Implementing HART in 2-Wire Field Sensor-Transmitters

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Introduction

Modern 4-20mA loop current drivers in loop powered field transmitters utilize the HART protocol to achieve digital bidirectional communication on top of the traditional 4-20mA current loop. The 4-20mA loop represents a single primary variable based on the value of the DC loop current. The addition of HART communication superimposes an AC coupled FSK waveform on the loop as digital data, often used for calibration and diagnostics. A key challenge for field transmitter designers is implementing HART on 2-wire analog output modules while achieving HART physical layer compliance and minimizing overall quiescent current. The DAC874xH family of devices are standalone modems supporting HART, Foundation Fieldbus, and Profibus PA. These HART certified modems feature SPI/UART interface options, internal filtering, and low quiescent current of 180µA (Max, -40°C to 85°C), making DAC874xH ideal for implementing HART certified 2-wire analog outputs for field transmitter applications.

2-Wire Analog Output Circuit

In low power field transmitters, the loop powered 2-wire analog output circuit is the ideal configuration as it eliminates the need for a separate power supply cable. In the loop powered 2-wire 4-20mA analog output, the analog signaling current and supply current are combined. The output NPN transistor is responsible for regulating the loop current to a minimum of 4mA. The regulator, op amp, DAC, modem, and sensing circuitry must therefore require less than 4mA of supply current.

In the 2-wire topology the loop power supply, transmitter, and analog input module are connected in a series loop. The transmitter regulates the loop current to indicate the sensor value (primary variable). The analog input module then calculates and digitizes the DC loop current for PLC processing.

Figure 1 shows the discrete implementation of the 2-wire analog output circuit and Equation 1 shows the DC transfer function. Resistors R1 and R2 set the span and zero-scale current respectively. The current flowing through R3 is multiplied by a gain of (1+R3/R4) setting the total loop current. R4 is a current sense resistor that provides feedback for regulation and R5 is a small degeneration resistance for stability. As shown in Figure 1 the ground point for this circuit represents the local transmitter ground and the quiescent current of the devices flows up from this ground (I_Q), across R4 and out of Loop-. All of the current flowing into Loop+ must flow out of Loop- as the power supply and signaling current are combined. The current flowing through the transistor can be viewed as the additional current required reach the current set point. A large ratio of R3/R4 is typically used so that most of the current flows through the BJT.

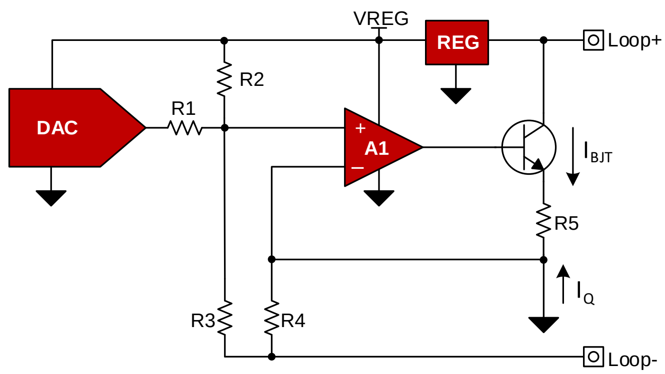

Figure 1. DC Loop Powered Transmitter Circuit

$$I_{OUT} = \left(\frac{V_{DAC}}{R_1} + \frac{V_{REG}}{R_2}\right) \times \left(\frac{R_3}{R_4} + 1\right) \quad (1)$$

HART Implementation in Loop Powered Transmitters

One drawback with the traditional 4-20mA field transmitter is that only one variable can be represented. The addition of HART provides an additional channel of communication between the field transmitter and analog input module through an FSK waveform representing digital data. Both the field transmitter and PLC can transmit and receive data over HART. The PLC acts as the master and requests data from the field transmitter to ensure that both devices are never transmitting simultaneously. HART is commonly used to transmit device information, diagnostic information, and can also be used to represent another process/control variable.

Figure 2 shows how the HART signal is coupled to the 2-wire transmitter circuit. As seen previously, R1-R5 are selected based on DC loop current requirements and the HART signal is injected as a current waveform through R6 and is multiplied (1+R3/R4) yielding the 1mAp-p AC waveform in the loop current . Equation 2 shows the required value of R6 to set the amplitude of the HART signal in the current loop.

