

DAC8742H, HART and FOUNDATION Fieldbus / PROFIBUS PA Modem

1 Features

- HART-Compliant Physical Layer Modem
 - 1200/2200 Hz HART FSK Sinusoids
 - Register Programmable Amplitude of TX Signals (DAC8741H / DAC8742H only)
 - Integrated RX Demodulator and Band-Pass Filter with Minimal External Components
- FOUNDATION Fieldbus Compatible H1 Controller and Medium Attachment Unit (MAU)
 - 31.25 kbit/s Communication Based on Manchester Coded Bus Powered (MBP)
 - Integrated Manchester Encoder and Decoder
 - Compatible with PROFIBUS PA
- Low Quiescent Current: 180 uA Max at Typical Industrial Operating Temperature Range (-40°C to 85°C)
- Integrated 1.5-V Reference
- Flexible Clocking Options
 - Internal Oscillator
 - External Crystal Oscillator
 - External CMOS Clock
- Digital Interface
 - DAC8742H: UART and SPI
- Reliability: CRC Bit Error Checking, Watchdog Timer
- Wide Operating Temperature: -55°C to 125°C
- 5 mm x 5 mm TQFP Package

2 Applications

- Industrial Process Control and Automation
- PLC or DCS I/O Modules
- Field and Sensor Transmitters

3 Description

The DAC8742H is a HART®, FOUNDATION Fieldbus™, and PROFIBUS PA compatible low power modem designed for industrial process control and industrial automation applications.

In HART mode, the DAC8742H integrates all of the required circuitry to operate as half-duplex HART physical layer modems, in either slave or master configurations with minimal external components for filtering. In FOUNDATION Fieldbus mode, the DAC8742H integrates all of the required circuitry to operate as half-duplex FOUNDATION Fieldbus compatible H1 Controllers and MAUs.

The HART, FOUNDATION Fieldbus, or PROFIBUS PA, data stream can be transferred from the microcontroller through either a UART interface or an integrated FIFO accessed by a SPI interface. The SPI interface includes an SDO pin for daisy-chain support, various interrupts, and other extended features.

Device Information⁽¹⁾

| PART NUMBER | PACKAGE | BODY SIZE (NOM) |
|-------------|-----------|-----------------|
| DAC8742H | TQFP (32) | 5 mm x 5 mm |

(1) For all available packages, see the orderable addendum at the end of the data sheet.



Simplified Schematic

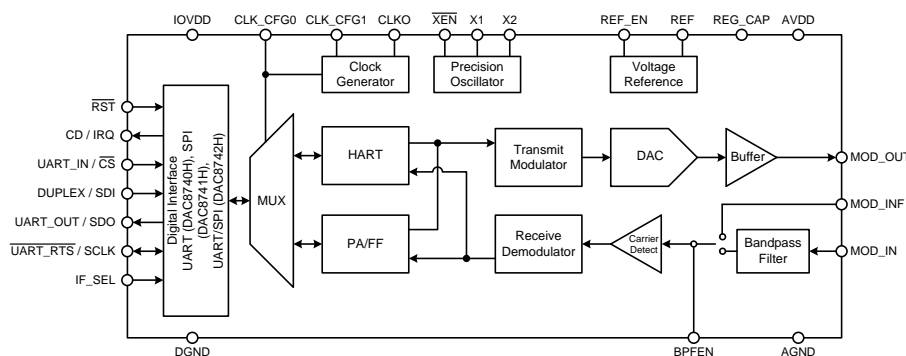


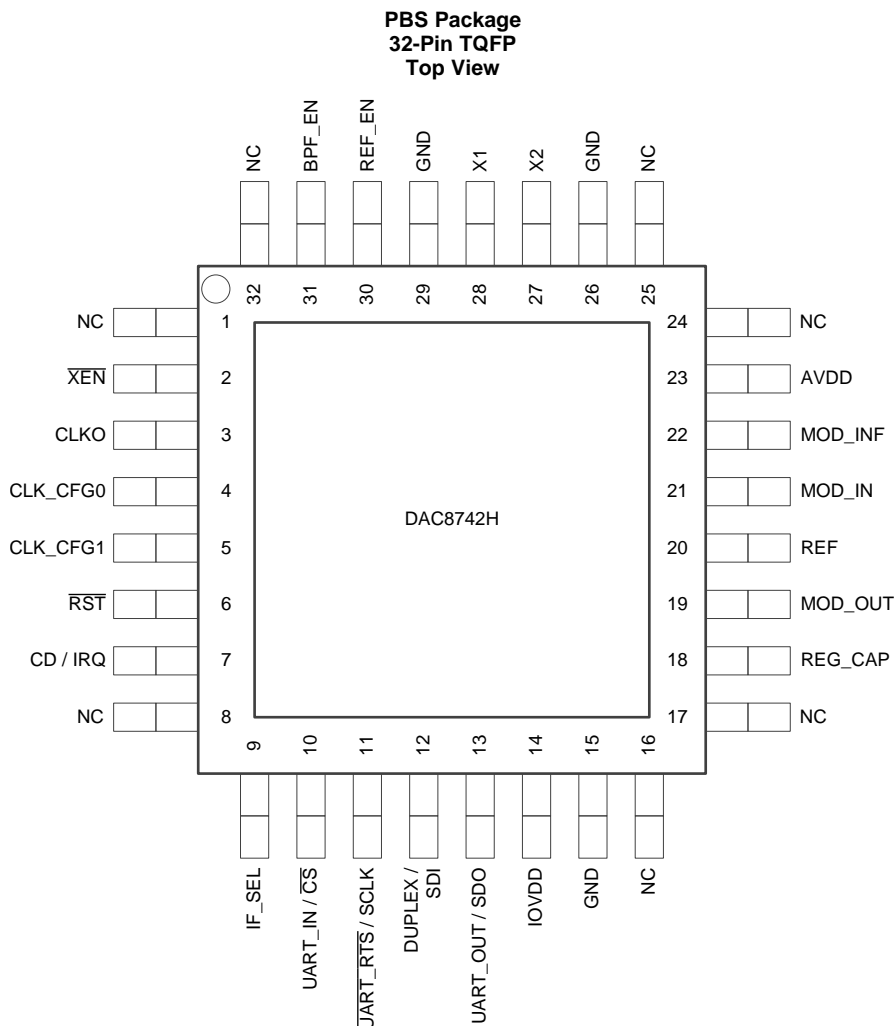
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4 Revision History

| DATE | REVISION | NOTES |
|---------------|----------|--|
| December 2018 | * | Initial release of DAC8742H standalone data sheet. |

5 Pin Configuration and Functions



Pin Functions

| PIN | | I/O | DESCRIPTION |
|-------------------------|-----|----------------|--|
| NAME | NO. | | |
| $\overline{\text{XEN}}$ | 2 | Digital Input | Crystal Oscillator Enable. Logic low on this pin enables the crystal oscillator circuit; in this mode an external crystal is required. Logic high on this pin disables the internal crystal oscillator circuit; in this mode an external CMOS clock or the internal oscillator are required. No digital input pin should be left floating. |
| CLKO | 3 | Digital Output | Clock Output. If using the internal oscillator or an external crystal, this pin can be configured as a clock output. |
| CLK_CFG0 | 4 | Digital Input | Clock Configuration Pin. This pin is used to configure the input/output clocking scheme. No digital input pin should be left floating. |
| CLK_CFG1 | 5 | Digital Input | Clock Configuration Pin. This pin is used to configure the input/output clocking scheme. No digital input pin should be left floating. |
| $\overline{\text{RST}}$ | 6 | Digital Input | Reset. Logic low on this pin places the DAC8742H into power-down mode and resets the device. Logic high returns the device to normal operation. No digital input pin should be left floating. |

Pin Functions (continued)

| PIN | | I/O | DESCRIPTION | | |
|-----------------|-----|-------------------------------|---|--|--|
| NAME | NO. | | | | |
| CD / IRQ | 7 | Digital Output | UART Mode | HART Mode | Carrier detect. A logic high on this pin indicates a valid carrier is present. |
| | | | | FF / PA Mode | While not transmitting, a logic high on this pin indicates a valid carrier is present. While transmitting, a logic high on this pin indicates that the jabber inhibitor has triggered. |
| | | | SPI Mode | Digital Interrupt. The interrupt can be configured as edge sensitive or level sensitive with positive or negative polarity, as set by the CONTROL register. Events that trigger an interrupt are controlled by the Modem IRQ Mask register. | |
| IF_SEL | 9 | Digital Input | Interface select. A logic high on this pin configures the device for SPI mode. A logic low on this pin configures the device for UART mode. An internal pull-down resistor is included. No digital input pin should be left floating. | | |
| UART_IN / CS | 10 | Digital Input | UART Mode | UART data input. | |
| | | | SPI Mode | SPI chip-select. Data bits are clocked into the serial shift register when CS is low. When CS is high, SDO is in a high-impedance state and data on SDI are ignored. No digital input pin should be left floating. No digital input pin should be left floating. | |
| UART_RTS / SCLK | 11 | Digital Input, Digital Output | UART Mode | HART Mode | Request to send a logic high on this pin enables the demodulator and disables the modulator. A logic low on this pin enables the modulator and disables the demodulator. No digital input pin should be left floating. |
| | | | | FF / PA Mode | This pin reports transmit FIFO threshold information as programmed by the packet initiation code. |
| | | | SPI Mode | SPI clock. Data can be transferred at rates up to 12.5MHz. Schmitt-Trigger logic input. | |
| DUPLEX / SDI | 12 | Digital Output | UART Mode | Digital input. Logic high enables full-duplex, or internal loop-back, test mode. | |
| | | | SPI Mode | SPI data input. Data is clocked into the 24-bit input shift register on the falling edge of the serial clock input. Schmitt-Trigger logic input. | |
| UART_OUT / SDO | 13 | Digital Output | UART Mode | UART data output. | |
| | | | SPI Mode | SPI data output. Data is valid on the falling edge of SCLK. | |
| IOVDD | 14 | Supply | Interface supply. Supply voltage for digital input and output circuitry. This voltage sets the logical thresholds for the digital interface. | | |
| GND | 15 | Supply | Digital ground. Ground reference voltage for all digital circuitry of the device. | | |
| REG_CAP | 18 | Analog Output | Capacitor for internal regulator. | | |
| MOD_OUT | 19 | Analog Output | Modem output. FSK output sinusoid in HART mode or Manchester coded data stream in FOUNDATION Fieldbus and PROFIBUS PA modes. Requires parallel capacitance of 5-22 nF in HART mode or 0-100 pF in FOUNDATION Fieldbus and PROFIBUS PA mode for stability. | | |
| REF | 20 | Analog Input or Output | When the internal reference is enabled this pin outputs the internal reference voltage. When the internal reference is disabled, this is the external 2.5V reference input. | | |
| MOD_IN | 21 | Analog Input | HART FSK input or FOUNDATION Fieldbus and PROFIBUS PA Manchester coded data stream input. If an external filter is used, do not connect this pin. | | |
| MOD_INF | 22 | Analog Input | If using the internal band-pass filter, connect 680 pF to this pin or 120 pF in FOUNDATION Fieldbus and PROFIBUS PA modes. If using an external filter, connect the output of that filter to this pin. | | |
| AVDD | 23 | Supply | Power supply. | | |
| GND | 26 | Supply | Analog ground. Ground reference voltage for power supply input. | | |
| X2 | 27 | Analog Input | Crystal stimulus. | | |
| X1 | 28 | Analog Input | Crystal/Clock input. | | |
| GND | 29 | Supply | Digital ground. Ground reference voltage for all digital circuitry of the device. | | |
| REF_EN | 30 | Digital Input | Reference enable. Logic high enables the internal 1.5V reference. No digital input pin should be left floating. | | |

Pin Functions (continued)

| PIN | | I/O | DESCRIPTION |
|--------|--------------------------------|---------------|--|
| NAME | NO. | | |
| BPF_EN | 31 | Digital Input | Filter enable. A logic high enables the internal band-pass filter. No digital input pin should be left floating. |
| NC | 1, 8, 16, 17, 24, 25, 32 | – | Do not connect these pins. |

6 Specifications

6.1 Absolute Maximum Ratings

Over operating free-air temperature range (unless otherwise noted)⁽¹⁾

| | | MIN | MAX | UNIT |
|---|---|------|-----------|------|
| Input voltage | AVDD to GND | -0.3 | 6 | V |
| | IOVDD to GND | -0.3 | 6 | |
| | Analog output voltage to GND | -0.3 | AVDD+0.3 | |
| | Digital output voltage to GND | -0.3 | IOVDD+0.3 | |
| Output voltage | Analog output pin to GND | -0.3 | AVDD+0.3 | V |
| | Digital output pin to GND | -0.3 | IOVDD+0.3 | |
| Input Current | Input current to any pin except supply pins | -10 | 10 | mA |
| Operating junction temperature, T _J | | -55 | 125 | °C |
| Junction temperature range (T _J max) | | | 150 | |
| Storage temperature, T _{stg} | | -60 | 150 | |

(1) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

6.2 ESD Ratings

| | | | VALUE | UNIT |
|--------------------|-------------------------|--|-------|------|
| V _(ESD) | Electrostatic discharge | Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins ⁽¹⁾ | ±8000 | V |
| | | Charged device model (CDM), per JEDEC specification JESD22-C101, all pins ⁽²⁾ | ±1500 | |

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

Over operating free-air temperature range (unless otherwise noted)

| | | MIN | NOM | MAX | UNIT |
|---|------------------|--------|--------|--------|------|
| POWER SUPPLY | | | | | |
| AVDD | | 2.7 | | 5.5 | V |
| IOVDD | | 1.71 | | 5.5 | V |
| ANALOG INPUTS | | | | | |
| External Reference Input Voltage | | 2.375 | 2.5 | 2.625 | V |
| DIGITAL INPUTS | | | | | |
| External Clock Source Frequency (HART Mode) | 3.6864 MHz Clock | 3.6469 | 3.6864 | 3.7232 | MHz |
| | 1.2288 MHz Clock | 1.2165 | 1.2288 | 1.2411 | MHz |

Recommended Operating Conditions (continued)

Over operating free-air temperature range (unless otherwise noted)

| | MIN | NOM | MAX | UNIT |
|---|------|-----|------|------|
| External Clock Source Frequency (FF / PA Modes) | 3.96 | 4 | 4.04 | MHz |

6.4 Thermal Information

| THERMAL METRIC ⁽¹⁾ | | DAC8742H | UNIT |
|-------------------------------|--|------------|------|
| | | PBS (TQFP) | |
| | | 32 PIN | |
| R _{θJA} | Junction-to-ambient thermal resistance | 79.7 | °C/W |
| R _{θJC(top)} | Junction-to-case (top) thermal resistance | 19.3 | °C/W |
| R _{θJB} | Junction-to-board thermal resistance | 33.2 | °C/W |
| Ψ _{JT} | Junction-to-top characterization parameter | 0.5 | °C/W |
| Ψ _{JB} | Junction-to-board characterization parameter | 32.9 | °C/W |
| R _{θJC(bot)} | Junction-to-case (bottom) thermal resistance | n/a | °C/W |

(1) For more information about traditional and new thermal metrics, see the Semiconductor and IC Package Thermal Metrics application report, SPRA953.

