LDTEDS: A Method for Long Distance Communication to Smart Transducers with TEDS

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The IEEE 1451.4 standard defines a Mixed-Mode Interface (MMI) that is alternately used for both Transducer Electronic Data Sheet (TEDS) data and analog signals. For some sensors such as IEPE accelerometers, the TEDS contains essential data pertaining to the transducer that the connected system may read via the same wires that the analog signal is delivered. Presently, the distance between TEDS transducers and the interrogating instrument is limited to 400 feet due to communication protocol and design of the 1-wire memory devices. In many shock and vibration test applications, safety, environment or other factors dictate that the cable runs to the transducers are in excess of 400 feet. In this paper, we present a method that we call Long Distance TEDS (LDTEDS) that allows instruments to communicate with TEDS equipped devices to 1500 feet.

INTRODUCTION

Recent advances in technology have led to the development of sensors with embedded memory used to store pertinent information related to the sensor such as make, model, serial number and sensitivity. This data may be automatically retrieved and utilized to set up the measurement system. Also, a channel table can be generated that gives correspondence between the signal conditioner channel and the attached sensor. This serves to reduce or eliminate bookkeeping errors associated with a manually generated channel table. The channel table may also list and display all pertinent sensor data, including position and orientation on the test article.

The IEEE 1451.4 standard defines interface and communication protocol for such sensors. The data contained in the memory is commonly referred to as the Transducer Electronic Datasheet or TEDS. Accelerometers with integrated electronics (known as IEPE) that contain TEDS have become commonplace in the market, with devices available from a number of manufacturers. These sensors may be effectively applied to test models; however, there is a restriction that the cable run between the signal conditioner and the sensor be limited to 400’ in order to be able to properly read the TEDS. For applications such as weapons test or vibration test on large structures, safety, environment, test article size and other factors often require cable runs in excess of 1000’ that have until now precluded the use of TEDS equipped sensors.

COMMUNICATION DISTANCE LIMITATIONS OF TEDS EEPROM

One-wire Electronically Erasable Programmable Read-Only Memory (EEPROM) devices are utilized as the memory for the TEDS. The Dallas Semiconductor DS2430A 256-bit EEPROM is commonly embedded in IEPE accelerometers for the TEDS memory and will be the device that we refer to in our discussion for this paper.

Referring to **Figure 1**, during normal operation, the signal conditioner is connected to the accelerometer output to measure analog data. Data is transferred serially to and from the TEDS device via a protocol that requires a single wire plus a return. For reading and writing data to the EEPROM, the signal conditioner interface contains a TEDS reader, which consists of a current source, a write switch and a receiver. The current source acts to pull down the line to the “open level” whenever the TEDS reader or the 1-wire device does not short it. The length of the cable run to the transducer is determined by how fast the current source can charge the cable capacitance. The DS2430A achieves specified logic levels with a 4mA current source.

The “short level” is the value that the line reaches when the TEDS reader shorts it. The 1-wire device short level is approximately 0.8V higher than the TEDS reader short level due to the isolation diode D2 in series with the 1-wire device. This diode is necessary to allow the 1-wire device to share the signal lines with an IEPE transducer.

