without harmonics) (SNR) | f _{IN} = 1MHz | T _A = +25°C | I | 57 | 60 | | 54 | 57 | dB | |
| | | T _A = 0°C to +70°C, T _A = -25°C to +85°C | IV | 55 | 58 | | 52 | 55 | | |
| | f _{IN} = 3.58MHz | T _A = +25°C | I | 56 | 58 | | 53 | 55 | | |
| | | T _A = 0°C to +70°C, T _A = -25°C to +85°C | IV | 54 | 56 | | 51 | 53 | | |
| | f _{IN} = 10MHz | T _A = +25°C | I | 50 | 53 | | 47 | 49 | | |
| | | T _A = 0°C to +70°C, T _A = -25°C to +85°C | IV | 47 | 50 | | 44 | 46 | | |
| Total Harmonic Distortion (THD) | f _{IN} = 1MHz | T _A = +25°C | I | 57 | 60 | | 54 | 57 | dB | |
| | | T _A = 0°C to +70°C, T _A = -25°C to +85°C | IV | 54 | 57 | | 51 | 54 | | |
| | f _{IN} = 3.58MHz | T _A = +25°C | I | 56 | 58 | | 53 | 55 | | |
| | | T _A = 0°C to +70°C, T _A = -25°C to +85°C | IV | 53 | 55 | | 50 | 52 | | |
| | f _{IN} = 10MHz | T _A = +25°C | I | 46 | 48 | | 43 | 45 | | |
| | | T _A = 0°C to +70°C, T _A = -25°C to +85°C | IV | 45 | 47 | | 42 | 44 | | |
| Signal-to-Noise and Distortion Ratio (SINAD) | f _{IN} = 1MHz | T _A = +25°C | I | 55 | 57 | | 52 | 54 | dB | |
| | | T _A = 0°C to +70°C, T _A = -25°C to +85°C | IV | 52 | | | 49 | | | |
| | f _{IN} = 3.58MHz | T _A = +25°C | I | 54 | 55 | | 51 | 52 | | |
| | | T _A = 0°C to +70°C, T _A = -25°C to +85°C | IV | 51 | | | 48 | | | |
| | f _{IN} = 10MHz | T _A = +25°C | I | 44 | 47 | | 41 | 44 | | |
| | | T _A = 0°C to +70°C, T _A = -25°C to +85°C | IV | 43 | | | 40 | | | |
| Spurious-Free Dynamic Range (SFDR) | f _{IN} = 1MHz | T _A = +25°C | V | 67 | | | 67 | | | dB |
| Differential Phase | f _{IN} = 3.58MHz and 4.35MHz | T _A = +25°C | V | 0.2 | | | 0.2 | | | Degrees |
| Differential Gain | f _{IN} = 3.58MHz and 4.35MHz | T _A = +25°C | V | 0.5 | | | 0.7 | | | % |

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ELECTRICAL CHARACTERISTICS (continued)

($V_{CC} = +5.0V$, $V_{EE} = -5.2V$, $DV_{CC} = +5.0V$, $V_{IN} = \pm 2.0V$, $V_{SB} = -2.0V$, $V_{ST} = +2.0V$, $f_{CLK} = 20MHz$, 50% clock duty cycle, $T_A = T_{MIN}$ to T_{MAX} , unless otherwise noted.)