6.5 Electrical Characteristics

All specifications over -40°C to +125°C ambient operating temperature, 2.7V ≤ AVDD ≤ 5.5V, 1.71V ≤ IOVDD ≤ 5.5V, Internal Reference, Internal Filter, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|--|------|-----|-----|------|
| POWER REQUIREMENTS | | | | | |
| IOVDD | | 1.71 | | 5.5 | V |
| AVDD | | 2.7 | | 5.5 | V |
| AVDD and IOVDD Supply Current (HART Mode) | | | | | |
| Demodulator active | External Clock, -40°C to 85°C | | 110 | 150 | μA |
| | External Clock, -55°C to 125°C | | | 220 | μA |
| | External Clock, -40°C to 85°C, External Reference | | 100 | 140 | μA |
| | External Clock, -55°C to 125°C, External Reference | | | 210 | μA |
| Modulator active | External Clock, -40°C to 85°C | | 160 | 180 | μA |
| | External Clock, -55°C to 125°C | | | 250 | μA |
| | External Clock, -40°C to 85°C, External Reference | | 150 | 170 | μA |
| | External Clock, -55°C to 125°C, External Reference | | | 240 | μA |
| Crystal Oscillator | External Crystal, 16pF at XTAL1 and XTAL2 | | 40 | 65 | μA |
| | External Crystal, 36pF at XTAL1 and XTAL2 | | 40 | 65 | μA |
| Internal Oscillator | External Reference | | 105 | 180 | μA |
| SPI Interface | Additional quiescent current required when interfacing via SPI | | 5 | | μA |
| AVDD and IOVDD Supply Current (FF/PA Mode) | | | | | |
| Decoder active | External Clock, -40°C to 85°C | | 160 | 220 | μA |
| | External Clock, -55°C to 125°C | | | 330 | μA |
| | External Clock, -40°C to 85°C, External Reference | | 175 | 200 | μA |
| | External Clock, -55°C to 125°C, External Reference | | | 320 | μA |
| Encoder active | External Clock, -40°C to 85°C | | 175 | 250 | μA |
| | External Clock, -55°C to 125°C | | | 360 | μA |
| | External Clock, -40°C to 85°C, External Reference | | 165 | 235 | μA |
| | External Clock, -55°C to 125°C, External Reference | | | 350 | μA |

Electrical Characteristics (continued)

All specifications over -40°C to +125°C ambient operating temperature, $2.7V \leq AVDD \leq 5.5V$, $1.71V \leq IOVDD \leq 5.5V$, Internal Reference, Internal Filter, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|---|--------|--------|--------|---------|
| Crystal Oscillator | External Crystal, 16pF at XTAL1 and XTAL2 | | 40 | 65 | μA |
| | External Crystal, 36pF at XTAL1 and XTAL2 | | 40 | 65 | μA |
| SPI Interface | Additional quiescent current required when interfacing via SPI | | 5 | | μA |
| AVDD and IOVDD Supply Current (All Modes) | | | | | |
| Power-Down Mode | Internal reference disabled, -40°C to 85°C, no active clock input | | 30 | 60 | μA |
| | Internal reference disabled, -55°C to 125°C, no active clock input | | | 182 | μA |
| CLOCK REQUIREMENTS | | | | | |
| EXTERNAL CLOCK (HART MODE) | | | | | |
| External Clock Source Frequency | 3.6864 MHz Clock | 3.6469 | 3.6864 | 3.7232 | MHz |
| | 1.2288 MHz Clock | 1.2165 | 1.2288 | 1.2411 | MHz |
| EXTERNAL CLOCK (FF/PA MODE) | | | | | |
| External Clock Source Frequency | 4 MHz Clock | 3.96 | 4 | 4.04 | MHz |
| INTERNAL OSCILLATOR | | | | | |
| Frequency | -40°C to 125°C | 1.2165 | 1.2288 | 1.2411 | MHz |
| VOLTAGE REFERENCE | | | | | |
| INTERNAL REFERENCE VOLTAGE | | | | | |
| Internal Reference Voltage | | 1.47 | 1.5 | 1.53 | V |
| Load Regulation | | | 1.3 | | V/mA |
| Capacitive Load | Guaranteed by design | | 1 | | μF |
| OPTIONAL EXTERNAL REFERENCE VOLTAGE | | | | | |
| External Reference Input Voltage | | 2.375 | 2.5 | 2.625 | V |
| External Reference Input Current | Demodulator | | 4.5 | | μA |
| | Modulator | | 4.5 | | μA |
| | Internal Oscillator | | 4.5 | | μA |
| | Power-Down | | 4.5 | | μA |
| HART MODEM | | | | | |
| MOD_IN INPUT (HART MODE) | | | | | |
| Input Voltage Range | External Reference Source, guaranteed by design. Signal applied at the input to the DC blocking capacitor. | 0 | | 1.5 | Vp-p |
| | Internal Reference Source, guaranteed by design. Signal applied at the input to the DC blocking capacitor. | 0 | | 1.5 | Vp-p |
| Receiver Sensitivity | Threshold for successful carrier detection and demodulation, assuming ideal sinusoidal input FSK signals with valid preamble using internal filter. | 80 | 100 | 120 | mVp-p |
| MOD_OUT OUTPUT (HART MODE) | | | | | |
| Output Voltage | AC-coupled (2.2μF), measured at MOD_OUT pin with 160Ω load | 450 | 460 | 480 | mVp-p |
| Mark Frequency | Internal Oscillator | | 1200 | | Hz |
| Space Frequency | Internal Oscillator | | 2200 | | Hz |
| Frequency Error | Internal Oscillator, -40°C to 125°C | -1 | | 1 | % |
| Phase Continuity Error | Guaranteed by design | | | 0 | Degrees |

Electrical Characteristics (continued)

All specifications over -40°C to +125°C ambient operating temperature, $2.7V \leq AVDD \leq 5.5V$, $1.71V \leq IOVDD \leq 5.5V$, Internal Reference, Internal Filter, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---------------------------------------|--|-------------|-------|--------------|--------|
| Minimum Resistive Load | 160Ω, AC coupled with 2.2μF, guaranteed by design | 160 | | | Ω |
| Transmit Impedance | RTS low, measured at the MOD_OUT pin, 1mA measurement current | | 13 | | Ω |
| | RTS high, measured at the MOD_OUT pin, ±200nA measurement current | | 250 | | kΩ |
| FF / PA MODEM | | | | | |
| MOD_IN INPUT (FF/PA MODE) | | | | | |
| Input Voltage Range | External Reference Source, specified by design. Signal applied at the input to the DC blocking capacitor. | 0 | | 1 | Vp-p |
| | Internal Reference enabled, specified by design. Signal applied at the input to the DC blocking capacitor. | 0 | | 1 | Vp-p |
| Receiver Jitter Tolerance | Edge-to-edge measurement of Manchester Encoded waveforms | -3.2 | | 3.2 | μs |
| Receiver Sensitivity | Threshold for successful carrier detection and decoding, assuming ideal Manchester Encoded input trapezoidal signals with 6μs rise time, valid preamble byte(s) and start delimiter byte, using internal filter. | 75 | | | mVp-p |
| MOD_OUT OUTPUT (FF/PA MODE) | | | | | |
| Output Voltage | | | 800 | | mVp-p |
| Maximum Amplitude Difference | Maximum difference in positive and negative amplitude signals | -50 | | 50 | mV |
| Transmit Bit Rate | | 31.1875 | 31.25 | 31.3125 | kbit/s |
| Transmit Jitter | Measured with respect to ideal crossing of high time and low time | -0.8 | | 0.8 | μs |
| Output Signal Distortion | Measured peak to trough distortion for positive and negative amplitude voltage outputs | -10 | | 10 | % |
| Rise and Fall Time | 10% to 90% of peak to peak signal | | | 8 | μs |
| Slew Rate | 10% to 90% of peak to peak signal | | | 0.2 | V/μs |
| DIGITAL REQUIREMENTS | | | | | |
| DIGITAL INPUTS | | | | | |
| V _{IH} , Input High Voltage | | 0.7 x IOVDD | | | V |
| V _{IL} , Input Low Voltage | | | | 0.3 x IOVDD | V |
| CLK_CFG0, Input High Voltage | Guaranteed by design | 0.8 x IOVDD | | | V |
| CLK_CFG0, Input Mid-Scale Voltage | Guaranteed by design | 0.4 x IOVDD | | 0.55 x IOVDD | V |
| CLK_CFG0, Input Low Voltage | Guaranteed by design | | | 0.15 x IOVDD | V |
| Input Current | | -1 | | 1 | μA |
| Input Capacitance | | | 5 | | pF |
| DIGITAL OUTPUTS | | | | | |
| V _{OH} , Output High Voltage | 200μA source/sink | IOVDD - 0.5 | | | V |
| V _{OL} , Output Low Voltage | 200μA source/sink | | | 0.4 | V |

6.6 Timing Requirements

All timing conditions guaranteed by design

| PARAMETER | | MIN | NOM | MAX | UNIT |
|-------------------------|--|-----|-----|-----|-----------|
| t_c | SCLK Cycle Time | 80 | | | ns |
| t_{w1} | SCLK High Time | 32 | | | ns |
| t_{w2} | SCLK Low Time | 32 | | | ns |
| t_{su} | /CS to SCLK Falling Edge Setup Time | 32 | | | ns |
| t_{su1} | Data Setup Time | 5 | | | ns |
| t_{h1} | Data Hold Time | 5 | | | ns |
| t_{d1} | SCLK Falling Edge to /CS Rising Edge | 32 | | | ns |
| t_{w3} | Minimum /CS High Time ⁽¹⁾ | 1 | | | us |
| t_v | SCLK Rising Edge to SDO Valid | 32 | | | ns |
| t_{rst} | Reset low time | 100 | | | ns |
| HART Mode Timing | | | | | |
| t_{cstart} | Carrier start time. Time from RTS falling edge to transmit carrier reaching its first peak. | | | 5 | Bit-Times |
| t_{cstop} | Carrier stop time. Time from RTS rising edge to transmit carrier amplitude falling below the receive amplitude | | | 3 | Bit-Times |
| t_{cdecay} | Carrier decay time. Time from RTS rising edge to carrier amplitude dropping to zero. | | | 6 | Bit-Times |
| t_{cdeton} | Carrier detect on. Time from valid carrier on receive path to CD rising edge. | | | 6 | Bit-Times |
| $t_{cdetoff1}$ | Carrier detect off. Time from valid carrier removed on receive path to CD falling edge. | | | 3 | ms |
| $t_{cdetoff2}$ | Carrier detect on when transitioning from transmit mode to receive mode in the presence of a constant valid receive carrier. | 2.1 | | | ms |
| t_{cos1} | Crystal oscillator power-up time from enabling the oscillator via clock configuration pins with 16pF load capacitors. | 25 | | | ms |
| t_{cos2} | Crystal oscillator power-up time from enabling the oscillator via clock configuration pins with 36pF load capacitors. | 25 | | | ms |
| t_{ref} | Reference power-up time from enabling via hardware pin. | 10 | | | ms |
| t_{pow} | Transition time from power-down mode to normal operating mode with external clock and external reference. | 30 | | | μs |

(1) Time between two consecutive \overline{CS} rising edges must be $\geq 3.06 \mu s$

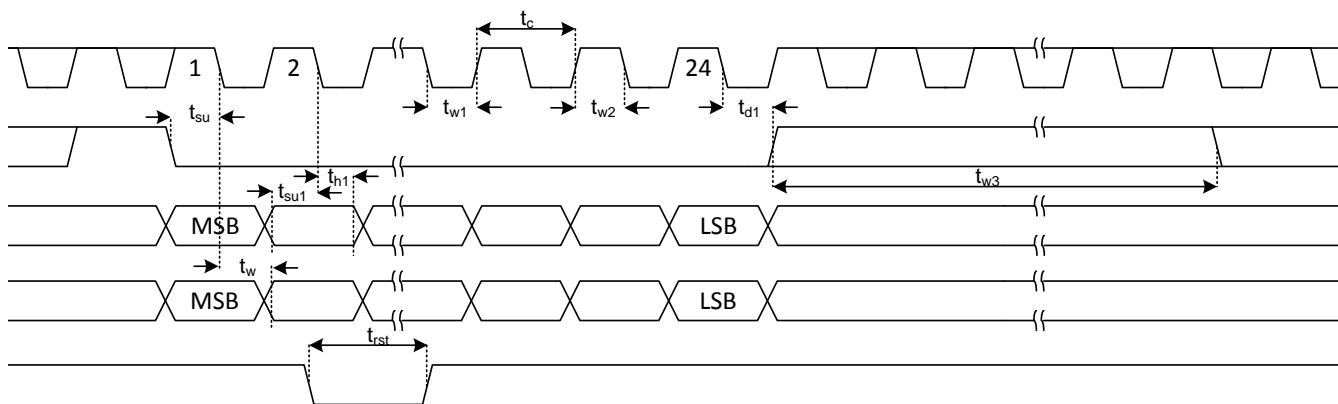


Figure 1. SPI Timing Diagram

6.7 Typical Characteristics

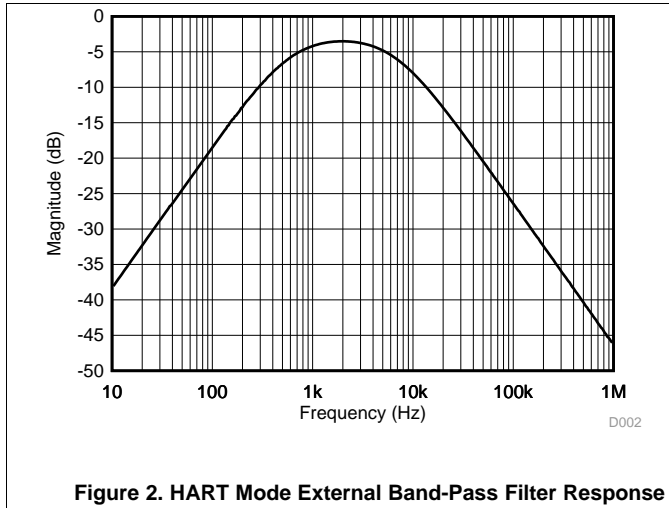


Figure 2. HART Mode External Band-Pass Filter Response

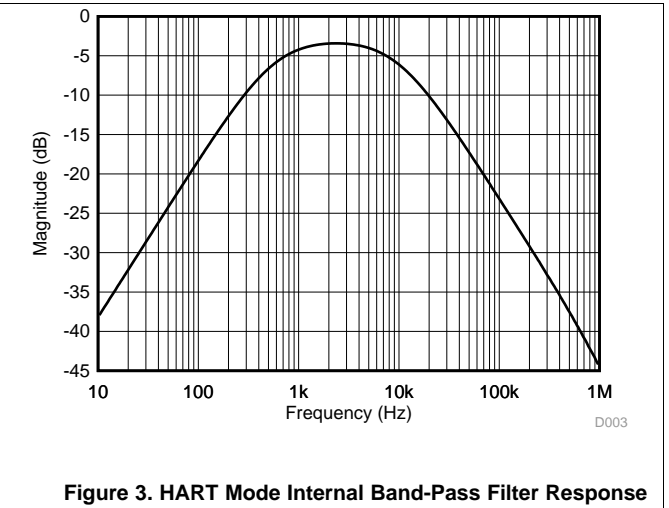


Figure 3. HART Mode Internal Band-Pass Filter Response

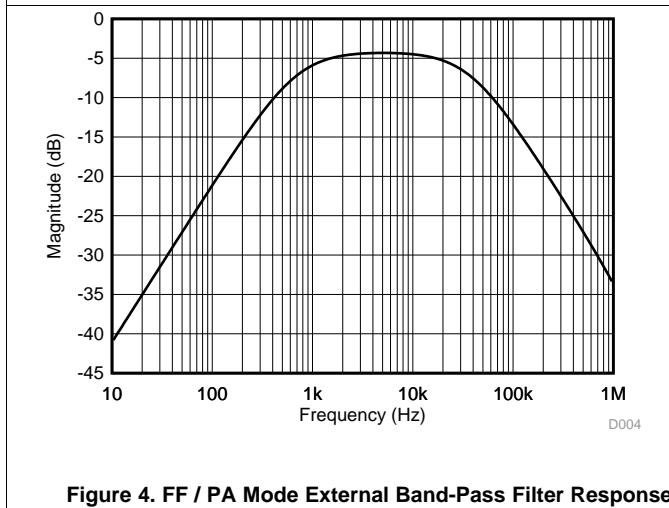


Figure 4. FF / PA Mode External Band-Pass Filter Response

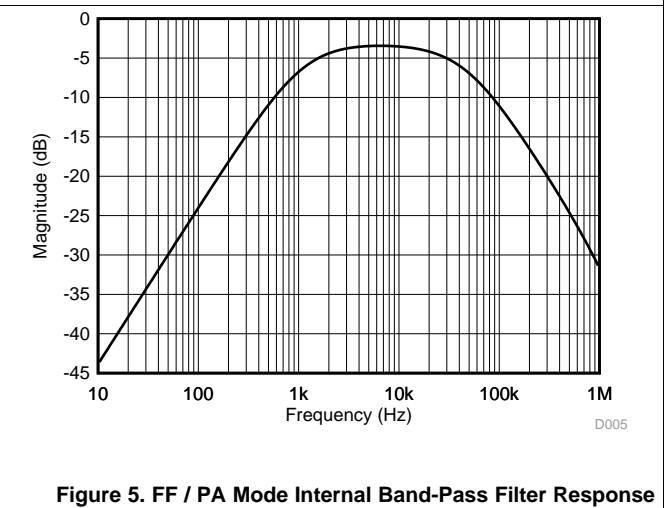


Figure 5. FF / PA Mode Internal Band-Pass Filter Response

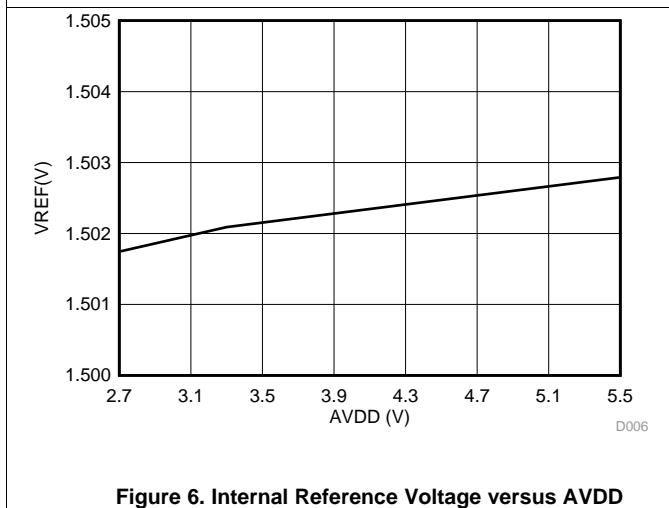


Figure 6. Internal Reference Voltage versus AVDD

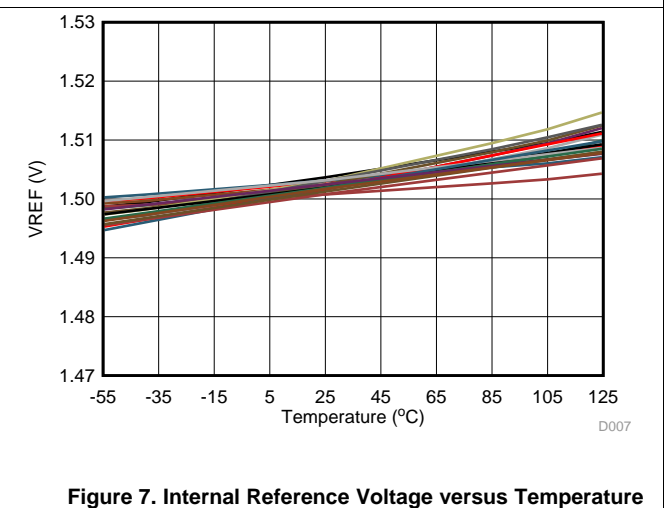
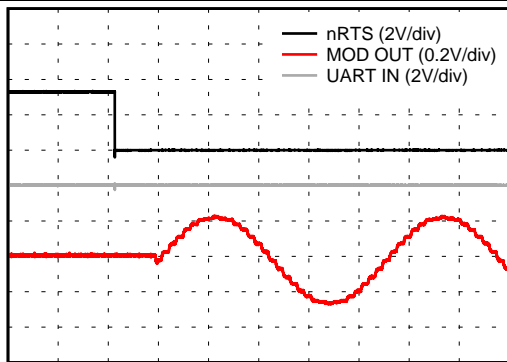


