Designing Foundation Fieldbus and Profibus PA Devices with the DAC874xH Modem Family

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TEXAS INSTRUMENTS

Introduction

Foundation™ Fieldbus H1 (FF) and Profibus PA (PA) are fully digital communication protocols for factory and process automation that offer many advantages compared to the traditional 4-20mA current loop. These protocols provide a real-time communication network between many devices in an industrial environment over a single cable. Similar to 4-20mA loops, FF and PA can provide power for loop-powered devices in addition to communication over the same two wires, supporting intrinsic safety applications. In addition to simple wiring, FF and PA networks benefit from higher speed communication, higher current for sensors/transmitters, and advanced diagnostic capabilities.

The DAC874xH family of devices are standalone modems supporting HART, Foundation Fieldbus, and Profibus PA. These modems feature SPI/UART interface options, an internal FF/PA input filter, low quiescent current, and internal voltage reference. The DAC874xH devices require few additional components to implement an FF/PA physical layer compliant medium attachment unit (MAU) making them ideal for FF and PA transmitter applications.

FF/PA Overview

The FF and PA busses consist of devices connected in parallel between two wires, a loop power supply with power conditioning, and two bus terminators (T1, T2) as shown in Figure 1. Devices on the bus communicate via a 0.75Vpp-1Vpp voltage waveform superimposed on the DC bus voltage representing Manchester encoded digital data. Transmitters and other devices produce this waveform by modulating the current they draw from the bus, typically +/-9mA from their DC value, allowing long distance communication. The AC current waveform is allowed to pass due to the combined impedance of the two terminators, creating the voltage waveform on the bus (+/-900mV). The bus power supply must provide power conditioning to ensure the signal integrity of the waveform on the bus. Terminators are installed on each end of the network, allowing a path for the AC current to flow. The link-master on the network is responsible for scheduling the communication between devices.

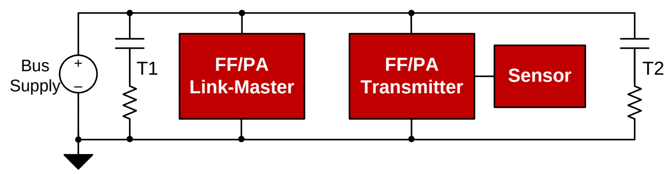

Figure 1. FF/PA Fieldbus Network

Design Considerations

The DAC874xH family of modems modulate and demodulate a low-speed 31.25kbit/s Manchester encoded voltage waveform, and these devices are compliant with both Foundation Fieldbus H1 and Profibus PA physical layers. An external circuit is required to convert this voltage modulation into the current waveform used by devices on the bus. The circuit is similar to the 2-wire 4-20mA loop powered field transmitter topology used in analog systems.

Figure 2 shows a simplified schematic of the external circuit required to implement an FF or PA device with DAC874xH. The amplifier A1 regulates the current through Q1 which sets the current through Q3 due to the current mirror formed by Q2 and Q3. The current mirror is used to force most of the loop current through the shunt regulator (REG) producing a stable regulated voltage that is not dependent on the loop voltage. Since the loop voltage changes by ~1Vpp, this configuration prevents the communication signal from feeding through to the regulated voltage used by the on-board circuitry. The ratio of R6:R7 should be large to allow only a small current to flow in the path of Q1. Additional start-up circuitry and filtering components are required to ensure correct operation when initially connected to loop power.

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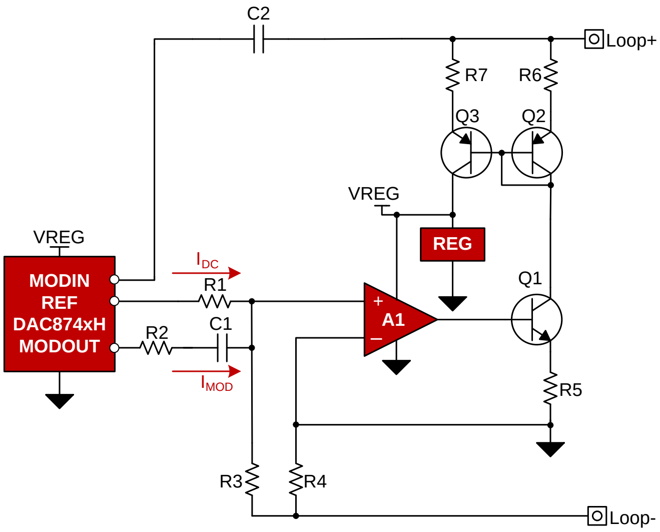

