In the previous articles, Time Domain Reflectometry (TDR) and how to apply TDR to level sensing were discussed. In this article, we move to the implementation of a TDR liquid level-sensing system.

Figure 1 shows the components needed for a TDR level-sensing system, including:

- Assembled PCB
- Assembled probe
- 0.187” Stainless-steel rod
- 0.5” Stainless-steel tube

All the components are easily obtained or manufactured. Any non-magnetic metal can be used for the probe. In this case, stainless steel was used.
TDR Detailed Implementation

To make a TDR measurement, a pulse must be generated with a fast fall time. This pulse is then sent down a transmission line to the level probe (see Figure 1). Finally, the reflection from the liquid-air interface must be digitized and a measurement of the pulse width must be made (see Article 2, Figure 3). Figure 2 shows a schematic of the TDR portion of the system.

Not shown is the PIC® microcontroller (PIC24FV32KA304), which is used for:

- Control
- Start Pulse generation
- Measurement of the Stop Pulse width

Pulse generation is accomplished with transistor Q3. When driven with a Start Pulse from the microcontroller, a fast falling edge is generated. This falling edge is driven onto the serpentine microstrip via R8 and C3. When an impedance mismatch occurs at the air/liquid interface, a reflection is generated and measured.

When making measurements with resolutions of 3.5 ps, calibration is needed. This is accomplished using Q4 and Q5. Making a measurement with Q4 and then Q5, thus, shorting the microstrip, gives two calibration points to calculate the gain and offset of the system’s linear transfer function.

The reflection is input into U12 (comparator), which generates the Stop Pulse. The stop pulse width represents the distance to the air/liquid interface (See Article 1, Figure 2).

Controlling and Making Measurements

All control and measurements are accomplished using the PIC24KV32KA304 microcontroller.

Calibration control is done using two signals: short coax middle and short coax end. When the PIC24KV32KA304 enables these signals, it will cause Q4 or Q5 to short the microstrip, creating a reflection at a known distance. This creates Stop Pulses that represent the exact distance to the middle and the end of the microstrip. Using these measurements, gain and offset can be calculated:
...where $T$ is time, and $V$ is voltage, as read by the ADC on the PIC24KV32KA304 (time is directly related to distance).

Time measurement is accomplished using a module on the MCU called the Charge-Time Measurement Unit (CTMU), which is configured to convert the Stop Pulse to a voltage.

CTMU - The Heart of the TDR Measurement

Time measurement is accomplished with the CTMU. This peripheral is found on many PIC microcontrollers, and can measure time with 3.5 ps resolution. The CTMU works by charging a capacitor with a constant current from a start event to a stop event, and measures the resulting voltage on the capacitor. The CTMU measures the time between two events. In this case, event 1 is the falling edge of the Stop Pulse and event 2 is the rising edge of the Stop Pulse.

Board Design

Figure 3: TDR Board

Figure 3 shows the critical components for the TDR board. With this board, measurements with a resolution of 0.02" have been made.
System Components Related to TDR:

- Microchip PIC24FV32KA304 Microcontroller with CTMU
- Linear Technology LT1711 4 ns comparator
- NXP BFG531 x 3 7 GHz transistors
- Misc.  Resistors and capacitors

Conclusion

An economical TDR level-measurement system is achievable and can produce 0.02” resolution, self calibration and independence from fluid type. It provides information on the fluid composition, as well. The system as configured:

- Used a 10.5” probe
- Had a measured resolution of .021”
- Accuracy over temperature of ±2%
- Could differentiate between diesel and gasoline and ethanol

Note: PIC is a registered trademark of Microchip Technology Inc. in the USA and other countries. All other trademarks mentioned herein are the property of their respective companies.