Figure 7. Internal Reference Voltage versus Temperature

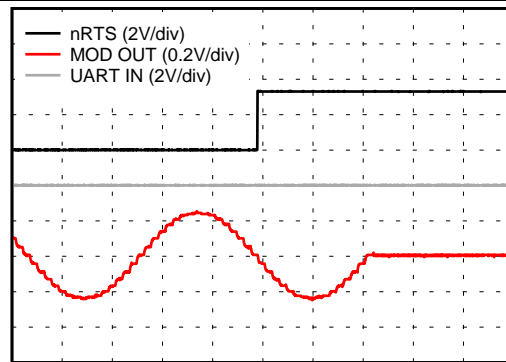
Typical Characteristics (continued)



0.1 ms/div

D008

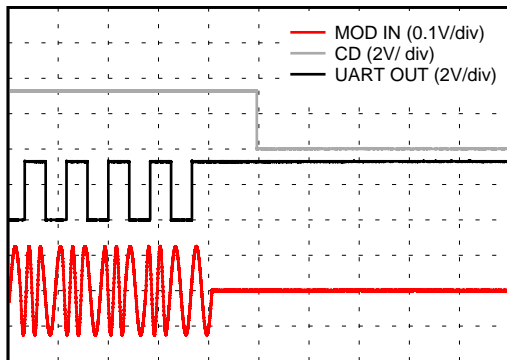
Figure 8. HART TX Carrier Start Time



0.1 ms/div

D009

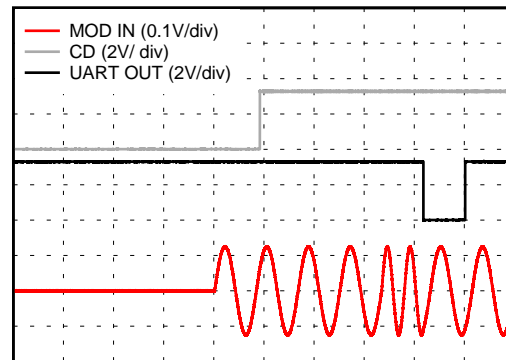
Figure 9. HART TX Carrier Stop / Decay Time



0.5 ms/div

D010

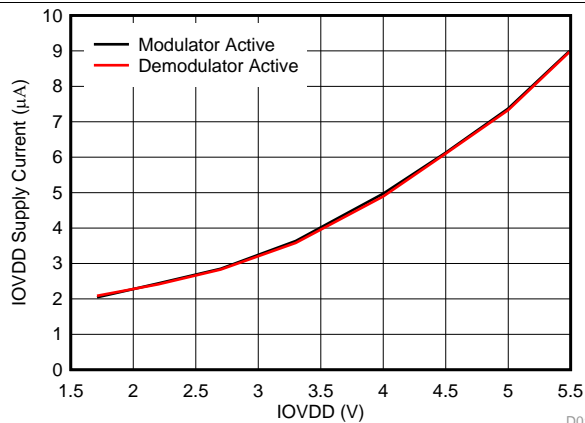
Figure 10. HART RX Carrier Detect Off Timing



1 ms/div

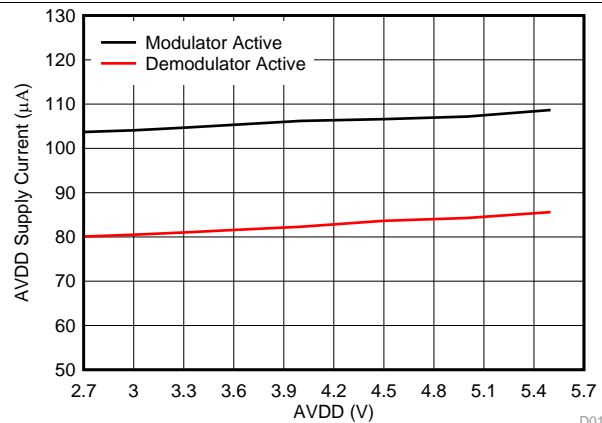
D011

Figure 11. HART RX Carrier Detect On Timing



D012

Figure 12. HART Mode IOVDD Supply Current versus Voltage with External Reference



D013

Figure 13. HART Mode AVDD Supply Current versus Voltage with External Reference

Typical Characteristics (continued)

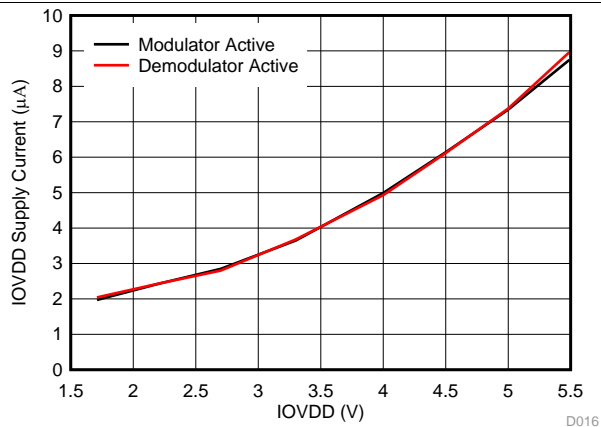


Figure 14. HART Mode IOVDD Supply Current versus Voltage with Internal Reference

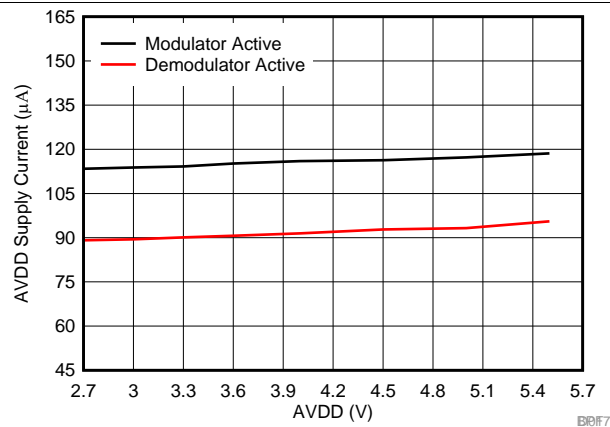


Figure 15. HART Mode AVDD Supply Current versus Voltage with Internal Reference

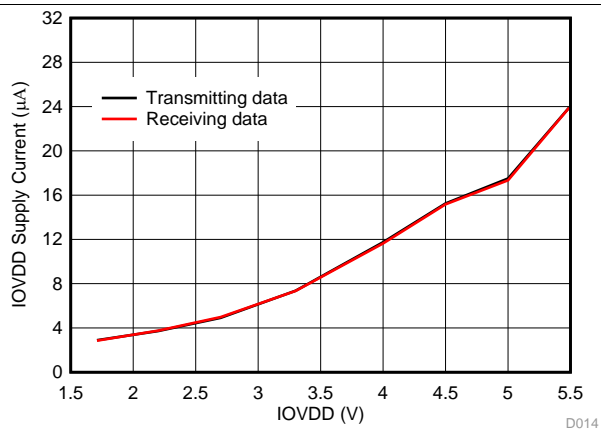


Figure 16. FF / PA Mode IOVDD Supply Current versus Voltage with External Reference

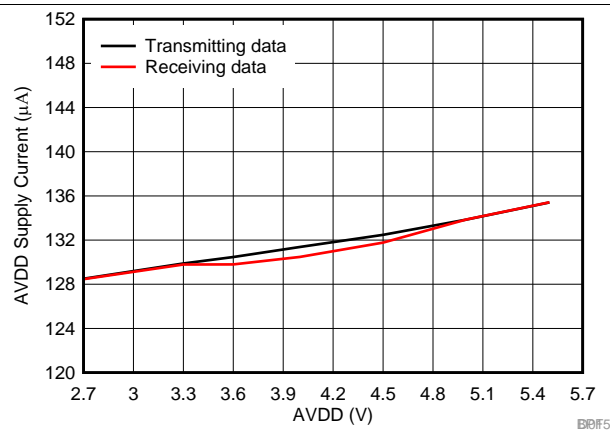


Figure 17. FF / PA Mode AVDD Supply Current versus Voltage with External Reference

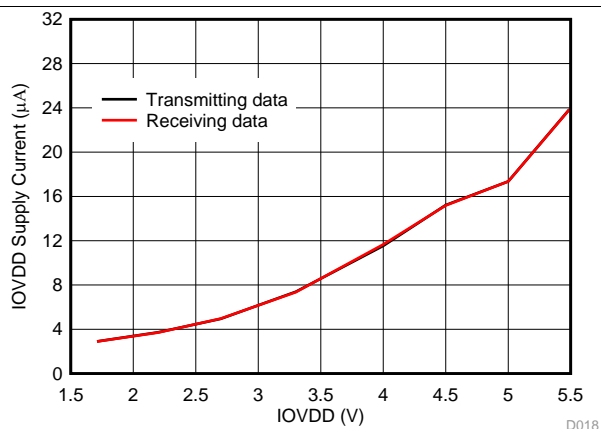


Figure 18. FF / PA Mode IOVDD Supply Current versus Voltage with Internal Reference

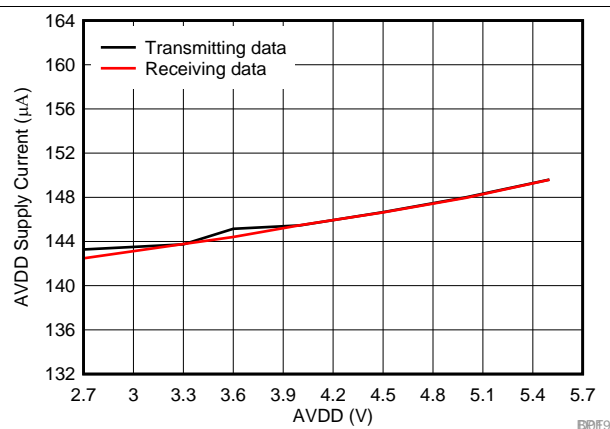


Figure 19. FF / PA Mode AVDD Supply Current versus Voltage with Internal Reference

Typical Characteristics (continued)

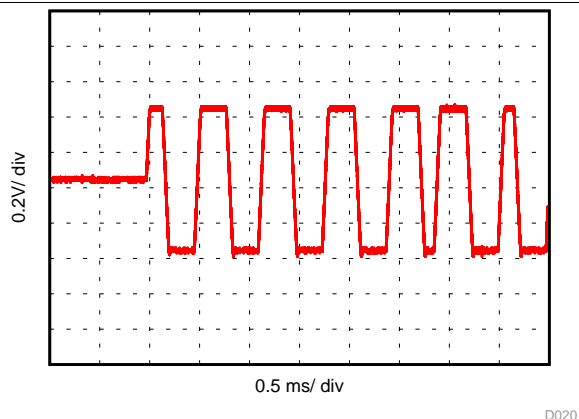


Figure 20. Typical Manchester Encoded Trapezoid, No Filter

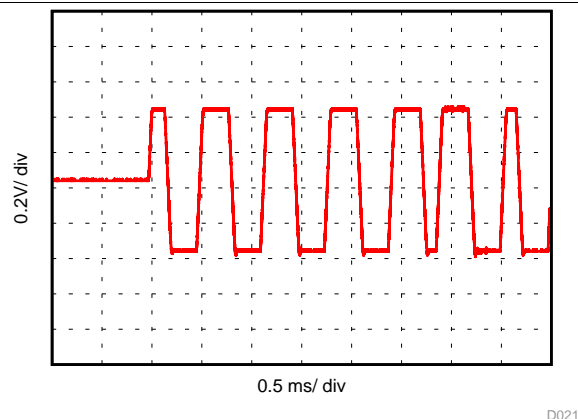


Figure 21. Typical Manchester Encoded Trapezoid, with Suggested Filter Response

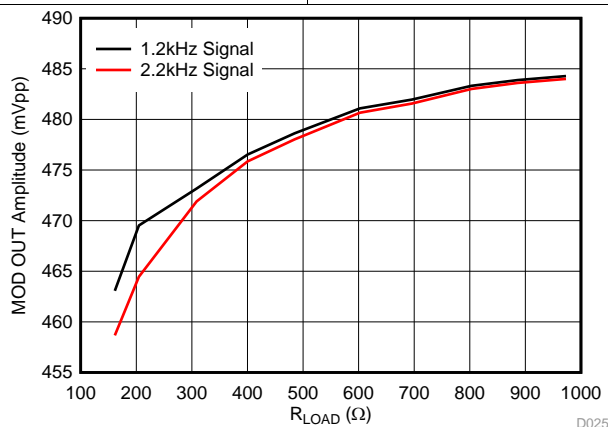


Figure 22. MOD_OUT Voltage versus R_LOAD

7 Detailed Description

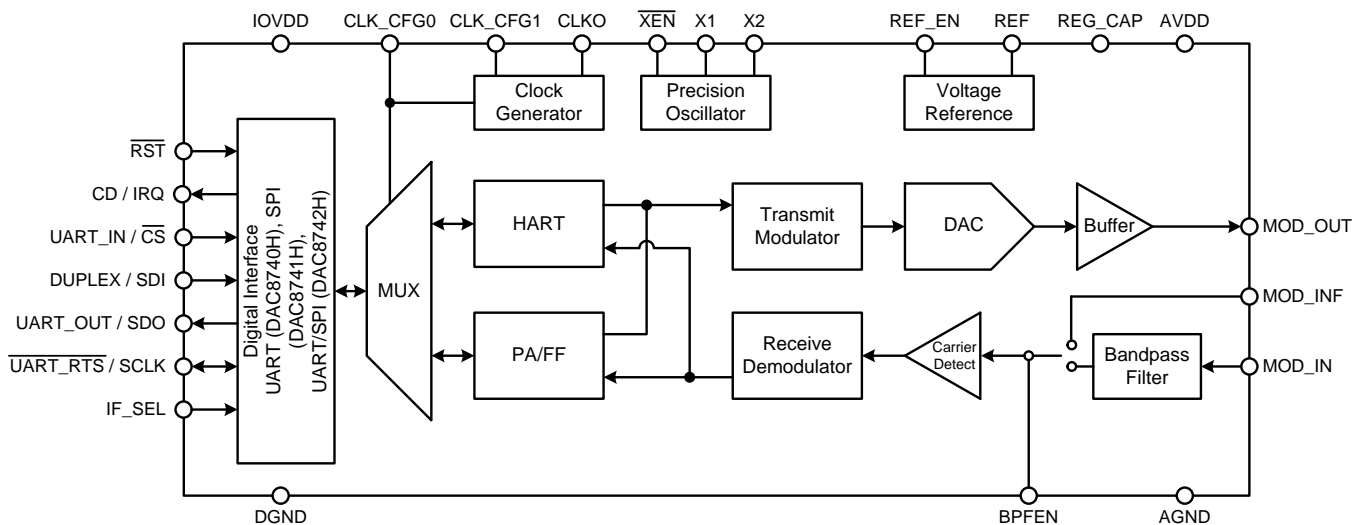
7.1 Overview

The DAC8742H is a HART® compliant and FOUNDATION Fieldbus® or PROFIBUS PA compatible low power modem designed for industrial process control and industrial automation applications.

In HART mode, the DAC8742H integrates all of the required circuitry to operate as half-duplex HART physical layer modems, in either slave or master configurations with minimal external components for filtering. In FOUNDATION Fieldbus mode, the DAC8742H integrate all of the required circuitry to operate as half-duplex FOUNDATION Fieldbus compliant H1 Controllers & MAUs.

The HART, FOUNDATION Fieldbus, or PROFIBUS PA, data stream can be transferred from the microcontroller through either a UART interface or an integrated FIFO accessed by a SPI interface. The SPI interface includes an SDO pin for daisy-chain support, various interrupts, and other extended features.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 HART Modulator

In SPI mode, HART data is loaded into a transmit FIFO via the SPI serial interface. In UART mode, the UART BAUD rate matches the HART BAUD rate and therefore the FIFO is bypassed. In both cases the input data is translated into the mark and space, 1200 Hz and 2200 Hz respectively, frequency shift keyed (FSK) analog signals used in HART communication through an internal HART modulator.

The HART modulator implements a look-up table containing 32 6-bit signed values which represent a single phase continuous sinusoidal cycle. A counter is implemented that incrementally loads the table values to a Digital-to-Analog Converter (DAC), at a clock frequency determined by the binary value of the input data, in order to create the mark and space analog output signals used to represent HART data.

The modem operates in half-duplex mode, unless placed in full-duplex mode, where the modulator and demodulator are not active simultaneously. The modem arbitrates over which component is active. To request that the modulator is activated UART devices toggle the RTS pin low, SPI devices toggle the RTS bit in the MODEM CONTROL register. These mechanics are explained in more detail in the respective sections of [Device Functional Modes](#).

In HART mode the MOD_OUT pin requires parallel capacitance of 5-22 nF or 0-100 pF in FOUNDATION Fieldbus and PROFIBUS PA mode for stability.