Figure 2. Loop-Powered FF/PA Transmitter Circuit (V-to-I Converter)

The loop current is set by the current injected into the node connected to the non-inverting terminal of A1 from the reference voltage (REF) and modulated voltage (MODOUT). The sum of the injected current is gained to the output loop current by the ratio of R3:R4. Since FF and PA are digital protocols high precision is not required making component tolerance less critical compared to analog current transmitters.

Equation 1 calculates the DC loop current based on R1, the DAC874xH reference voltage (1.5V), and the gain resistors R3/R4. The DC current for transmitters is usually set between 10mA and 20mA depending on the requirements of the on-board circuitry. Equation 2 calculates the loop current modulation based on R2, the DAC874xH MODOUT voltage (800mVpp), and the gain resistors R3/R4. Capacitors C1 and C2 AC couple the voltage FF/PA waveforms in the transmit and receive path of the modem.

$$I_{DC} = \left(\frac{V_{REF}}{R1}\right)\left(\frac{R3}{R4}+1\right) \quad (1)$$

$$I_{MOD} = \left(\frac{V_{MOD}}{R2}\right)\left(\frac{R3}{R4}+1\right) \quad (2)$$

Figure 3 shows an example of the transmit waveform measured on the fieldbus. This waveform was measured with the FF/PA reference design using DAC8742H connected to a bus with two terminators. The current modulation of the reference design is +/- 9mA with a DC current of 16mA to allow for sensor quiescent current. This corresponds to the 900mVpp waveform on the bus that transmits the Manchester encoded data.

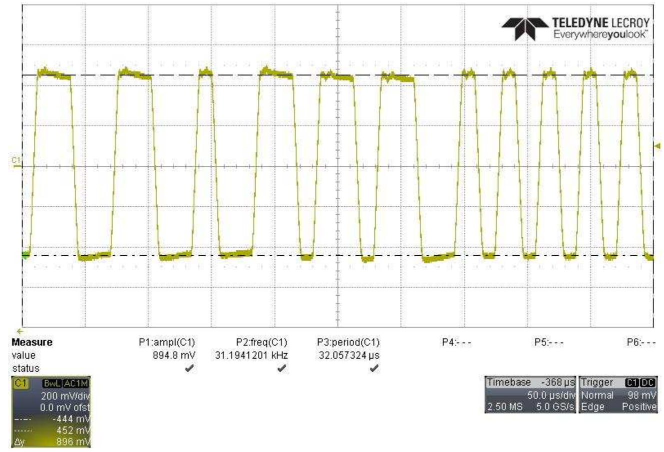

Figure 3. Bus Voltage with FF/PA Signal Transmitted

Physical Layer Compliance

FF and PA devices require a physical layer compliance test to ensure interoperability with all other FF/PA devices. The test requires transmitting a request to the device under test and measuring various characteristics of the DUT reply waveform. Foundation Fieldbus and Profibus PA share a similar physical layer but the test specifications differ slightly. The transmitter must have an appropriate FF or PA software stack in order to undergo the testing process. Some of the tests include measuring the transmit waveform amplitude, distortion, slew rate and bit rate. Loop powered devices must also meet the start-up current requirement defined in the specification. For more information on physical layer testing refer to the FF/PA reference design.

Conclusion

The DAC874xH devices are the only stand-alone Foundation Fieldbus, Profibus PA, and HART modems currently available in the industry. A single modem supporting both HART and FF/PA allows for reduced qualifying time for engineers designing both HART and FF/PA hardware. A universal FF/PA + HART transmitter can be designed that requires only a BOM change to switch between the protocols, without qualifying additional ICs. With DAC874xH devices and simple, low-cost external circuitry, a physical layer compliant FF or PA transmitter can be implemented, offering greater functionality in automation control applications than traditional 4-20mA current loops.

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