| PARAMETER | CONDITIONS | TEST LEVEL | MAX1160A | | | MAX1160B | | | UNITS |
|----------------------------------|--|------------|----------|------|-------|----------|------|-------|---------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| DIGITAL INPUTS | | | | | | | | | |
| Logic 1 Voltage | | V | 2.4 | | 4.5 | 2.4 | | 4.0 | V |
| Logic 0 Voltage | | V | | | 0.8 | | | 0.8 | V |
| Maximum Input Current Low | $T_A = +25^\circ C$ | IV | 0 | 5 | 20 | 0 | 5 | 20 | μA |
| Maximum Input Current High | $T_A = +25^\circ C$ | IV | 0 | 5 | 20 | 0 | 5 | 20 | μA |
| Pulse Width Low (CLK) | | IV | 20 | | | 20 | | | ns |
| Pulse Width High (CLK) | | IV | 20 | | 300 | 20 | | 300 | ns |
| DIGITAL OUTPUTS | | | | | | | | | |
| Logic 1 Voltage | | IV | 2.4 | | | 2.4 | | | V |
| Logic 0 Voltage | | IV | | | 0.6 | | | 0.6 | V |
| POWER-SUPPLY REQUIREMENTS | | | | | | | | | |
| Voltages | V_{CC} | IV | 4.75 | | 5.25 | 4.75 | | 5.25 | V |
| | DV_{CC} | IV | 4.75 | 5.0 | 5.25 | 4.75 | 5.0 | 5.25 | |
| | $-V_{EE}$ | IV | -4.95 | -5.2 | -5.45 | -4.95 | -5.2 | -5.45 | |
| Currents | I_{CC} | VI | | 118 | 145 | | 118 | 145 | mA |
| | $D I_{CC}$ | VI | | 40 | 55 | | 40 | 55 | |
| | $-I_{EE}$ | VI | | 40 | 57 | | 40 | 57 | |
| Power Dissipation | | VI | | 1.0 | 1.3 | | 1.0 | 1.3 | W |
| Power-Supply Rejection | $V_{CC} = 5V \pm 0.25V$, $V_{EE} = -5.2V \pm 0.25V$ | V | | 1.0 | | | 1.0 | | LSB |

TEST LEVEL CODES

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. Unless otherwise noted, all tests are pulsed; therefore, $T_j = T_C = T_A$.

TEST LEVEL

I
II
III
IV
V
VI

TEST PROCEDURE

100% production tested at the specified temperature.
100% production tested at $T_A = +25^\circ C$, and sample tested at the specified temperatures.
QA sample tested only at the specified temperatures.
Parameter is guaranteed (but not tested) by design and characterization data.
Parameter is a typical value for information purposes only.
100% production tested at $T_A = +25^\circ C$. Parameter is guaranteed over specified temperature range.

Pin Description

| PIN | NAME | FUNCTION |
|--------|-----------|-----------------------|
| 1, 13 | DGND | Digital Ground |
| 2 | D0 | TTL Output (LSB) |
| 3–10 | D1–D8 | TTL Outputs |
| 11 | D9 | TTL Output (MSB) |
| 12 | D10 | TTL Output Overrange |
| 14, 28 | DV_{CC} | +5V Supply (digital) |
| 15 | CLK | Clock |
| 16, 27 | V_{EE} | -5.2V Supply (analog) |