Feature Description (continued)

7.3.2 HART Demodulator

The HART demodulator converts the HART FSK input signals applied at the MOD_IN or MOD_INF pins, depending on whether an external filter is implemented, to binary data that is loaded into a receive FIFO in SPI mode. Data in the receive FIFO can then be read by the host controller via SPI serial interface. In UART mode received data is directly fed through to the UART interface.

When a valid carrier is detected on devices using the UART interfaces, the CD pin will toggle high. For devices using the SPI interface, the IRQ pin will toggle indicating an alarm condition. The MODEM STATUS register can then be read to determine the source of the interrupt, which includes a bit for carrier detection in DB1. Hysteresis is implemented with the carrier detect feature in order to prevent erroneous carrier detection signals. More details are explained in the respective [Device Functional Modes](#) sections.

7.3.3 FOUNDATION FIELDBUS / PROFIBUS PA Manchester Encoder

FOUNDATION FIELDBUS or PROFIBUS PA data is loaded into a transmit FIFO via UART or SPI interfaces which is translated into the Manchester encoded binary analog signals used in both FOUNDATION FIELDBUS and PROFIBUS PA bus protocols through an internal Manchester encoder.

The Manchester encoder interacts with the DAC to transmit positive and negative amplitude signals, with respect to a positive common mode voltage, to create the Manchester encoded analog outputs at 31.25kHz BAUD. A binary 0 is represented by a low-to-high transition and a binary 1 is represented by a high-to-low transition.

In both UART and SPI interfaced device, the encoder is activated any time there is data available in the transmit FIFO and the decoder is not receiving data. In order to prevent FIFO buffer overflow, for UART mode the CD pin acts as an interrupt to indicate when the FIFO level has exceed a programmed threshold in the packet initiation code. In SPI mode the transmit FIFO threshold programmed in the FIFO LEVEL SET register can trigger an interrupt on the IRQ pin. Once the IRQ interrupts is triggered, the MODEM STATUS register can then be read to determine the source of the interrupt, which includes a bit for the FIFO level in DB4. More details are explained in the respective [Device Functional Modes](#) sections.

7.3.4 FOUNDATION FIELDBUS / PROFIBUS PA Manchester Decoder

The FOUNDATION FIELDBUS and PROFIBUS PA decoder converts the Manchester encoded data applied at the MOD_IN or MOD_INF pins, depending on whether an external filter is implemented, to binary data that is loaded into a receive FIFO. Data in the receive FIFO can then be read by the host controller via UART or SPI serial interfaces.

When valid data is provided to the decoder, binary data is read out serially on the UART interface. For SPI devices, the receive FIFO is loaded until the threshold programmed in FIFO LEVEL SET is met which will trigger an interrupt on the IRQ pin. The MODEM STATUS register can then be read to determine the source of the interrupt, which includes a bit for the FIFO level in DB7, indicating that data is ready to be read on the SPI bus. More details are explained in the respective [Device Functional Modes](#) sections.

7.3.5 Internal Reference

An internal reference is included in the DAC8742H. The REF_EN pin is used to enable or disable the internal reference, when the internal reference is disabled an external reference must be provided at the REF pin. In SPI mode, the $\overline{\text{PDVREF}}$ bit in the CONTROL register can be used to enable or disable the internal reference via software. If the REF_EN pin is set high, the register contents of the $\overline{\text{PDVREF}}$ bit is ignored.

| INTERFACE | $\overline{\text{PDVREF}}$ | REF_EN | REFERENCE MODE |
|-----------|----------------------------|--------|--------------------|
| UART | 1 (Default) | 0 | External Reference |
| UART | 1 (Default) | 1 | Internal Reference |
| SPI | 1 (Default) | 1 | Internal Reference |
| SPI | 0 | 1 | Internal Reference |
| SPI | 1 (Default) | 0 | External Reference |
| SPI | 0 | 0 | External Reference |

7.3.6 Clock Configuration

All of the devices in the DAC8742H family support a variety of clocking options in order to provide system flexibility and reduce overall current consumption in HART applications. The clocking options include: an internal oscillator (HART mode only), an external crystal oscillator, or an external CMOS clock. The selection of the clocking scheme is controlled by the XEN, CLK_CFG1, and CLK_CFG0 pins as described in the table below.

The internal oscillator takes approximately 50 ms to start oscillating from when it is enabled. During this time period the device is unable to perform modulation or demodulation activities.

Table 1. Clock Configuration Table

| XEN | CLK_CFG1 | CLK_CFG0 | CLKO | DESCRIPTION | MODE |
|-----|----------|----------|------------------|--|--|
| 1 | 0 | 0 | No Output | 3.6864MHz CMOS clock connected at XTAL1 | HART |
| 1 | 0 | 1 | No Output | 1.2288MHz CMOS clock connected at XTAL1 | |
| 1 | 1 | 0 | No Output | Internal oscillator enabled | |
| 1 | 1 | 1 | 1.2288MHz Output | Internal oscillator enabled, CLKO enabled | |
| 0 | 0 | 0 | No Output | Crystal oscillator enabled | |
| 0 | 0 | 1 | 3.6864MHz Output | 3.6864MHz crystal oscillator, CLKO enabled | |
| 0 | 1 | 0 | 1.8432MHz Output | 3.6864MHz crystal oscillator, CLKO enabled | |
| 0 | 1 | 1 | 1.2288MHz Output | 3.6864MHz crystal oscillator, CLKO enabled | |
| 1 | 0 | 0.5 | No Output | 4MHz CMOS clock connected at XTAL1 | FOUNDATION FIELD BUS & PROFIBUS PA |
| 1 | 1 | 0.5 | No Output | 2MHz CMOS clock connected at XTAL1 | |
| 0 | 0 | 0.5 | No Output | 4MHz crystal oscillator | |
| 0 | 1 | 0.5 | 4MHz Output | 4MHz crystal oscillator, CLKO enabled | |

7.3.7 Reset and Power-Down

The $\overline{\text{RST}}$ pin functions as both a hardware reset and a power-down. When the pin is brought low a reset is issued, restoring all device components to their default state. While the pin is kept low, the device is in a power-down state where the internal reference is disabled, the modulator and demodulator or encoder and decoder are disabled, serial data output lines are high-impedance, MOD_OUT impedance is set to 70 k Ω , and the clock output is disabled. If an external crystal oscillator is used, the crystal oscillator circuit remains active to reduce start-up time when exiting the power-down state. Clock configuration pins remain active in power-down allowing the crystal oscillator to be disabled if desired.

7.3.8 Full-Duplex Mode

In full-duplex mode the modulator and demodulator (HART mode) or encoder and decoder (FOUNDATION FIELD BUS or PROFIBUS PA mode) are simultaneously enabled. This allows a self-test feature to verify functionality of the transmit and receive signal chains to improve system diagnostics.

7.3.9 I/O Selection

The DAC8742H implements both SPI and UART interfaces. Only one interface is active at a time for the DAC8742H. The interface mode is selected by the IF_SEL pin: a logic high on this pin sets the device to SPI mode and a logic low sets the device to UART mode. An internal pull-down resistor is included to ensure power-up in a known state, by default the pull-down sets the interface to UART mode. If changing I/O modes after power-up, a reset command should be issued on $\overline{\text{RST}}$.

7.3.10 Jabber Inhibitor

The DAC8742H implements a Jabber Inhibitor feature in FOUNDATION FIELDBUS or PROFIBUS PA modes which prevents the encoder from continuously transmitting data on the bus for longer than a programmed threshold controlled by the UART or SPI interface. In SPI mode this threshold is programmed by the PAFF_JABBER register, in UART mode this threshold is programmed by the four byte initialization sequence before each transmission. This is described in further detail in the Device Functional Modes and Register Map sections.

7.4 Device Functional Modes

7.4.1 UART Interfaced HART

When interfacing the HART modem via the UART interface, the device can be thought of as a simple UART-to-HART or HART-to-UART direct feedthrough converter. The UART data is transmitted and received at 1200 BAUD, which is matched to the HART FSK input and output signals.

The HART communication protocol is a half-duplex protocol which means that either the modulator or demodulator is active, and never simultaneously enabled. The device arbitrates over which component of the modem is active at all times based on activity on the HART bus. Bus activity is interfaced to the host controller through the CD and $\overline{\text{RTS}}$ pins.

By default when $\overline{\text{RTS}}$ is high the demodulator is active and the modulator is inactive. When a valid carrier is detected and data is being received by the modem, the CD pin is toggled high and binary UART data is provided at the output. If a request to send is issued by toggling the RTS pin low while CD is high, the demodulator remains at priority and any data provided at the UART input is ignored. When CD is low no valid carrier is present and when $\overline{\text{RTS}}$ is brought low the modulator is activated and UART input data is latched into the modulator and placed onto the HART bus.

7.4.2 UART Interfaced FOUNDATION FIELDBUS / PROFIBUS PA

FOUNDATION FIELDBUS and PROFIBUS PA are half-duplex communication protocols where only the encoder or decoder are active at any time and the DAC8742H arbitrates over which path is active. When interfacing the FOUNDATION FIELDBUS or PROFIBUS PA modem via the UART interface, data placed in the transmit FIFO is automatically placed on the FF/PA bus until the FIFO is empty any time the device is not receiving data, assuming correct data format.

When receiving data the decoder will expect a preamble byte(s) and a start delimiter byte. These bytes, as well as the stop byte, will be stripped from the UART communication and only the first data byte will be transmitted to start the data packet. The host controller must use a timer to detect the end of the packet. Each byte transmitted on the UART will be at 57.6 kHz BAUD and byte spacing of 256 us. If a new byte has not been started within 512 us it can be assumed that the incoming packet has ended.

The device expects to see a four byte sequence to initiate transmission: 0xEA followed by 0x80-0x9F, where bits 4:3 of the second byte configure an interrupt threshold for the transmit FIFO level and bits 2:0 set the number of preamble bytes to be transmitted. The third byte contains the information to configure the Jabber Inhibitor followed by the final byte of 0xAE. To send inverted Manchester encoded data the first byte, 0xEA, is inverted to 0x15 and the first three bits of the second byte are inverted such that the range of values for the second byte are from 0x60-0x7F. The functionality of bits 4:3 and 2:0 and the Jabber Inhibitor byte remain the same and the final byte is inverted to 0x51. The details concerning this four byte sequence are explained in the tables below.

| Mode | B3 | | | | | | | | B2 | | | | | | | |
|--------------|-------|---|---|---|---|---|---|---|----|----|----|-----------|----|-----------|----|----|
| | D7:D0 | | | | | | | | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
| Non-inverted | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | D2M_LEVEL | | PRE_BYTES | | |
| Inverted | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | D2M_LEVEL | | PRE_BYTES | | |

| Mode | B1 | B0 | | | | | | | |
|--------------|----------------|----|----|----|----|----|----|----|----|
| | D7:D0 | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
| Non-inverted | JABBER_TIMEOUT | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 |
| Inverted | JABBER_TIMEOUT | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |

| CONTROL BITS | DESCRIPTION | | |
|--------------|---|---|---|
| D2M_LEVEL | 0 | 0 | Alarm on UART_RTS when transmit FIFO has less than 2 bytes loaded |
| | 0 | 1 | Alarm on UART_RTS when transmit FIFO has less than 4 bytes loaded |
| | 1 | 0 | Alarm on UART_RTS when transmit FIFO has less than 6 bytes loaded |
| | 1 | 1 | Alarm on UART_RTS when transmit FIFO has less than 8 bytes loaded |
| PRE_BYTES | Number of preamble bytes is equivalent to the straight binary decimal value in this register plus one | | |

The JABBER_TIMEOUT bits control the timeout period for the Jabber Inhibitor. If a value of 0x0 is programmed the Jabber Inhibitor is disabled. Otherwise the timer will be programmed in 2.048ms increments such that the timeout can be calculated as shown below. If the Jabber Inhibitor triggers the CD pin will be taken high. The CD pin will be returned to logic low when the silence period of 3 seconds has ended.

$$\text{TimeOut} = \text{JABBER_TIMEOUT} \times 2.048\text{ms} \quad (1)$$

The encoder will begin transmitting data once the following conditions are met: a valid four-byte transmission initiation sequence has been sent to the device, the FIFO is not empty, and the device is not receiving data. Transmission will begin by sending the preamble byte(s) followed by a start delimiter. Then, the encoder will begin to remove data from the FIFO – this creates at least a five-byte lag of the encoder with respect to the UART.

During transmission of a packet the UART must take care to ensure that the FIFO does not become empty before the packet is complete. The encoder transmits at a BAUD rate of 31.25 kHz or 256 μs per byte in the FIFO so the UART must keep up with this rate. The four-byte sequence that initiates a transmission includes setting a transmit FIFO threshold in bits 4:3. When the FIFO level is less than or equal to this threshold the UART_RTS pin will be taken high, this can be leveraged to ensure the FIFO is not prematurely empty. Once the FIFO is empty a stop delimiter is placed on the bus. Once the FIFO is empty a new packet can be initiated with a new four-byte transmission initiation sequence.

The device expects UART BAUD rate of 57.6 kHz. This BAUD rate is faster than the 31.25 kHz BAUD rate specified by FOUNDATION FIELDBUS and PROFIBUS PA, therefore FIFO overflow is possible. In order to prevent FIFO overflow, the UART_RTS pin FIFO threshold alarm can be leveraged by never adding more data to the FIFO than it can contain based on the programmed alarm threshold.

7.4.3 SPI Interfaced HART

When interfacing the HART modem via the SPI interface, the device utilizes transmit and receive FIFOs that are 9-bits wide and 16 locations deep to buffer all HART data.

The HART communication protocol is half-duplex protocol which means that either the modulator or demodulator is active, and never simultaneously enabled. The device arbitrates over which component of the modem is active at all times based on activity on the HART bus. Bus activity is interfaced to the host controller through the IRQ pin and MODEM STATUS register.

By default the demodulator is active and the modulator is inactive. When a valid carrier is detected and data is being received by the modem, the CD bit (bit 1) in the MODEM STATUS register is set high. If the CD bit (bit 1) in the MODEM IRQ MASK register is set to 0, this will also cause the IRQ pin to toggle as programmed in the status CONTROL register. The IRQ pin may be programmed to be edge sensitive or level sensitive, the polarity of the signal is also programmable. When the IRQ pin toggles, the MODEM STATUS register should be read to determine the source of the interrupt. Receive data can be read from the RECEIVE FIFO by issuing an SPI read command.

Alternatively, the CD pin can be ignored by setting the CD bit (bit 1) in the MODEM IRQ MASK register to a 1. In this mode the IRQ pin will not toggle when the CD bit in the MODEM STATUS register is a 1. Instead, a RECEIVE FIFO read event can be triggered by the RECEIVE FIFO level threshold. This is achieved by programming the FIFO LEVEL SET register (bits 7:4) to the desired threshold value from 1-15, if a full FIFO (level 16 threshold) is desired the M2D FIFO FULL alarm can be used instead. If the M2D FIFO LEVEL bit (bit 7) in the MODEM IRQ MASK register is set to 0, the IRQ pin will toggle and the MODEM STATUS register should be read to determine the source of the interrupt. Receive data can then be read from the RECEIVE FIFO by issuing an SPI read command.

If data is placed in the transmit FIFO while the demodulator is active and the CD bit is high, the data remains in the FIFO until the modulator is activated. To request that the modulator is activated and the demodulator is deactivated the RTS bit (bit 0) in the MODEM CONTROL register should be set high. When the modulator is activated and the demodulator is deactivated the clear to send, or CTS, bit (bit 0) in the MODEM STATUS register is set high. If the CTS bit (bit 0) in the MODEM IRQ MASK register is set to a 0 this will cause the IRQ pin to toggle, indicating that transmit FIFO data will begin to be placed on the bus.

The level of the transmit FIFO may be monitored in order to avoid buffer overflow. This can be done either by watching for a buffer full or buffer threshold event. To monitor by a FIFO level threshold the FIFO LEVEL SET register (bits 3:0) can be programmed to the desired threshold value from 1-15. If the D2M FIFO LEVEL bit (bit 4) in the MODEM IRQ MASK register is set to a 0, this will cause the IRQ pin to toggle. Similarly an alarm can be triggered based on the D2M FIFO FULL bit in the MODEM STATUS register.

7.4.4 SPI Interfaced FOUNDATION FIELDBUS / PROFIBUS PA

FOUNDATION FIELDBUS and PROFIBUS PA are half-duplex communication protocols where only the encoder or decoder are active at any time and the DAC8742H arbitrates over which path is active. When interfacing the FOUNDATION FIELDBUS or PROFIBUS PA encoder via SPI interface, data is placed in transmit and receive FIFOs that are each 16-bytes deep to buffer all data.

When receiving data the decoder will expect a preamble byte(s) and a start delimiter byte, followed by the data bytes for the packet, and concluded with a stop delimiter byte. All of these bytes are placed into the RECEIVE FIFO where bits 7:0 represent the data and bit 8 is used as a special bit to indicate the start of a packet, with data 0x014D, the end of a packet, with data 0x0126, or a half-bit slip, with data 0x0100. If a half-bit slip occurs it is recommended to discard the packet. A timer is not necessary to detect the end of receiving a packet in SPI mode because the stop delimiter is included in the RECEIVE FIFO data.

In order to prevent RECEIVE FIFO overflow, alarms are available to watch a threshold of the FIFO or when the FIFO is full. If the FIFO is full it is possible for data to be lost. This is achieved by programming the FIFO LEVEL SET register (bits 7:4) to the desired threshold value from 1-15, if a full FIFO (level 16 threshold) is desired the M2D FIFO FULL alarm can be used instead. If the M2D FIFO LEVEL bit (bit 7) in the MODEM IRQ MASK register is set to 0, the IRQ pin will toggle and the MODEM STATUS register should be read to determine the source of the interrupt. Receive data can then be read from the RECEIVE FIFO by issuing an SPI read command.