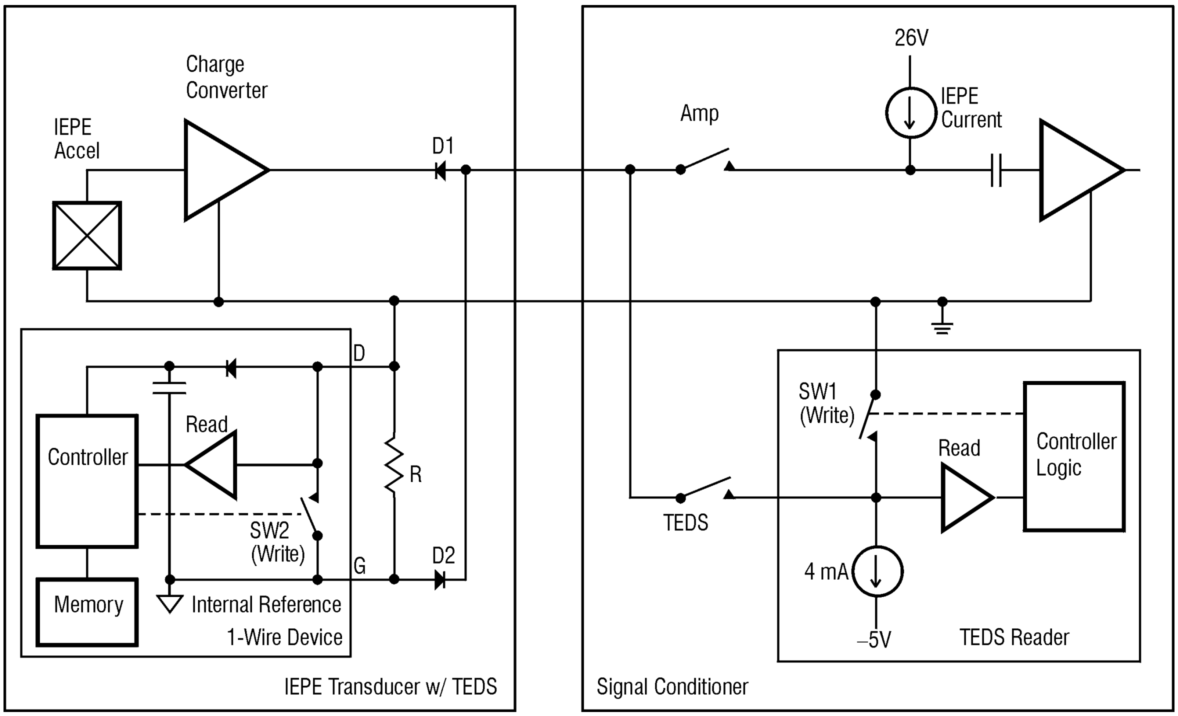

Figure 1: *TEDS 1-Wire Communication between Signal Conditioner and Sensor*

The DS2430A, as with all of the Dallas 1-wire devices, has four types of 1-wire signaling: The Reset and Presence pulses (as part of the reset sequence), Write 0, Write 1 and Read data. The DS2430A must be initialized before sending or receiving data. The initialization consists of a reset pulse sent by the TEDS reader, followed by the presence pulse returned by the 1-wire device. After the presence pulse is received, data may be communicated between the TEDS reader and the DS2430A.

Data communication takes place by adhering to strict timing protocols. The timing diagrams for the read and write timing slots are shown in **Figures 2 and 3**. Communication between the TEDS reader and the 1-wire device for a Read or Write operation is started in an identical manner by initiating a start pulse via TEDS reader switch SW1. For a Write 0 (**Figure 2**), the pulse length must be a minimum of 60µsec. For a Write 1, the pulse must be a maximum of 15µsec. When SW1 opens, the line is driven to the open level (-5V) by the current source in the TEDS reader. In all cases, the data must be maintained to desired logic levels between 15µsec and 60µsec from the beginning of the start pulse.

During a read timing slot (**Figure 3**), SW1 is driven to produce a start pulse that is a minimum of 1µsec in duration. If the 1-wire device wants to deliver logic 1, it does nothing, allowing the line to be driven to the open level by the current source. The line must reach the detection threshold within 15µsec from the beginning of the start pulse or the TEDS reader may erroneously detect logic 0. To deliver logic 0, the 1-wire device must hold the line down with SW2 for a minimum of 15µsec after the beginning of the start pulse. When SW2 opens, the line is driven back to the open level by the current source.