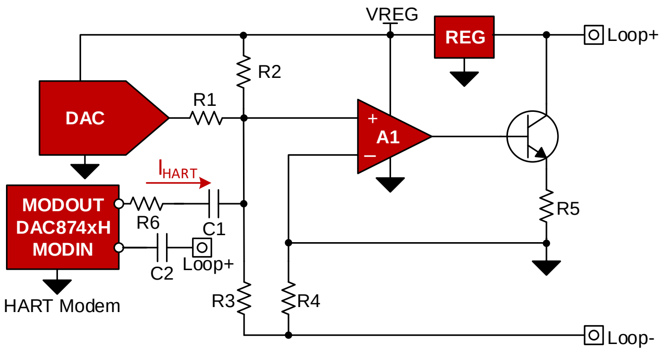

Figure 2. HART Coupling in Loop Powered Transmitter

$$R_6 = \frac{V_{HARTpk-pk}}{I_{OUTpk-pk}}\left(1+\frac{R_3}{R_4}\right) \tag{2}$$

As shown in Figure 2 MODIN is coupled to Loop+ where the HART signal from the input module is received as a voltage waveform across the sense resistor. In both the 2-wire and 3-wire transmitter configurations, the analog output module transmits HART in the current domain since it is responsible for regulating the current. The input module (master) transmits HART in the voltage domain across the sense resistor since it has no control over the loop current.

The additional considerations for HART implementations in the 2-wire transmitter are modem quiescent current and the related overall current consumed by the sensor, transmitter, and supporting circuitry or devices. The modem should have as low quiescent current to leave room for the other sensor-transmitter elements. DAC874xH devices have 180µA maximum quiescent current over temperature (-40°C to 85°C) with the modulator active, leaving significant headroom for other circuitry.

The overall current consumption must also be considered to avoid clipping of the HART signal. The nominal zero-scale current is 4mA but if HART signaling is required at zero-scale then the sensor-transmitter must consume less than 3.5mA as the HART signal is 1mAp-p. This can be further complicated if under current values are used for error signaling as described by the NAMUR specification. An error or alarm may be represented by setting the current to 3.6mA for instance. During the error HART communication may still be required to transmit diagnostic information. To avoid HART signal clipping the sensor-transmitter must consume less than 3.1mA of total quiescent current.

Figure 3 shows the voltage across a 250ohm load resistor connected to a two-wire transmitter. The DC current value is set to approximately 5mA which is represented by the DC voltage of 1.26V across the load resistor. The HART waveform can be seen superimposed on top of this DC voltage as a 250mVpp signal which corresponds to a 1mAp-p current waveform.

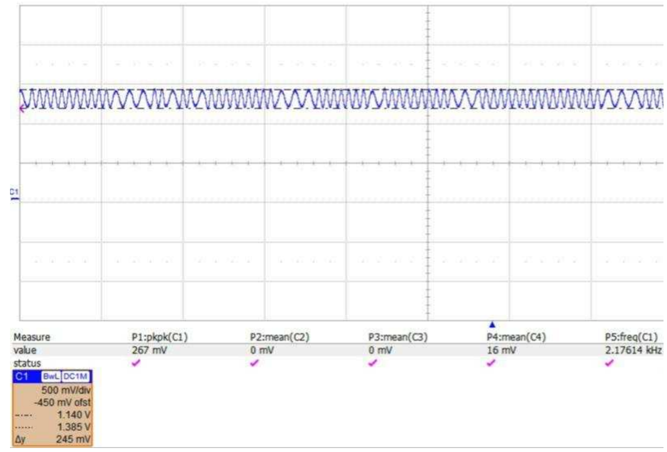

Figure 3. 2-Wire Transmitter DC Value with HART

HART Physical Layer Compliance

Achieving HART physical layer certification in 2-wire transmitter designs can be especially challenging due to power supply and analog signals sharing the same transmitter connections. The input capacitance must be minimized to achieve high input impedance which can limit the selection of LDOs and transient protection components. The HART certification process includes tests to assess waveshape, noise, analog rate of change, and input impedance to ensure the transmitter complies with the physical layer specification. The DAC874xH family of modems have been tested and HART registered in a 2-wire transmitter reference design.

Conclusion

An increasing number field transmitter designs are including HART to take advantage of the additional communication it adds to the traditional 4-20mA loop. The incorporation of HART creates additional design challenges, particularly for the 2-wire field transmitter, to ensure HART physical layer compliance. DAC874xH HART modems are HART physical layer certified enabling designers to meet system level HART compliance. The devices need minimal supporting components, offer multiple interfaces with extended SPI features, and require minimal input current to meet the requirements of field transmitter design.

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