The encoder will begin to send data by sending the preamble byte(s) followed by a start delimiter when the TRANSMIT FIFO is not empty and the device is not receiving data. The number of preamble bytes used in the packet is controlled by the PAFF PREAMBLE bits (bits 14:12) in the MODEM CONTROL REGISTER. The polarity of the Manchester encoded data can also be programmed by the PAFF POLARITY bit (bit 15) in the MODEM CONTROL REGISTER. After transmitting the preamble byte(s) and start delimiter the encoder will begin taking data from the TRANSMIT FIFO.

During transmission the SPI controller must take care to ensure that the TRANSMIT FIFO does not become empty before the packet is complete. When the TRANSMIT FIFO is empty a stop delimiter is placed on the bus.

The level of the transmit FIFO may be monitored in order to avoid buffer overflow. This can be done either by watching for a buffer full or buffer threshold event. To monitor by a FIFO level threshold the FIFO LEVEL SET register (bits 3:0) can be programmed to the desired threshold value from 1-15. If the D2M FIFO LEVEL bit (bit 4) in the MODEM IRQ MASK register is set to a 0, this will cause the IRQ pin to toggle. Similarly an alarm can be triggered based on the D2M FIFO FULL bit in the MODEM STATUS register.

The Jabber Inhibitor threshold can be programmed by the PAFF_JABBER register (address 0x27). The 8-bit value programmed in this register can be used to calculate the threshold using the equation below. When the timeout triggers the JAB_ON bit in the STATUS register will be taken high and transmission will be blocked for the 3 second timeout period. The JAB_OFF bit will go high when the timeout period has expired. Both JAB_ON and JAB_OFF bits trigger an IRQ event, meaning the IRQ pin will be triggered for both events.

$$\text{TimeOut} = \text{JABBER_TIMEOUT} \times 2.048\text{ms} \quad (2)$$

7.4.5 Interface

7.4.5.1 UART

The behavior of the UART interface changes based on whether the device is operating in HART mode or in FOUNDATION FIELDBUS and PROFIBUS PA mode.

In HART mode, the device expects 1 start bit, 8 data bits, 1 odd parity bit, and 1 stop bit or an 8O1 UART character format. The transmit path of the device acts as a direct feedthrough of the UART input to the HART FSK output, therefore the UART BAUD rate from the host controller must be 1200Hz \pm 1% as required by the HART standard. The receive path of the device will also operate at 1200Hz \pm 1%.

In FOUNDATION FIELDBUS and PROFIBUS PA mode the UART interface expects 1 start bit, 8 data bits, no parity bit, and 1 stop bit or an 8N1 UART character format. In this mode the UART interfaces transmit and receive FIFOs so the BAUD rate is not required to match the 31.25 kHz BAUD used by FOUNDATION FIELDBUS and PROFIBUS PA. In this mode the expected transmit and receive UART BAUD is 57.6 Hz \pm 2.5%.

7.4.5.1.1 UART Carrier Detect

The behavior of the carrier detect or CD pin changes depending on whether the device is in HART mode or FOUNDATION FIELDBUS and PROFIBUS PA mode.

In HART mode the pin operates as a carrier detect pin. When a valid carrier is detected and the modem is receiving data the CD pin is taken high. When the CD pin is high, UART data sent to the device and the request to send, or RTS, pin will be ignored until the carrier is no longer present.

In FOUNDATION FIELDBUS and PROFIBUS PA the CD pin operates as a carrier detect pin when not in transmit mode. When the CD pin is high, UART data sent to the device will be ignored until the carrier is no longer present. When in transmit mode the CD pin functions as an alarm indicator that the jabber inhibitor has triggered and further UART transmission data will be ignored. In general if the CD pin is high the host controller should not be sending transmit data to the device.

7.4.5.2 SPI

The SPI interface can operate on SCLK speeds up to 12.5 MHz, but the frame-rate must be greater than 2442 ns in HART mode and 3000 ns in FOUNDATION FIELDBUS and PROFIBUS PA mode. Frames must contain at least 24-bits without CRC enabled and 32-bits with CRC enabled. The data within the frame is right justified, meaning that upon the rising edge of CS the right-most, or last, 24-bits or 32-bits will be evaluated as the input data word. Two modes of SPI are supported by the interface: clock polarity 0 and clock phase 1 or clock polarity 1 and clock phase 0.

The SDO pin will output data on the rising edge of SCLK or the falling edge of CS. SDO will always provide information from the previous frame, if the previous frame was a read then the output data will be the requested data. If the previous write was a command or register write, that data will be repeated. This allows a method for the user to verify what was written to the device. If CRC is enabled and write data is being repeated on SDO, the CRC provided during the previous frame will be output – not a newly calculated CRC.

The SPI frame structure is shown in the figure below. The frame includes a read/write bit, followed by a 7-bit address, then 16-bit write data for a write frame or don't care bits for a read frame. If CRC is enabled, an additional 8-bits are placed at the end of the frame containing the CRC word.

| R/W FRAME | D23 | D22:16 | D15:0 |
|-------------|-----|---------------|------------|
| Write Frame | 0 | 7-Bit Address | Write Data |
| Read Frame | 1 | 7-Bit Address | X |

7.4.5.2.1 SPI Cyclic Redundancy Check

The SPI interface includes an optional CRC mode to enhance the reliability of the interface by blocking erroneous commands sent to the device due to noise or other errors sources. When writing to or reading from the device the last 8-bits in the frame contain the CRC word which is calculated based on the polynomial x^8+x^2+x+1 . If a bad CRC word is included in a write-frame to the device, the frame will be ignored. When reading from the device, the host controller should check the CRC word to validate the frame.

Read commands with a bad CRC value will output 0x80000000 and, in the case of a receive FIFO read, prevent data from leaving the FIFO and subsequently being lost.

7.4.5.2.2 SPI Interrupt Request

SPI interfaced devices include an interrupt request, or IRQ, pin to communicate the occurrence of a variety of events to the host controller. The behavior of the IRQ pin is controlled by the CONTROL register and MODEM IRQ MASK register.

The CONTROL register allows the host controller to configure the IRQ pin as level sensitive or edge sensitive via the IRQ LEVEL bit (bit 2). For both level sensitive and edge sensitive modes, the polarity of the IRQ pin can be set via the IRQ POLARITY bit (bit 3) in the CONTROL register.

The MODEM IRQ MASK register allows the controller to decide which events are able to trigger the IRQ pin to toggle. If a logic 0 is written to the respective bit, that event is allowed to toggle the IRQ pin. If a logic 1 is written to the respective bit, the event is masked from the IRQ pin.

When an event occurs the IRQ pin signal, in the case of level-sensitive configurations, is latched and the IRQ pin voltage stays at logic high until the status has been reset, or cleared, by reading the contents of the MODEM_STATUS register. In the case of edge-sensitive configurations a pulse is generated any time a new event is detected.

7.5 Register Maps

[Table 2](#) lists the memory-mapped registers for the DAC8742H. All register offset addresses not listed in [Table 2](#) should be considered as reserved locations and the register contents should not be modified.

Table 2. DAC8742H Registers

| Offset | Acronym | Register Name | Section |
|--------|----------------|-------------------------|--------------------|
| 2h | CONTROL | CONTROL Register | Go |
| 7h | RESET | RESET Register | Go |
| 20h | MODEM_STATUS | MODEM STATUS Register | Go |
| 21h | MODEM_IRQ_MASK | MODEM IRQ MASK Register | Go |
| 22h | MODEM_CONTROL | MODEM CONTROL Register | Go |
| 23h | FIFO_D2M | FIFO D2M Register | Go |
| 24h | FIFO_M2D | FIFO M2D Register | Go |
| 25h | FIFO_LEVEL_SET | FIFO LEVEL SET Register | Go |
| 27h | PAFF_JABBER | PAFF JABBER Register | Go |

Complex bit access types are encoded to fit into small table cells. [Table 3](#) shows the codes that are used for access types in this section.

Table 3. DAC8742H Access Type Codes

| Access Type | Code | Description |
|-------------------------------|------|--|
| Read Type | | |
| R | R | Read |
| Write Type | | |
| W | W | Write |
| Reset or Default Value | | |
| -n | | Value after reset or the default value |

7.5.1 CONTROL Register (Offset = 2h) [reset = 0x8042]

This register controls the SPI watch-dog timer, internal reference, CRC mode, IRQ pin behavior, and SDO pin behavior.

CONTROL is shown in [Figure 23](#) and described in [Table 4](#).

Return to [Summary Table](#).

Figure 23. CONTROL Register

| | | | | | | | |
|----------|--------|----------|--------|----------|-----------|-------|-------|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| WDTO | | | WDT | RESERVED | | | |
| R/W | | | R/W | R | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| RESERVED | PDVREF | RESERVED | CRC_EN | IRQ_POL | IRQ_LEVEL | SDO_Z | SDO_B |
| R | R/W | R | R/W | R/W | R/W | R/W | R/W |

Table 4. CONTROL Register Field Descriptions

| Bit | Field | Type | Reset | Description | | | |
|-------|-----------|------|-----------|---|-----|-----|---------------------|
| 15-13 | WDTO | R/W | 100 | SPI Watch-dog Timer (based on 3.6864MHz Clock) | | | |
| | | | | D15 | D14 | D13 | Timeout Period |
| | | | | 0 | 0 | 0 | 50 ms |
| | | | | 0 | 0 | 1 | 100 ms |
| | | | | 0 | 1 | 0 | 500 ms |
| | | | | 0 | 1 | 1 | 1 second |
| | | | | 1 | 0 | 0 | 2 seconds (default) |
| | | | | 1 | 0 | 1 | 3 seconds |
| | | | | 1 | 1 | 0 | 4 seconds |
| 1 | 1 | 1 | 5 seconds | | | | |
| 12 | WDT | R/W | 0 | 0 = SPI Watch-dog Timer Disabled (default) 1 = SPI Watch-dog Timer Enabled | | | |
| 11-7 | RESERVED | R | 00000 | Reserved | | | |
| 6 | PDVREF | R/W | 1 | This bit is only functional if the hardware reference enabled is enabled. 0 = Internal reference is powered down 1 = Internal reference is powered up (default) | | | |
| 5 | RESERVED | R | 0 | Reserved | | | |
| 4 | CRC_EN | R/W | 0 | 0 = No CRC (default) 1 = CRC is enabled | | | |
| 3 | IRQ_POL | R/W | 0 | 0 = IRQ is active low (default) 1 = IRQ is active high | | | |
| 2 | IRQ_LEVEL | R/W | 0 | 0 = IRQ creates a pulse for edge sensitivity (default) 1 = IRQ asserts to a level until MODEM STATUS is read | | | |
| 1 | SDO_Z | R/W | 1 | 0 = SDO will be driven during writes and read requests 1 = SDO will be HiZ during writes requests (default) | | | |
| 0 | SDO_B | R/W | 0 | 0 = SDO will remain filled from last frame (default) 1 = SDO will clear with the beginning of each frame | | | |

7.5.2 RESET Register (Offset = 7h) [reset = 0x0000]

Writing 0x0001 to this register will reset all registers to their default values and the FIFOs will be emptied.

RESET is shown in [Figure 24](#) and described in [Table 5](#).

Return to [Summary Table](#).

Figure 24. RESET Register

| | | | | | | | |
|----------|----|----|----|----|----|---|-----|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| RESERVED | | | | | | | |
| R | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| RESERVED | | | | | | | RST |
| R | | | | | | | R/W |

Table 5. RESET Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|----------|------|--------------------|--|
| 15-1 | RESERVED | R/W | 00000000 000000 | Reserved |
| 0 | RST | W | 0 | Writing a 1 to this bit triggers a software reset. |

7.5.3 MODEM_STATUS Register (Offset = 20h) [reset = 0x0000]

The modem status register is a read/write register. When an event occurs, the corresponding bit to indicate that event is set to a logic 1 in this register. The status bits are sticky, meaning they are not cleared unless a 1 is written to the corresponding bit position, except for carrier detect, or CD, which responds based on the presences of a carrier, the FIFO level registers, which respond based on the conditions of the FIFOs, and JAB_OFF and JAB_ON which represent the current status of the jabber inhibitor. CTS will assert after RTS is set and no carrier is present if not operating in full-duplex mode.

MODEM_STATUS is shown in [Figure 25](#) and described in [Table 6](#).

Return to [Summary Table](#).

Figure 25. MODEM_STATUS Register

| | | | | | | | |
|----------------|---------------|----------------|----------------|---------------|----------------|-----|-----|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| RST | JAB_OFF | JAB_ON | GAP | FRAME | PARITY | WDT | CRC |
| R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| FIFO_M2D LEVEL | FIFO_M2D FULL | FIFO_M2D EMPTY | FIFO_D2M LEVEL | FIFO_D2M FULL | FIFO_D2M EMPTY | CD | CTS |
| R/W | R/W | R/W | R/W | R/W | R/W | R | R |

Table 6. MODEM_STATUS Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|----------------|------|-------|---|
| 15 | RST | R/W | 0 | A reset has occurred |
| 14 | JAB_OFF | R/W | 0 | This bit goes high when the jabber inhibitor timeout period has expired |
| 13 | JAB_ON | R/W | 0 | This bit goes high when the jabber inhibitor has been triggered |
| 12 | GAP | R/W | 0 | A gap error in HART mode |
| 11 | FRAME | R/W | 0 | A frame error in HART mode or a 1/2 bit slip in FF/PA mode |
| 10 | PARITY | R/W | 0 | A Parity error in HART mode |
| 9 | WDT | R/W | 0 | The watch-dog timer has expired |
| 8 | CRC | R/W | 0 | An incorrect CRC word was provided in a read or write command |
| 7 | FIFO_M2D_LEVEL | R/W | 0 | The receive FIFO is at the programmed level |
| 6 | FIFO_M2D_FULL | R/W | 0 | The receive FIFO is full |
| 5 | FIFO_M2D_EMPTY | R/W | 0 | The receive FIFO is empty |

Table 6. MODEM_STATUS Register Field Descriptions (continued)

| Bit | Field | Type | Reset | Description |
|-----|----------------|------|-------|---|
| 4 | FIFO_D2M_LEVEL | R/W | 0 | The transmit FIFO is at the programmed level |
| 3 | FIFO_D2M_FULL | R/W | 0 | The transmit FIFO is full |
| 2 | FIFO_D2M_EMPTY | R/W | 0 | The transmit FIFO is empty |
| 1 | CD | R | 0 | In HART mode, a valid carrier has been detected |
| 0 | CTS | R | 0 | In HART mode, the modem is cleared to send data and the modulator is active |

7.5.4 MODEM_IRQ_MASK Register (Offset = 21h) [reset = 0x0024]

This register controls which MODEM STATUS events are allowed to trigger an interrupt on the IRQ pin. A 0 in the respective bit position allows the interrupt event to toggle the IRQ pin. A 1 in the respective bit position blocks the interrupt event from toggling the IRQ pin, but the event can still be detected by reading the MODEM STATUS register.

MODEM_IRQ_MASK is shown in [Figure 26](#) and described in [Table 7](#).

Return to [Summary Table](#).

Figure 26. MODEM_IRQ_MASK Register

| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
|----------------|---------------|----------------|----------------|---------------|----------------|-----|-----|
| RESERVED | JAB_OFF | JAB_ON | GAP | FRAME | PARITY | WDT | CRC |
| R | R/W | R/W | R/W | R/W | R/W | R/W | R/W |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| FIFO_M2D LEVEL | FIFO_M2D FULL | FIFO_M2D EMPTY | FIFO_D2M LEVEL | FIFO_D2M FULL | FIFO_D2M EMPTY | CD | CTS |
| R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W |

Table 7. MODEM_IRQ_MASK Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|----------------|------|-------|---|
| 15 | RESERVED | R/W | 0 | Reserved |
| 14 | JAB_OFF | R/W | 0 | Writing a 1 to this bit blocks the JAB_OFF event from triggering the IRQ pin |
| 13 | JAB_ON | R/W | 0 | Writing a 1 to this bit blocks the JAB_ON event from triggering the IRQ pin |
| 12 | GAP | R/W | 0 | Writing a 1 to this bit blocks the GAP event from triggering the IRQ pin |
| 11 | FRAME | R/W | 0 | Writing a 1 to this bit blocks the FRAME event from triggering the IRQ pin |
| 10 | PARITY | R/W | 0 | Writing a 1 to this bit blocks the PARITY event from triggering the IRQ pin |
| 9 | WDT | R/W | 0 | Writing a 1 to this bit blocks the WDT event from triggering the IRQ pin |
| 8 | CRC | R/W | 0 | Writing a 1 to this bit blocks the CRC event from triggering the IRQ pin |
| 7 | FIFO_M2D_LEVEL | R/W | 0 | Writing a 1 to this bit blocks the FIFO_M2D_LEVEL event from triggering the IRQ pin |
| 6 | FIFO_M2D_FULL | R/W | 0 | Writing a 1 to this bit blocks the FIFO_M2D_FULL event from triggering the IRQ pin |
| 5 | FIFO_M2D_EMPTY | R/W | 1 | Writing a 1 to this bit blocks the FIFO_M2D_EMPTY event from triggering the IRQ pin |
| 4 | FIFO_D2M_LEVEL | R/W | 0 | Writing a 1 to this bit blocks the FIFO_D2M_LEVEL event from triggering the IRQ pin |
| 3 | FIFO_D2M_FULL | R/W | 0 | Writing a 1 to this bit blocks the FIFO_D2M_FULL event from triggering the IRQ pin |
| 2 | FIFO_D2M_EMPTY | R/W | 1 | Writing a 1 to this bit blocks the FIFO_D2M_EMPTY event from triggering the IRQ pin |

Table 7. MODEM_IRQ_MASK Register Field Descriptions (continued)

| Bit | Field | Type | Reset | Description |
|-----|-------|------|-------|--|
| 1 | CD | R/W | 0 | Writing a 1 to this bit blocks the CD event from triggering the IRQ pin |
| 0 | CTS | R/W | 0 | Writing a 1 to this bit blocks the CTS event from triggering the IRQ pin |

7.5.5 MODEM_CONTROL Register (Offset = 22h) [reset = 0x0048]

This register controls various modem features including: FF/PA Manchester data polarity, number of FF/PA preamble bits, analog output amplitude, modem enable, duplex mode, and request to send.