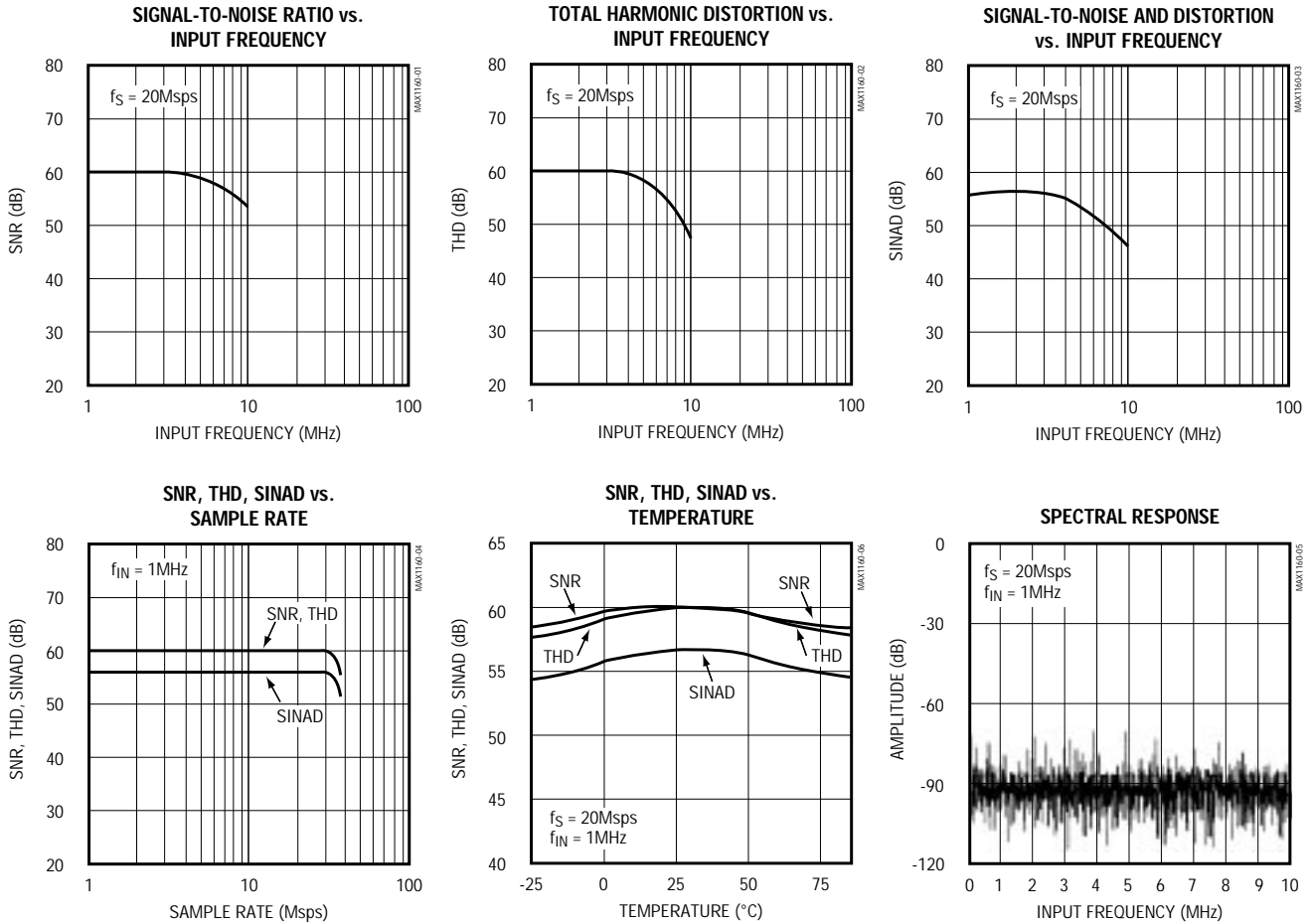
| PIN | NAME | FUNCTION |
|--------|----------|--------------------------------------|
| 17, 26 | AGND | Analog Ground |
| 18, 25 | V_{CC} | +5V Supply (analog) |
| 19 | VFT | Force for Top of Reference Ladder |
| 20 | VST | Sense for Top of Reference Ladder |
| 21 | V_{IN} | Analog Input |
| 22 | VRM | Middle of Voltage Reference Ladder |
| 23 | VSB | Sense for Bottom of Reference Ladder |
| 24 | VFB | Force for Bottom of Reference Ladder |

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Typical Operating Characteristics

($T_A = +25^\circ\text{C}$, unless otherwise noted.)



Detailed Description

The MAX1160 requires few external components to achieve the stated operation and performance. Figure 2 shows the typical interface requirements when using the MAX1160 in normal circuit operation. The following section provides a description of the pin functions, and outlines critical performance criteria to consider for achieving the optimal device performance.

Power Supplies and Grounding

The MAX1160 requires -5.2V and +5V analog supply voltages. The +5V supply is common to analog V_{CC} and digital DV_{CC} . A ferrite bead in series with each supply line reduces the transient noise injected into the analog V_{CC} . Connect these beads as close to the device as possible. The connection between the beads and the MAX1160 should not be shared with any other device. Bypass each power-supply pin as close to the device as possible. Use $0.1\mu\text{F}$ for V_{EE} and V_{CC} , and $0.01\mu\text{F}$ for DV_{CC} (chip capacitors are recommended).

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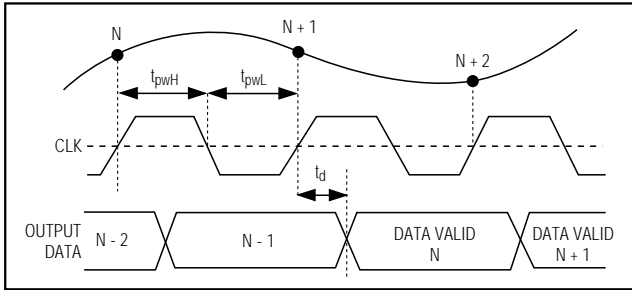