MODEM_CONTROL is shown in [Figure 27](#) and described in [Table 8](#).

Return to [Summary Table](#).

Figure 27. MODEM_CONTROL Register

| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
|----------|---------------|--------|----------|--------|----------|--------|---|
| FFPA_POL | FFPA_PREAMBLE | | RESERVED | | | TX_AMP | |
| R/W | R/W | | R | | | R/W | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| TX_AMP | | MOD_EN | | DUP_EN | RESERVED | RTS | |
| R/W | | R/W | | R/W | R | R/W | |

Table 8. MODEM_CONTROL Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|---------------|------|-------|---|
| 15 | FFPA_POL | R/W | 0 | Sets the transmitted polarity of the Manchester encoded data 0 = Logical 1 is transmitted as a transition from high-to-low (default) 1 = Logical 1 is transmitted as a transition from low-to-high |
| 14-12 | FFPA_PREAMBLE | R/W | 0 | Number of preamble bytes sent is the value programmed in this register plus 1 |
| 11-9 | RESERVED | R | 0 | Reserved |
| 8-4 | TX_AMP | R/W | 00100 | Unsigned binary value that controls the amplitude (HART mode only) of the transmitted waveform in 25mVpp steps. Default value 00100 for 500mVpp output amplitude. Amplitude may vary from 400mVpp to 800mVpp. |
| 3 | MOD_EN | R/W | 1 | 0 = Disables TX/RX of the modem 1 = Enables TX/RX of the modem (default) |
| 2 | DUP_EN | R/W | 0 | 0 – TX FIFO is not connected to RX FIFO (default) 1 = Connects TX FIFO to RX FIFO |
| 1 | RESERVED | R | 0 | Reserved |
| 0 | RTS | R/W | 0 | 0 = No active request to send in HART mode (default) 1 = Active request to send in HART mode |

7.5.6 FIFO_D2M Register (Offset = 23h) [reset = 0x0200]

This register interfaces the FIFO that transmits data from the digital interface to the modem.

FIFO_D2M is shown in [Figure 28](#) and described in [Table 9](#).

Return to [Summary Table](#).

Figure 28. FIFO_D2M Register

| | | | | | | | |
|------------|----|----|----|------------|-----------|------------|------------|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| FIFO_LEVEL | | | | LEVEL_FLAG | FULL_FLAG | EMPTY_FLAG | PARITY_BIT |
| R | | | | R | R | R | W |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| DATA | | | | | | | |
| W | | | | | | | |

Table 9. FIFO_D2M Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|------------|------|-------|--|
| 15-12 | FIFO_LEVEL | R | 0 | Reads back the current level of the FIFO, read only |
| 11 | LEVEL_FLAG | R | 0 | Indicates the programmed level has been reached, read only |
| 10 | FULL_FLAG | R | 0 | Indicates the FIFO is full, read only |
| 9 | EMPTY_FLAG | R | 1 | Indicates the FIFO is empty, read only |
| 8 | PARITY_BIT | W | 0 | Odd parity for 8-bit data read on bus, write only |
| 7-0 | DATA | W | 0 | Data transmitted from the digital interface to the modem, write only |

7.5.7 FIFO_M2D Register (Offset = 24h) [reset = 0x0200]

This register interfaces the FIFO that receives data from the modem to the digital interface. This register is read only

FIFO_M2D is shown in [Figure 29](#) and described in [Table 10](#).

Return to [Summary Table](#).

Figure 29. FIFO_M2D Register

| | | | | | | | |
|------------|----|----|----|------------|-----------|------------|------------|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| FIFO_LEVEL | | | | LEVEL_FLAG | FULL_FLAG | EMPTY_FLAG | PARITY_BIT |
| R | | | | R | R | R | R |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| DATA | | | | | | | |
| R | | | | | | | |

Table 10. FIFO_M2D Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|------------|------|-------|---|
| 15-12 | FIFO_LEVEL | R | 0 | Reads back the current level of the FIFO, read only |
| 11 | LEVEL_FLAG | R | 0 | Indicates the programmed level has been reached, read only |
| 10 | FULL_FLAG | R | 0 | Indicates the FIFO is full, read only |
| 9 | EMPTY_FLAG | R | 1 | Indicates the FIFO is empty, read only |
| 8 | PARITY_BIT | R | 0 | Odd parity for 8-bit data read on bus, read only |
| 7-0 | DATA | R | 0 | Data transmitted from the modem to the digital interface, read only |

7.5.8 FIFO_LEVEL_SET Register (Offset = 25h) [reset = 0x0000]

This register programs the alarm threshold for both transmit and receive FIFOs. Each bit field allows for the FIFO alarm threshold to be programmed to integer values from 1-15.

FIFO_LEVEL_SET is shown in [Figure 30](#) and described in [Table 11](#).

Return to [Summary Table](#).

Figure 30. FIFO_LEVEL_SET Register

| | | | | | | | |
|-----------|----|----|----|-----------|----|---|---|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| RESERVED | | | | | | | |
| R | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| M2D_LEVEL | | | | D2M_LEVEL | | | |
| R/W | | | | R/W | | | |

Table 11. FIFO_LEVEL_SET Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-----------|------|----------|---|
| 15-8 | RESERVED | R | 00000000 | Reserved |
| 7-4 | M2D_LEVEL | R/W | 0000 | The binary value in this register sets the modulator FIFO alarm threshold |
| 3-0 | D2M_LEVEL | R/W | 0000 | The binary value in this register sets the demodulator FIFO alarm threshold |

7.5.9 PAFF_JABBER Register (Offset = 27h) [reset = 0x0000]

This register controls the jabber inhibitor time-out behavior. The time-out can be calculated using the equation below with PAFF_JABBER in decimal format.

PAFF_JABBER is shown in [Figure 31](#) and described in [Table 12](#).

Return to [Summary Table](#).

Figure 31. PAFF_JABBER Register

| | | | | | | | |
|-------------|----|----|----|----|----|---|---|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| RESERVED | | | | | | | |
| R | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| PAFF_JABBER | | | | | | | |
| R/W | | | | | | | |

Table 12. PAFF_JABBER Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-------------|------|----------|------------------------------------|
| 15-8 | RESERVED | R | 00000000 | Reserved |
| 7-0 | PAFF_JABBER | R/W | 00000000 | TimeOut = JABBER_TIMEOUT * 2.048ms |

8 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

The DAC8742H family of devices integrates modem functionality for several largely used Industrial protocols: Highway Addressable Remote Transducer (HART), FOUNDATION Fieldbus (FF), and PROFIBUS (PA). The different modes are set via the CLK_CFGx pins of the device that allow the device to either enter HART or PAFF mode. In HART mode, a 1200-/2200-Hz HART FSK Signal is modulated and demodulated, while the PAFF mode communicates via a 31.25 Kbit/s Manchester coded/encoded signal. The small package sizes, wide temperature range and low quiescent current make this device an ideal candidate for applications in Industrial Process Control and Automation.

8.1.1 Design Recommendations

Local power supply decoupling is recommended by placing 10- μ F capacitors on the IOVDD and AVDD supply lines, and 0.1- μ F capacitors close to the DAC8742H supply pins. Ceramic capacitor types such as C0G or X7R are recommended for its optimal performance across temperature, and very low dissipation factor. DC bias characteristics of the capacitors should also be considered when selecting passive components, such as the voltage rating and equivalent series resistance (ESR).

8.1.2 Selecting the Crystal/Resonator

Both communication modes, HART and PAFF, require different clocking frequencies for correct operation: HART – 1.2288 MHz or 3.686 MHz, PAFF – 4 MHz. In addition to selecting the communication mode, the CLK_CFGx and XEN pins also select whether an internal oscillator or external clock source is configured for device operation. The configuration table is explained in [Table 1](#). Accuracy over the applications temperature range should be considered when selecting the external crystal or resonator. Furthermore, crystals with a low drift specification over the desired application temperature range should also be selected when using the DAC8742H devices in HART, FOUNDATION Fieldbus, and PROFIBUS PA applications as communication timing is critical. In order to reduce quiescent current consumption, the XTAL nets should be optimized during layout to reduce any length that may increase net capacitance. This increase in capacitance is directly proportion to current consumption.

8.1.3 Included Functions and Filter Selection

As a highly integrated device, the DAC8742H not only includes the modulation and demodulation capabilities for the previously described industrial protocols, but also includes an internal reference, and integrated receive bandpass filter, with other aforementioned functions. In HART mode, an internal amplifier provides high output drive capability, and can drive a wide range of purely capacitive loads, ranging from 5 nF to 22 nF. The lower value specified in the load range is to ensure output stability. Two different filter configurations, external and internal, are achievable through the BPF_EN digital input -- logic high on this pin enables the internal bandpass filter. The external filter configuration is shown in [Figure 32](#). The example provided displays the DAC8742H device configured with an external reference and external bandpass filter.

Application Information (continued)

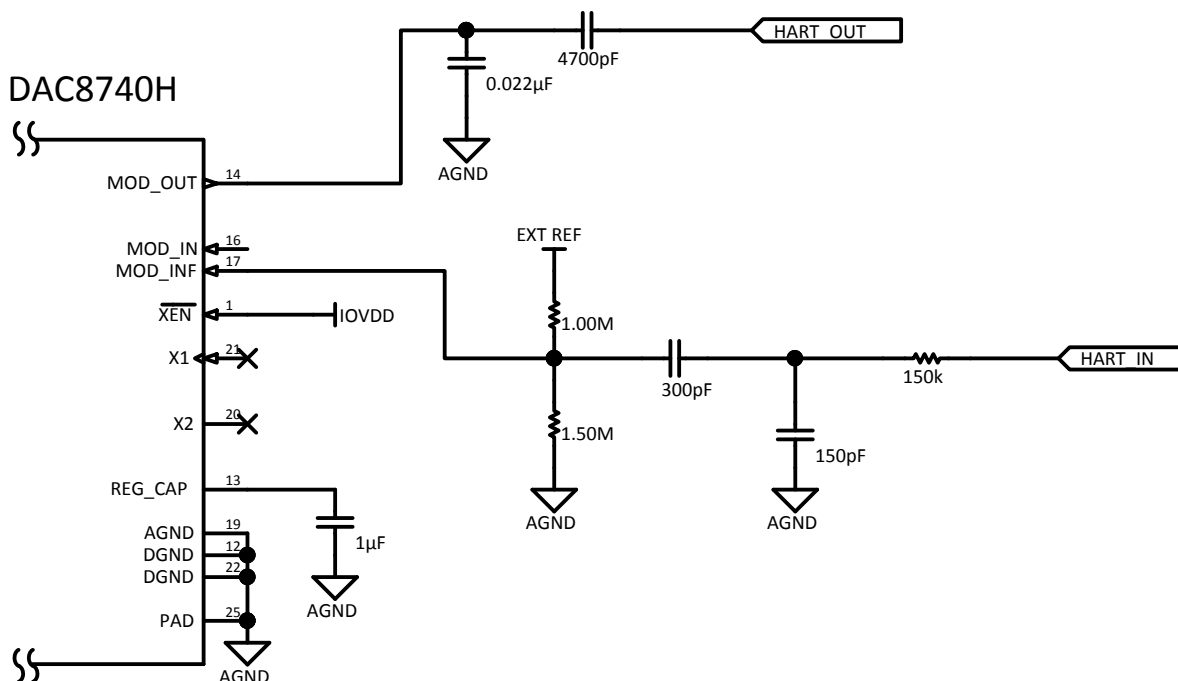


Figure 32. HART Mode: DAC8742H Passive Selection For External Bandpass Filter and External Reference

The second configuration, which can reduce costs associated with PCB development and BOM component counts, additionally aids in the optimization of board space. This optimization gives the user flexibility into achieving industrial applications with smaller form factor sizes. The internal filter configuration, with correct MOD_IN, MOD_INF, and MOD_OUT connections, is shown in Figure 33.

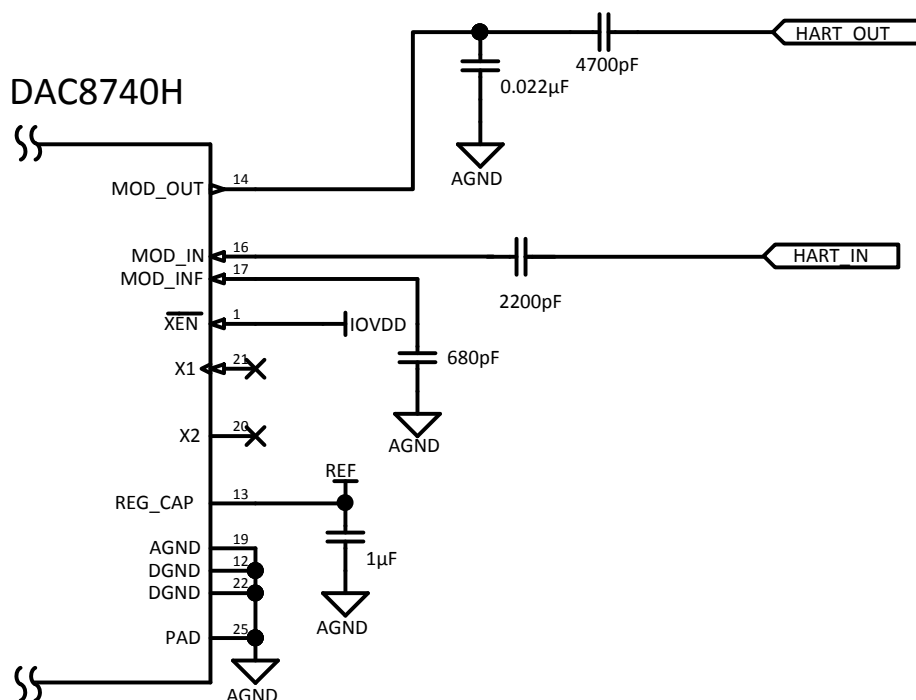
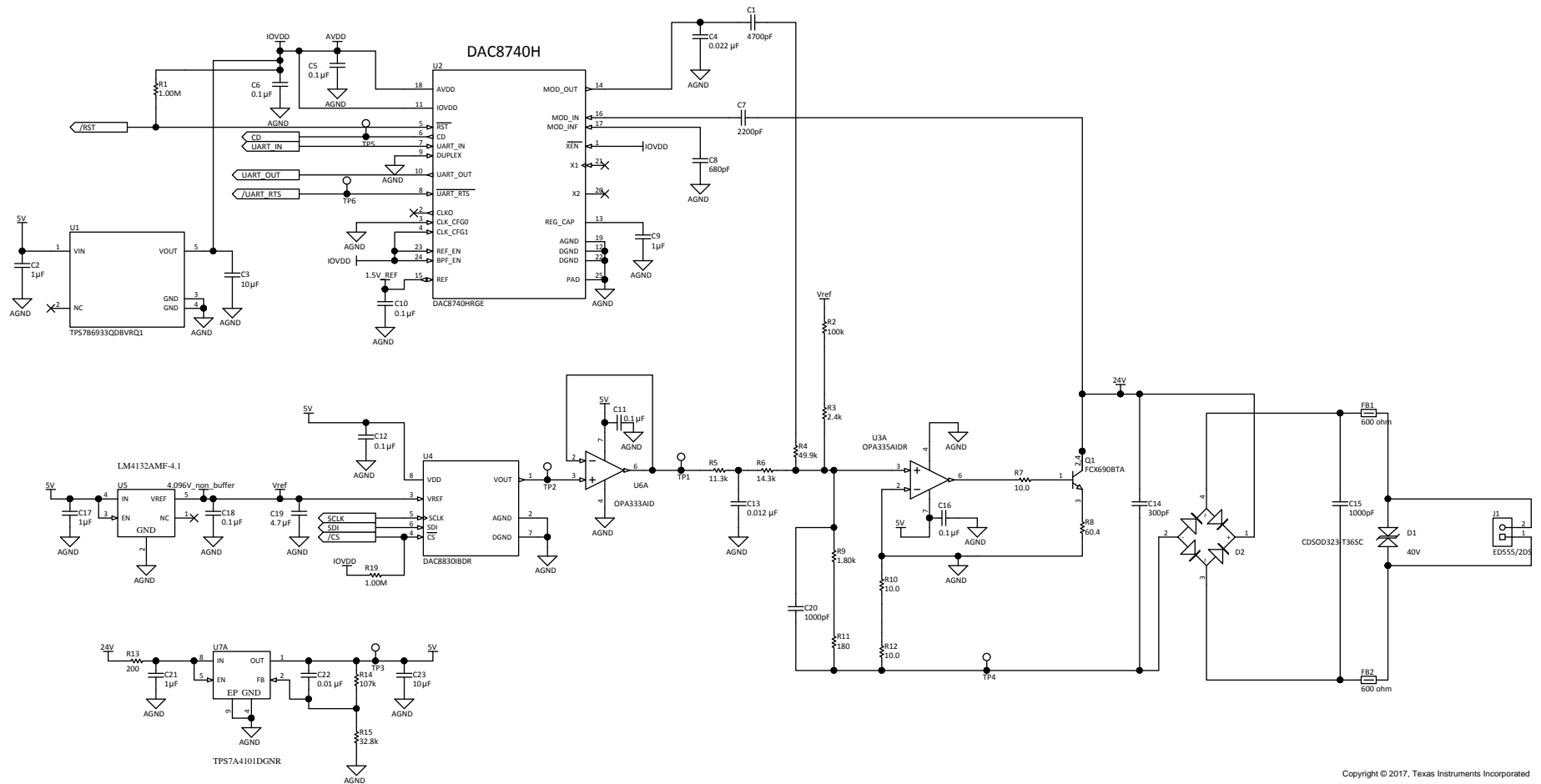


Figure 33. HART Mode: DAC8742H Passive Selection For Internal Filter

8.2 Typical Application

The application schematic shown in Figure 34 is described in the following sections.



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Figure 34. 2-Wire Transmitter with DAC8742H HART Modem Design Schematic

8.2.1 Design Requirements

The application presented in Figure 34 represents a loop-powered, 2-wire, smart 4-mA to 20-mA transmitter that commonly resides in factory control and industrial automation sectors. In this application, the DAC8742H enables a smart interface by providing HART communication, which is responsible for modulating two-way digital information that encapsulate a wide variety of data, including device/sensor information, calibration data, and system diagnostic information. This circuit has been successfully HART certification and registered with the FieldComm Group.

8.2.2 Detailed Design Procedure

8.2.2.1 DAC8742H HART Modem

In this design the DAC8742H internal reference and bandpass filter was chosen to optimize board area, consequently reducing form factor and cost. X7R, 10% accurate, bypass capacitances of 1- μ F and 0.1- μ F values were chosen for the reference and supplies, respectively.

The DAC8742H device interfaces with the MSP430FR5969, or other similar host controller, through a standard UART interface. The DAC8742H digital pins connected through this interface include `UART_RTS`, `UART_OUT` (TX), `UART_IN` (RX), and `CD`.

The remaining portion of the schematic includes other TI devices that aid in the realization of a highly accurate 4-mA to 20-mA, 2-wire transmitter. This combination of circuitry is ideally suited for remote signal conditioning of a wide variety of sensors and transducers, including thermocouples, RTDs, thermistors, and strain gauge bridges.

The two-wire transmitter is powered from an external DC power supply that is connected via the two BUS supply lines. The transmitter communicates by sourcing a 4-mA to 20-mA current through the connected bus, and back to the central host, which is typically a PLC analog input module. This expressed range of 4 mA to 20 mA is typically employed to adhere to industry standard, and ensures that the transmitter receives a minimum of 4 mA for correct powered operation.

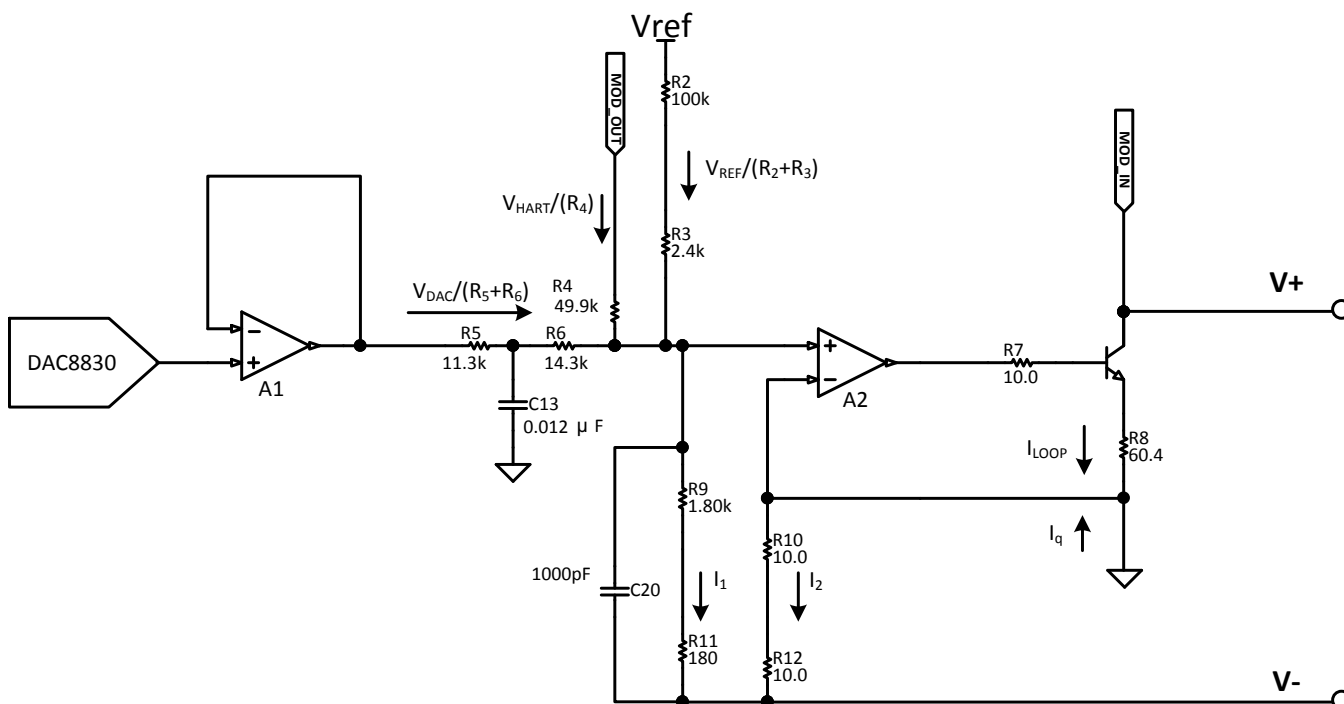


Figure 35. Simplified Schematic of the 2-Wire Current Loop

8.2.2.2 2-Wire Current Loop

The A2 operational amplifier employs negative feedback to ensure potentials at both input nodes, V+ and V-, are equivalent. This establishes the set of KCL equations (1) – assuming no HART communication, $V_{HART} = 0$ V.

$$I_1 = V_{DAC}/(25.6k) + V_{REF}/(102.4k) \quad (3)$$

A2 also drives the base of the NPN BJT, Q1, which enables current to flow from its collector through emitter pins and through the R8 resistor, while maintaining an equivalent potential drop from its input nodes to the net represented by TP4. This ensures that the combined voltage drop across R9 and R11 is equivalent to the combined drop of R10 and R12.

Using this relationship, along with current [Equation 3](#) and [Equation 4](#), I_{OUT} is calculated as follows:

$$I_2 = I_1 * (1.80k + 180) / (10 + 10) = I_1 * (1.980k / 20) = I_1 * 99 \quad (4)$$

$$I_{OUT} = I_1 + I_2 = [VDAC / (25.6k) + VREF / (102.4k)] * I_1 * 99 = [VDAC / (25.6k) + VREF / (102.4k)] * (100) \quad (5)$$

For a VREF value of 4.096 V, the zero-scale portion of the transfer function, $[VREF / (102.4k)] * (100)$, translates to 4 mA, while the span, $[VDAC / (25.6k)] * 100$, encompasses 16 mA. This final product is a system capable of sourcing 4 mA to 20 mA, which is dependent on DAC output voltage. The value of R4 is responsible for converting the 500-mV p-p HART signal into a 1-mA p-p frequency shift keyed (FSK) signal that resides on top of the 4-mA to 20-mA analog current signal.

8.2.2.3 Regulator

The primary supply for the transmitter is the TPS7A4101 device, which is a 50-V input, 50-mA Single output low-dropout linear regulator with very low quiescent current, 25 μ A. The device supplies a well-regulated voltage rail (1% accuracy), operating within an extended temperature range of -40°C to 125°C , and also withstands and maintains regulation during very high and fast voltage transients. In this design the LDO converts the external supply to a 5-V rail that is used by the DAC8830, LM4132 and OPA333/OPA335. The 200- Ω resistor that separates the loop supply from the LDO acts as a current limiting resistor at startup and additionally improves the overall receiver impedance of the design.

Generally, series references are preferred over shunt references because of their lower power consumption; in this case the LM4132 exhibits a maximum of 60- μ A quiescent current. Moreover, the device has an initial accuracy of 0.05% with a specified temperature coefficient of 10 ppm/ $^{\circ}\text{C}$ or less, and is capable of operating with these metrics at an extended temperature range of -40°C to 125°C .

In order to generate a 3.3-V supply for the DAC8742H, the TPS7B6933-Q1, a low-dropout linear regulator with low quiescent current, is incorporated into the design. This LDO is capable of operating over a wide temperature range of -40°C to 125°C , while exhibiting a maximum quiescent value of 25 μ A over this temperature range.

8.2.2.4 DAC

After sufficient bypass, this precision reference voltage is applied to the VREF pin of the DAC8830 device. An accurate reference along with an accurate DAC are largely responsible for the overall accuracy of the current loop, as any accuracy errors associated with the DAC will propagate through the rest of the signal chain and decrease the accuracy of the solution. In this case, the DAC8830, a 16-bit voltage-output DAC with excellent linearity (1 LSB INL), low glitch, low noise, and fast settling was chosen to set the base line performance of the design.

8.2.2.5 Amplifiers

Next, the voltage output is buffered with the OPA333 CMOS operation amplifier, which features near-zero drift over time and temperature, low quiescent current (17 μ A), and single supply operation with rail-to-rail output that swings within 50 mV of the supply rail.

As with the OPA333, the OPA335 was chosen due to its excellent DC accuracy specifications. These parameters include low input bias current, low offset voltage, and high CMRR/PSRR. In addition to these DC specifications, the OPA335 features an operating bandwidth of up to 2 MHz, which provides ample margin for HART communication.

8.2.2.6 Diodes

For transient voltage protection, a 40-V bidirectional transient voltage suppressor (TVS) diode is placed across the BUS lines of the design. Certain criteria should be considered when making this diode selection, such as the diode's working voltage, breakdown voltage, leakage current and power rating. In addition to these parameters, leakage current should also be factored into the design as it will impact the accuracy of the analog current loop.

2-wire polarity protection is also employed by using the DSRHD10 as a diode bridge rectifier. The placement of this component ensures that the current loop will always correctly operate regardless of the arrangement of input connections. As with other elements, leakage and biasing voltage should be considered as it will affect system accuracy and compliance voltage.

8.2.2.7 Passives

Among the passives included in the design, the gain setting resistors should be chosen to exhibit tight tolerances in order to achieve high accuracy. These resistors -- R4, R5, R6, R9, R11, R10, and R12 -- are primarily responsible for setting the gain of the current loop, along with primary path of the output current flow. Since the biased transistor, Q1, is responsible for sourcing most of the output current, components in the path of this current flow should be chosen with appropriate power ratings. In this case R8 is a 0.25-W resistor.

8.2.3 Application Curves

Five hundred datapoints were taken on five different boards, producing the 4 to 20-mA transfer function below in Figure 36. The total unadjusted error (TUE) of the transmitters is displayed in Figure 37.

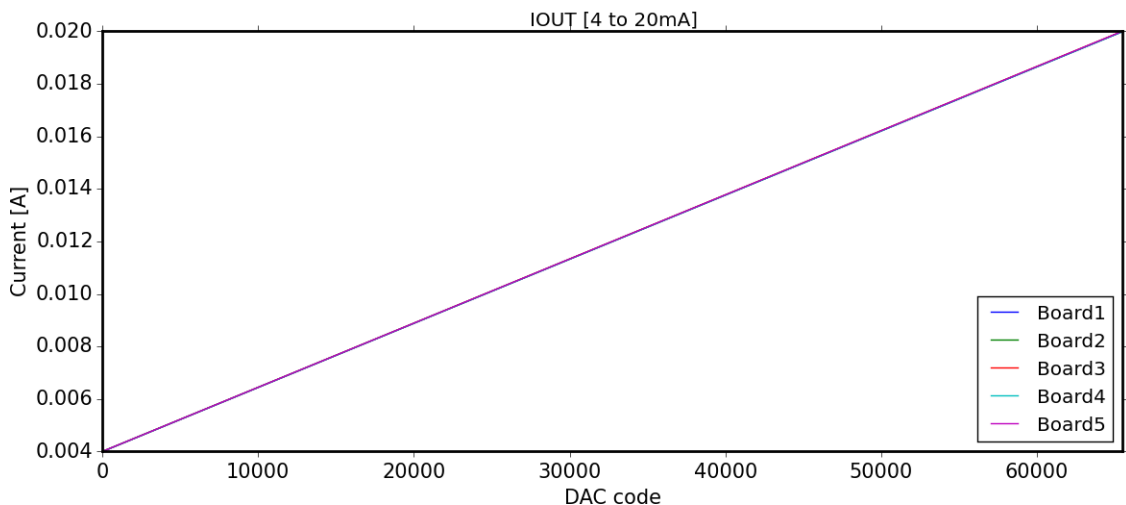


Figure 36. 4-20mA Transfer Function

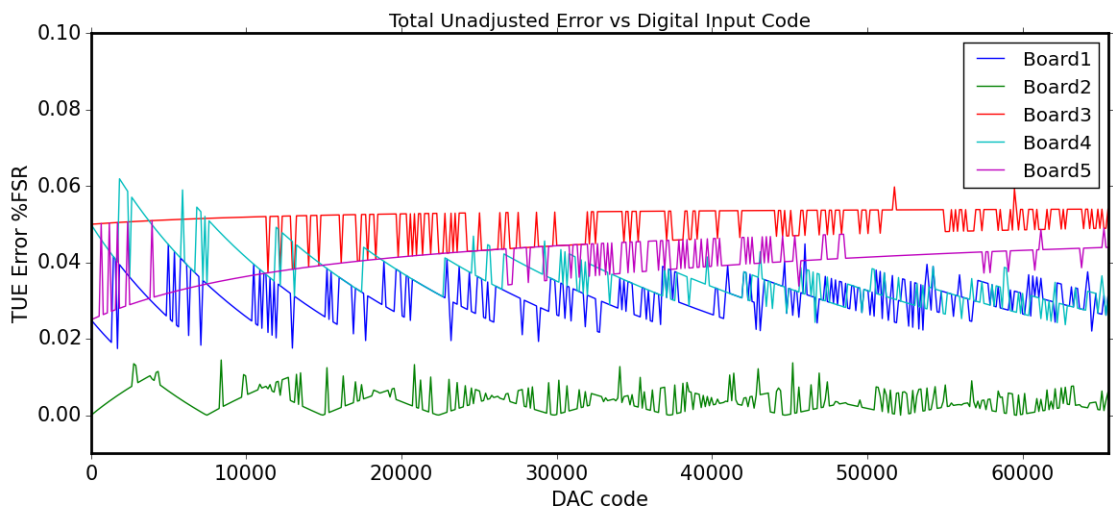


Figure 37. Total Unadjusted Error Graph of Application Circuit

9 Power Supply Recommendations

The DAC8742H can operate with analog supplies from 2.7 V to 5.5 V and digital supplies from 1.71 V to 5.5 V, enabling interfacing host controller platforms with low voltage digital logic. For applications that are particularly focused on reducing power dissipation in the modem, it is suggested to use the lowest supply voltage available for both analog and digital supplies.

10 Layout

10.1 Layout Guidelines

Precision designs require careful layout, the list below provides some insight into good layout practices.

- All Power Supply pins should be bypassed to ground with a low ESR ceramic bypass capacitor. The typical recommended bypass capacitance is 0.1 to 1 μF ceramic with a X7R or NP0 dielectric.
- Power supply and Reference bypass capacitors should be placed close to terminals to minimize inductance and optimize performance.
- A high-quality ceramic type NP0 or X7R is recommended for its optimal performance across temperature, and very low dissipation factor.
- The digital and analog sections should have proper placement with respect to the digital and analog components. The separation of analog and digital circuitry will allow for better design and practice as it will ensure less coupling into neighboring blocks, and will minimize the interaction between analog and digital return currents.