Figure 1a. Timing Diagram

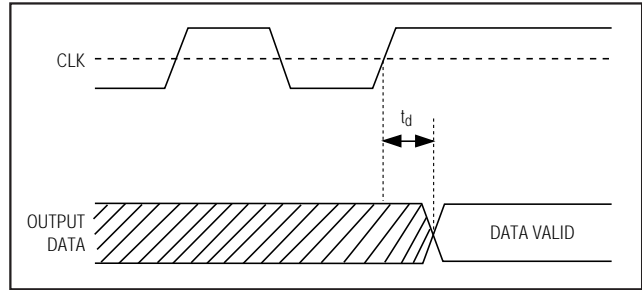


Figure 1b. Single-Event Clock

Table 1. Timing Parameters

| PARAMETER | DESCRIPTION | MIN | TYP | MAX | UNITS |
|-----------|-------------------------------------|-----|-----|-----|-------|
| t_d | CLK to Data Valid Propagation Delay | | 14 | 18 | ns |
| t_{pwH} | CLK High Pulse Width | 20 | | 300 | ns |
| t_{pwL} | CLK Low Pulse Width | 20 | | | ns |

The MAX1160 has two grounds: AGND and DGND. These internal grounds are isolated on the device. Use ground planes for optimum device performance. Use DGND for the DV_{CC} return path (typically 40mA) and for the return path for all digital output logic interfaces. Separate AGND and DGND from each other, connecting them together only through a ferrite bead at the device.

Connect a Schottky or hot carrier diode between AGND and V_{EE}. The use of separate power supplies between V_{CC} and DV_{CC} is not recommended due to potential power-supply-sequencing latchup conditions. For optimum performance, use the recommended circuit shown in Figure 2.

Voltage Reference

The MAX1160 requires the use of two voltage references: VFT and VFB. VFT is the force for the top of the voltage-reference ladder (typically +2.5V); VFB (typically -2.5V) is the force for the bottom of the voltage-reference ladder. Both voltages are applied across an 800Ω internal reference-ladder resistance. The +2.5V voltage source for reference VFT must be current limited to 20mA (max) if a different driving circuit is used in place of the recommended reference circuit shown in Figures 2 and 3. In addition, there are three reference-ladder taps (VST, VRM, and VSB). VST is the sense for the top of the reference ladder (+2V), VRM is the midpoint of the ladder (typically 0V), and VSB is the sense for the

bottom of the reference ladder (-2V). The voltages at VST and VSB are the device's true full-scale input voltages when VFT and VFB are driven to the recommended voltages (typically +2.5V and -2.5V, respectively). These points should be used to monitor the device's actual full-scale input range. When not being used, a decoupling capacitor of 0.01μF (chip capacitor preferred) connected to AGND from each tap is recommended to minimize high-frequency noise injection.

Figure 2 shows an example of a recommended reference-driver circuit. IC1 is a MAX6225, a 2.5V reference with an accuracy of 0.2%. The 10kΩ potentiometer R1 supports a minimum adjustable range of 0.6%. Use an OP07 or equivalent device for IC2. R2 and R3 must be matched to within 0.1% with good TC tracking to maintain 0.3LSB matching between VFT and VFB. If 0.1% matching is not met, then R4 can be used to adjust the VFB voltage to the desired level. Adjust VFT and VFB such that VST and VSB are exactly +2V and -2V, respectively.

The analog input range scales proportionally with respect to the reference voltage if a different input range is required. The maximum scaling factor for device operation is ±20% of the recommended reference voltages of VFT and VFB. However, because the device is laser trimmed to optimize performance with ±2.5V references, its accuracy degrades if operated beyond a ±2% range.

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The following errors are defined:

- +FS error = top of ladder offset voltage
= $\Delta(+FS - VST + 1LSB)$
- FS error = bottom of ladder offset voltage
= $\Delta(-FS - VSB - 1LSB)$

where the +FS (full-scale) input voltage is defined as the output transition between 11 1111 1110 and 11 1111 1111, and the -FS input voltage is defined as the output transition between 00 0000 0000 and 00 0000 0001 (Table 2).

Analog Input

VIN is the analog input. The full-scale input range will be 80% of the reference voltage, or $\pm 2V$ with $VFB = -2.5V$ and $VFT = +2.5V$.

The analog input's drive requirements are minimal when compared to conventional flash converters. This is due to the MAX1160's extremely low (5pF) input capacitance and very high (300k Ω) input resistance. For example, for an input signal of $\pm 2V_{p-p}$ with a 10MHz input frequency, the peak output current required for the driving circuit is only 628 μA .