10.2 Layout Example

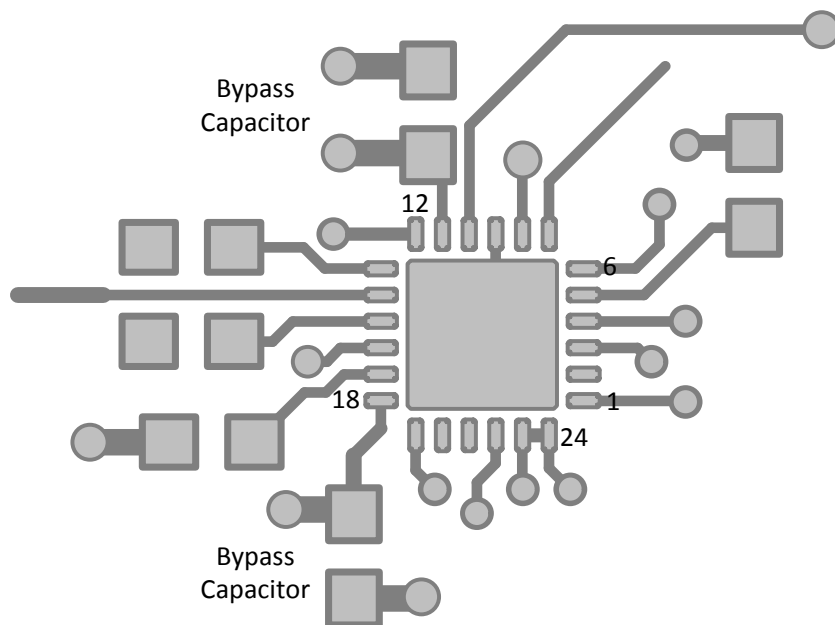


Figure 38. DAC8742H Basic Layout Example

Layout Example (continued)

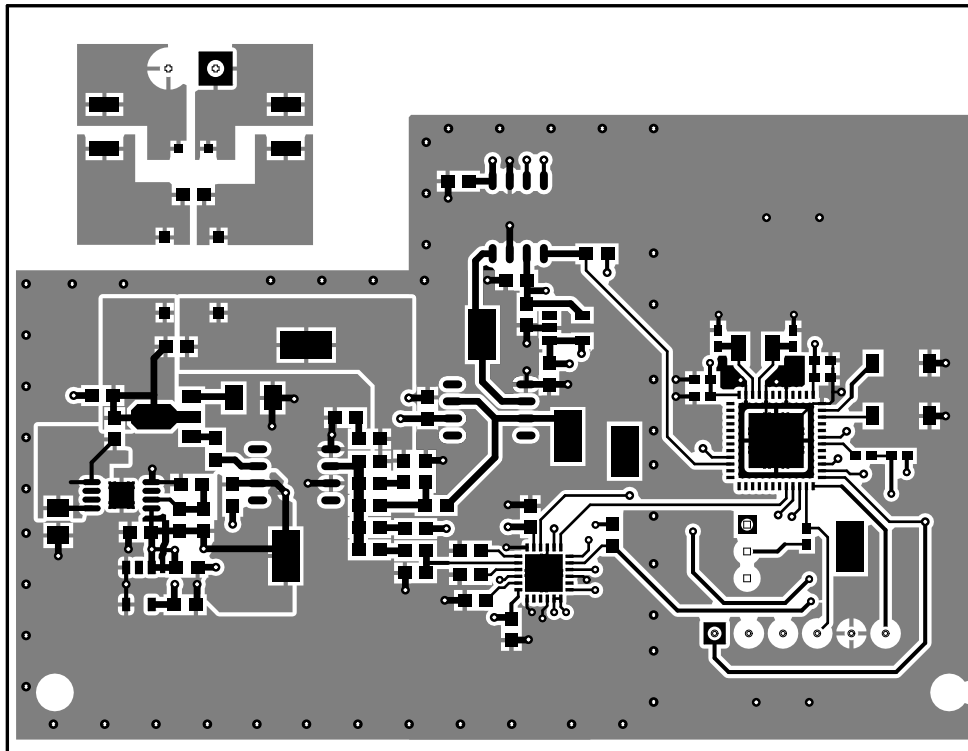


Figure 39. 2-Wire Transmitter with DAC8742H HART Modem Layout - Top Layer

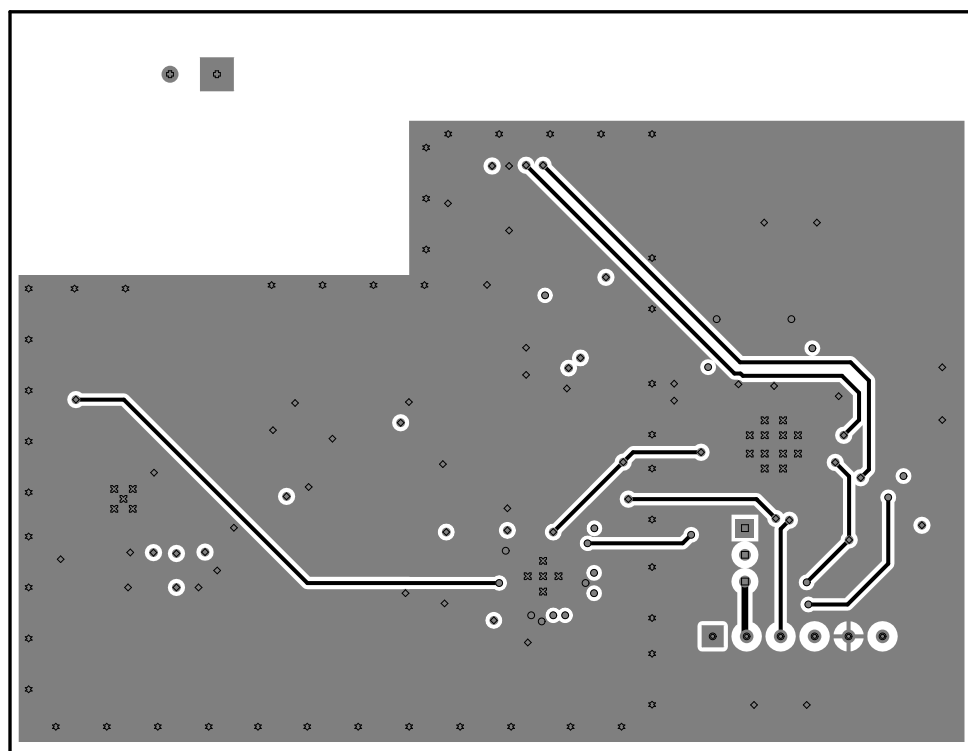


Figure 40. 2-Wire Transmitter with DAC8742H HART Modem Layout - Bottom Layer

11 Device and Documentation Support

11.1 Documentation Support

11.1.1 Related Documentation

For related documentation see the following: DAC8742H Evaluation Module User's Guide ([SLAU700](#))

11.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

11.3 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

TI E2E™ Online Community *TI's Engineer-to-Engineer (E2E) Community*. Created to foster collaboration among engineers. At [e2e.ti.com](#), you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support *TI's Design Support* Quickly find helpful E2E forums along with design support tools and contact information for technical support.

11.4 Trademarks

E2E is a trademark of Texas Instruments.
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All other trademarks are the property of their respective owners.

11.5 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

11.6 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|------------------|---------------|--------------|-----------------|------|-------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|-------------------------|
| DAC8742HPBS | ACTIVE | TQFP | PBS | 32 | 250 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -55 to 125 | 8742H | Samples |
| DAC8742HPBSR | ACTIVE | TQFP | PBS | 32 | 1000 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -55 to 125 | 8742H | Samples |

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

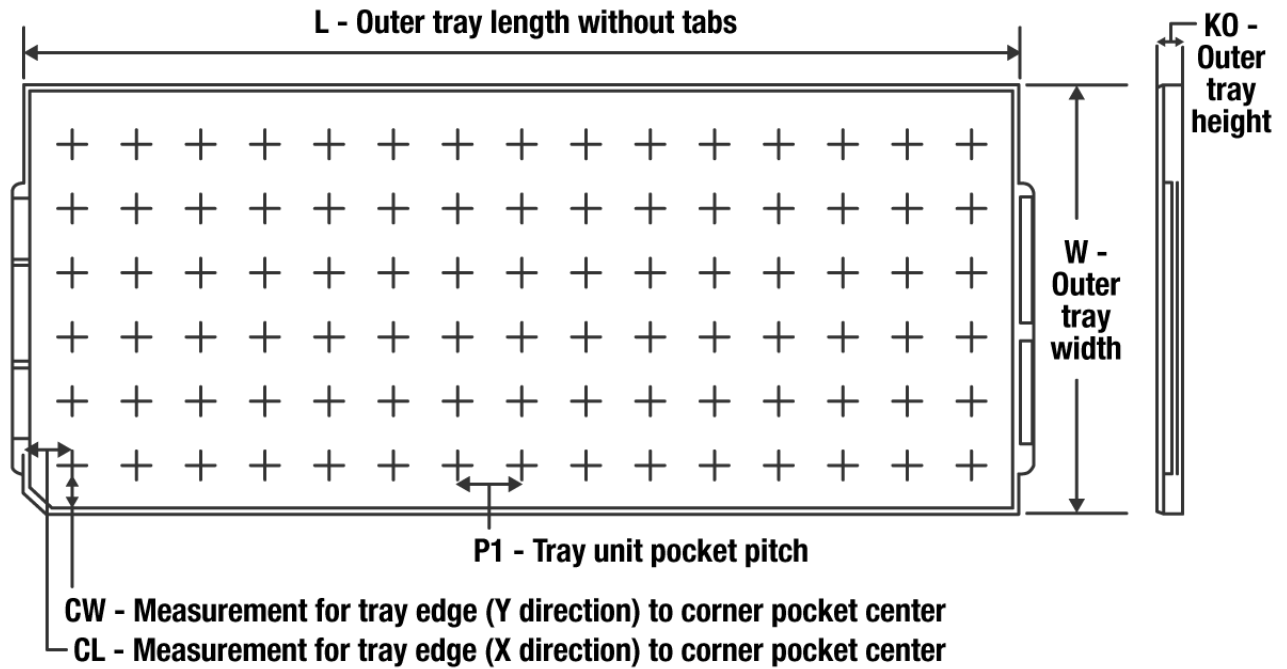
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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TRAY


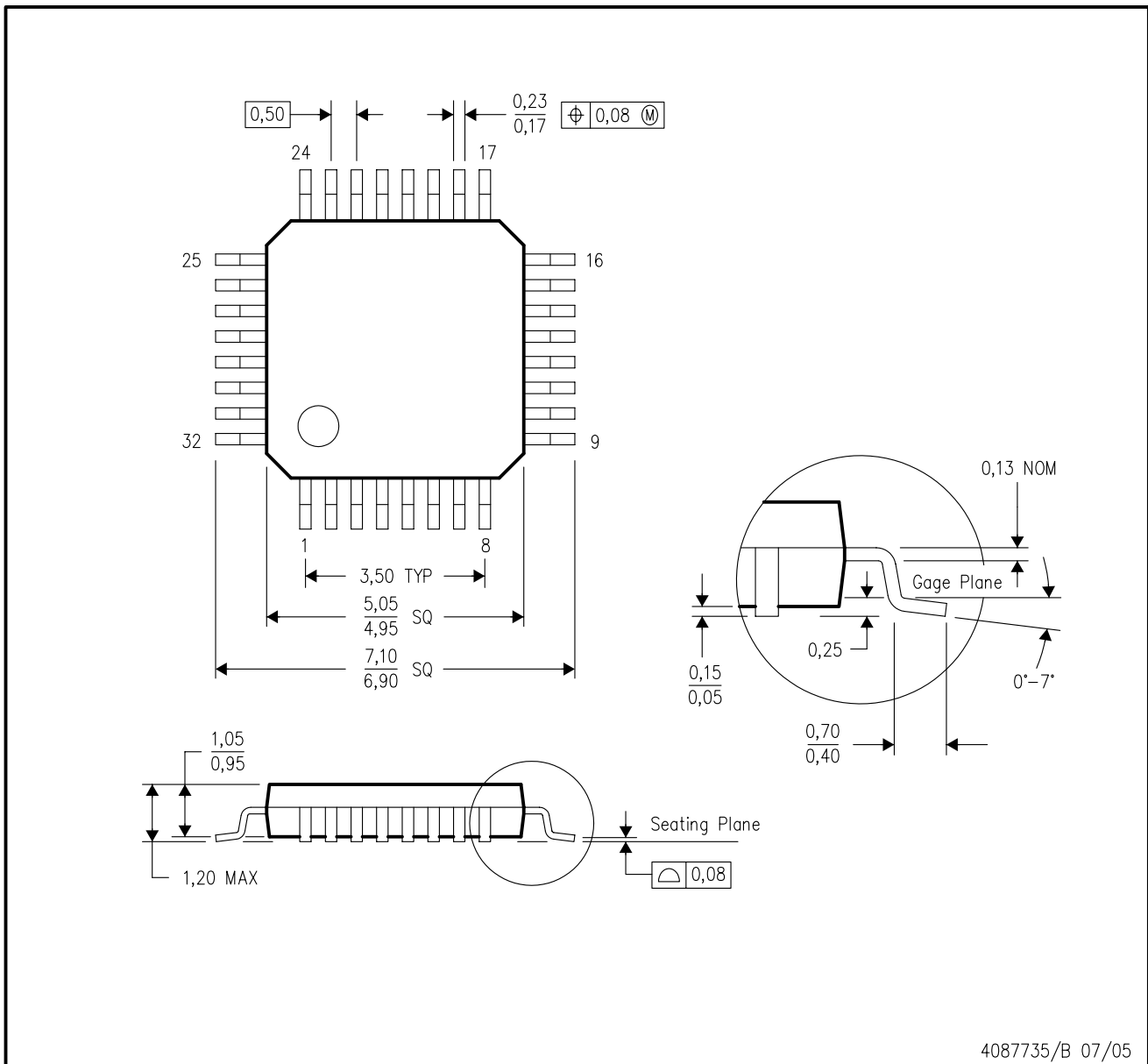
Chamfer on Tray corner indicates Pin 1 orientation of packed units.

*All dimensions are nominal

| Device | Package Name | Package Type | Pins | SPQ | Unit array matrix | Max temperature (°C) | L (mm) | W (mm) | K0 (µm) | P1 (mm) | CL (mm) | CW (mm) |
|-------------|--------------|--------------|------|-----|-------------------|----------------------|--------|--------|---------|---------|---------|---------|
| DAC8742HPBS | PBS | TQFP | 32 | 250 | 10 X 25 | 150 | 315 | 135.9 | 7620 | 12.2 | 11.1 | 11.25 |

PBS (S-PQFP-G32)

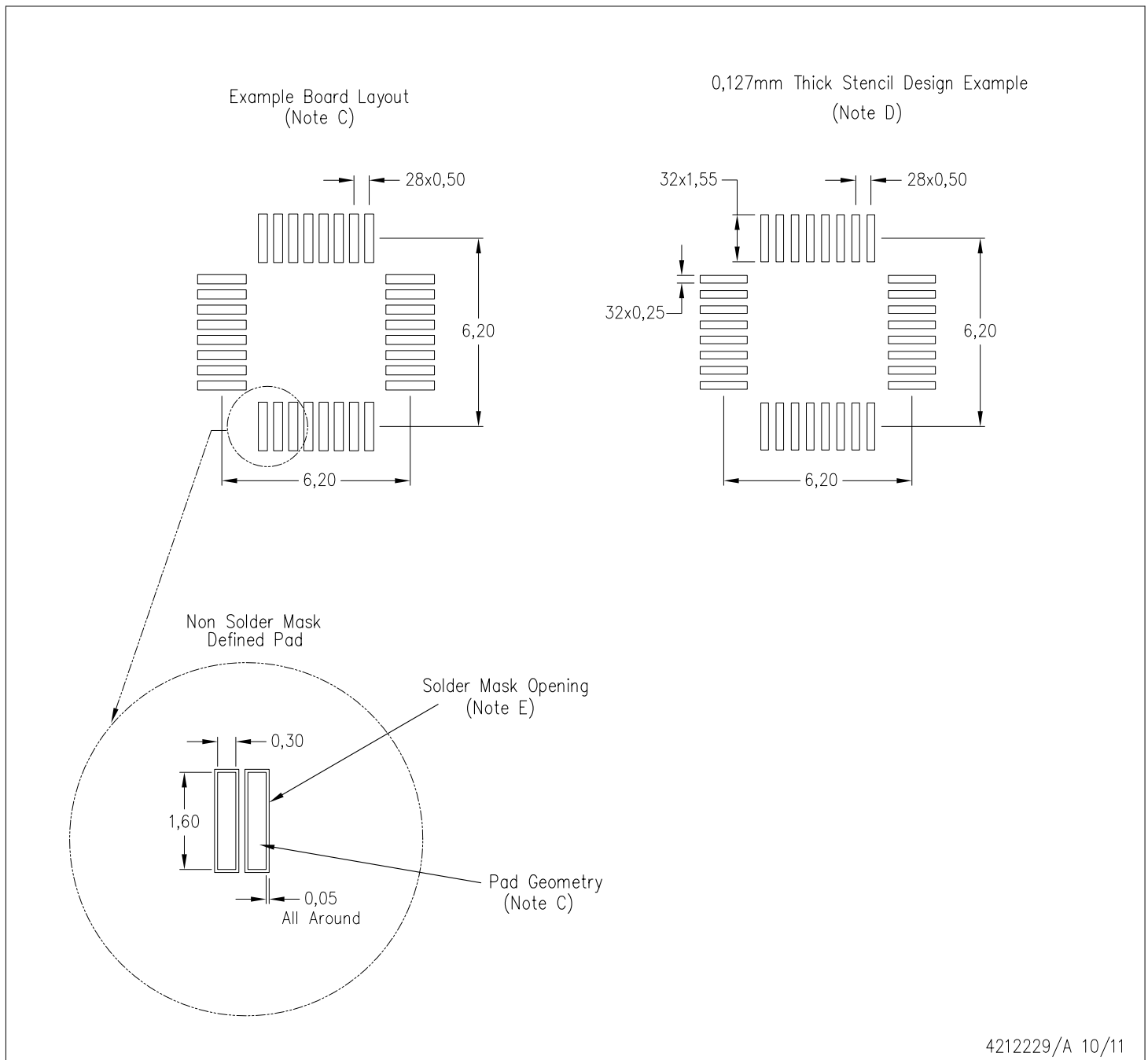
PLASTIC QUAD FLATPACK



- NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.

PBS (S-PQFP-G32)

PLASTIC QUAD FLATPACK



- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Publication IPC-7351 is recommended for alternate designs.
 - D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
 - E. Customers should contact their board fabrication site for recommended solder mask tolerances between and around signal pads.

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