Clock Input

The MAX1160 is driven from a single-ended TTL input (CLK). The CLK pulse width (t_{pWH}) must be kept between 20ns and 300ns to ensure proper operation of the internal track/hold amplifier (Figure 1a). When operating the MAX1160 at sampling rates above 3Msps, it is recommended that the clock input duty cycle be kept at

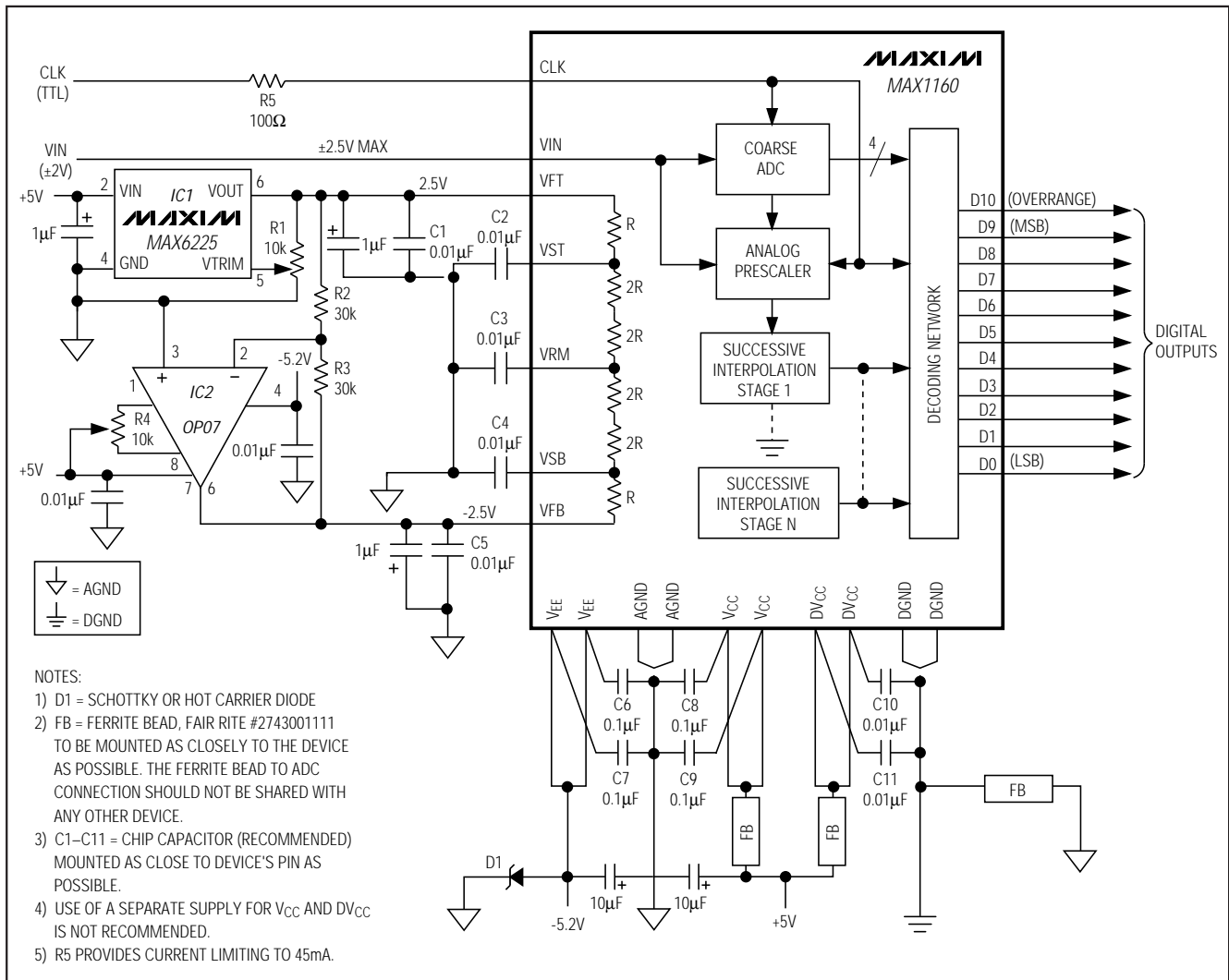


Figure 2. Typical Operating Circuit

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Table 2. Output Data Information

| ANALOG INPUT | OVERRANGE D10 | OUTPUT CODE D9-D0 |
|------------------|---------------|-------------------|
| $> +2V + 1/2LSB$ | 1 | 11 1111 1111 |
| $+2V - 1LSB$ | 0 | 11 1111 1110 |
| 0V | 0 | 00 0000 0000 |
| $-2V + 1LSB$ | 0 | 00 0000 0000 |
| $< -2V$ | 0 | 00 0000 0000 |

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

50% to optimize performance, but performance will not be degraded if kept within the 40% to 60% range. The analog input signal is latched on the rising edge of CLK.

The clock input must be driven from fast TTL logic ($V_{IH} \leq 4.5V$, $t_{RISE} < 6ns$). In the event the clock is driven from a high current source, use a 100Ω resistor (R5) in series to limit current to approximately 45mA.

Digital Outputs

The format of the output data (D0–D9) is straight binary (Table 2). The outputs are latched on the rising edge of CLK with a typical propagation delay of 14ns. There is a one-clock-cycle latency between CLK and the valid output data (Figure 1a).

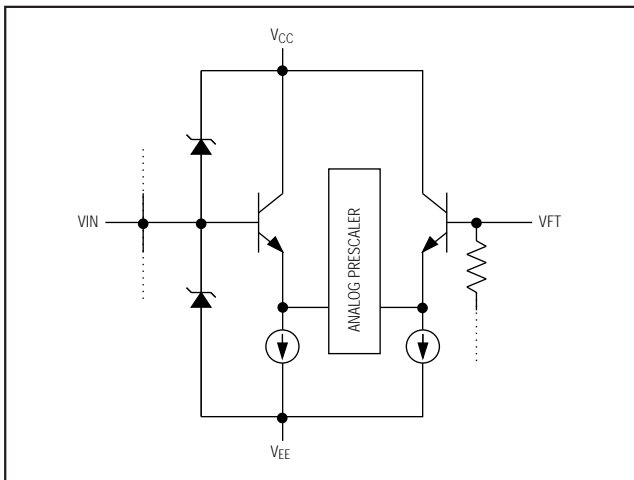


Figure 3. Analog Equivalent Input Circuit

The digital outputs' rise and fall times are not symmetrical. Typical propagation delay is 14ns for the rise time and 6ns for the fall time (Figure 4). The nonsymmetrical rise and fall times create approximately 8ns of invalid data.

Overrange Output

The overrange output (D10) is an indication that the analog input signal has exceeded the positive full-scale input voltage by 1LSB. When this condition occurs, D10 will switch to logic 1. All other data outputs (D0–D9) will remain at logic 1 as long as D10 remains at logic 1. This feature makes it possible to include the MAX1160 in higher-resolution systems.

Evaluation Board

The MAX1160 EV kit is available to help designers demonstrate the MAX1160's full performance. This board includes a reference circuit, a clock-driver circuit, output data latches, and an on-board reconstruction of the digital data. A separate data sheet describing the operation of this board is also available. Contact the factory for price and availability.

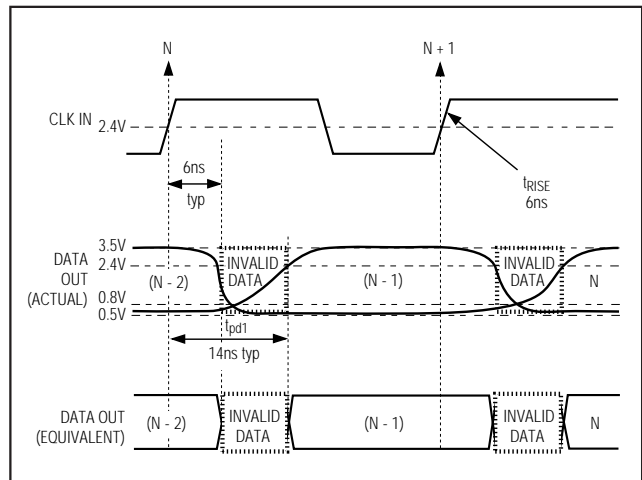


Figure 4. Digital Output Characteristics

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