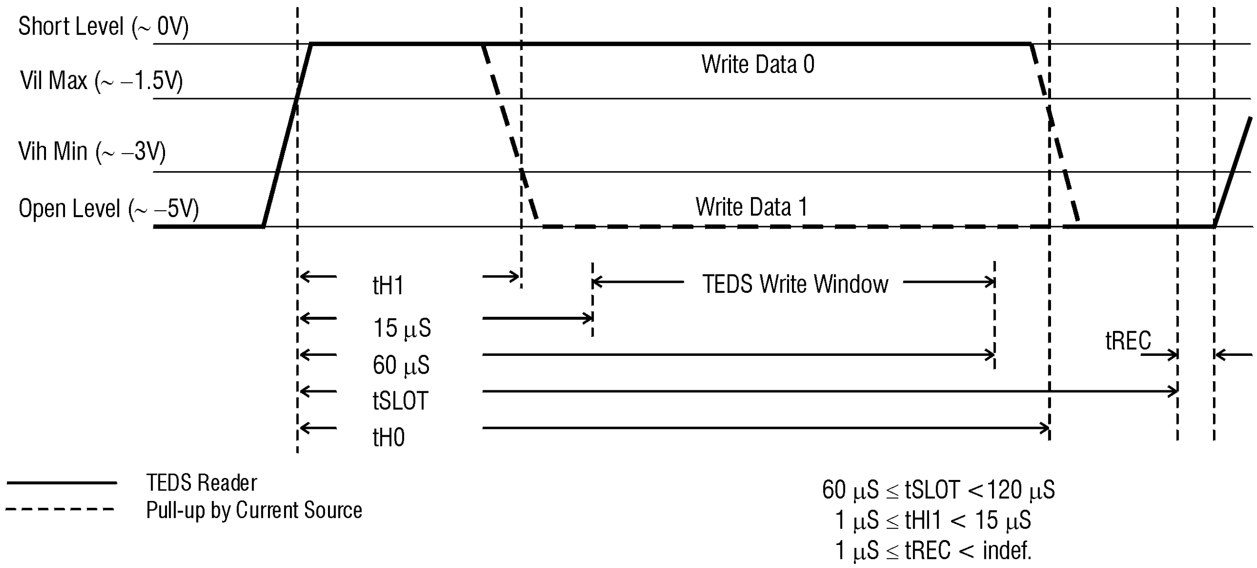

Figure 2: *TEDS Write Timing*

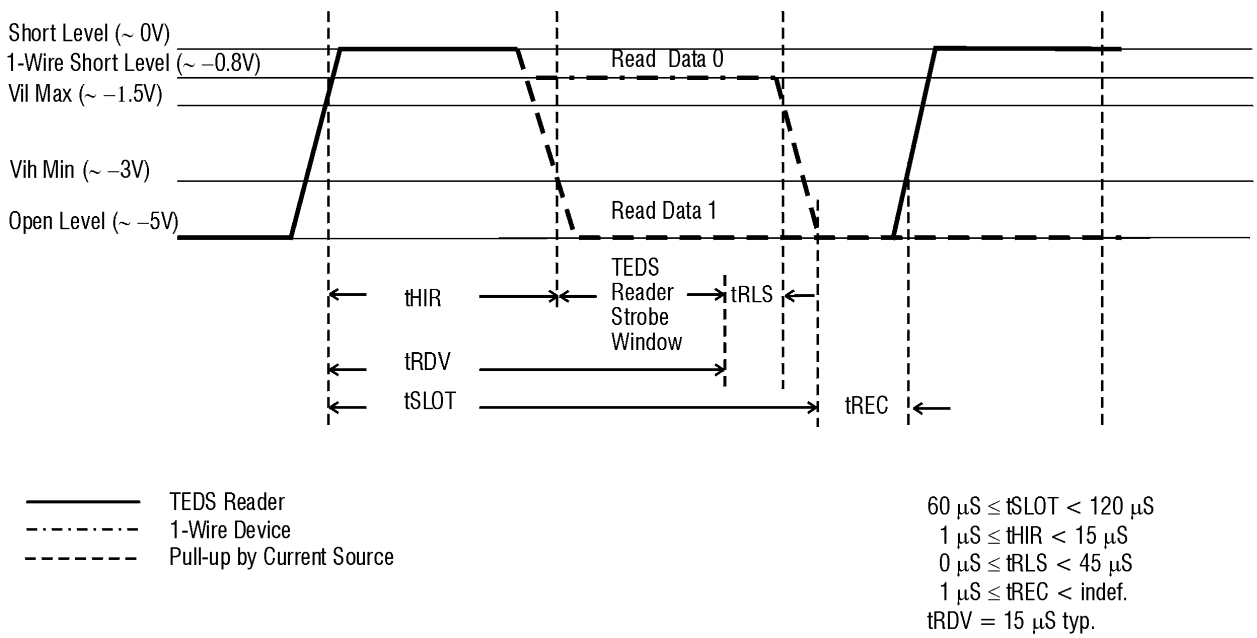

Figure 3: *TEDS Read Timing*

The ability of the interface to adhere to the timing slot restrictions will be limited by the time it takes the current source to drive the line high in the presence of any cable capacitance. The cable capacitance, *Cc*, that can be supported given the charging time, T_C, is given by:

$$Cc = T_c\, I / V_L \qquad (1)$$

Where *I* is the charging current of 4mA. Assuming a start pulse of 5µsec, then the current source has T_C of 10µsec to drive the line to a valid logic 1 level before the DS2430A begins sampling. V_L equals V_{IH} of the 1-wire device (2.2V) plus the voltage drop of the blocking diode (0.8V) or 3V. The evaluation of **Equation (1)** with Tc = 10µsec, I = 4mA and V_L = 3V predicts a maximum cable capacitance of 0.013µF or 444 feet of 30 pF/ft coaxial cable.

$$Ccmax = (10\mu sec)(4mA)/(3V) = 0.013\mu F \qquad (2)$$

Note that this analysis ignores the effects of 1-wire device capacitance and the resistance added across the 1-wire device that compensates for the blocking diode D2.

Figure 4 shows actual scope traces derived by reading a Kistler Model 8772A accelerometer with a conventional TEDS reader developed by Precision Filters over 500' of RG58 30pF/ft coaxial cable. The start pulse width is designed to be 4.3µsec. Note that that the logic 1 level is marginal at 15µsec due to the 4mA current source having to drive the 0.015µF of cable capacitance. Clearly, additional cable capacitance will cause the TEDS reader to erroneously interpret a Read 1 as a Read 0. For a Read 0, the 1-wire device holds the line at the 1-wire short level and releases the line at approximately 25µsec after the start pulse.

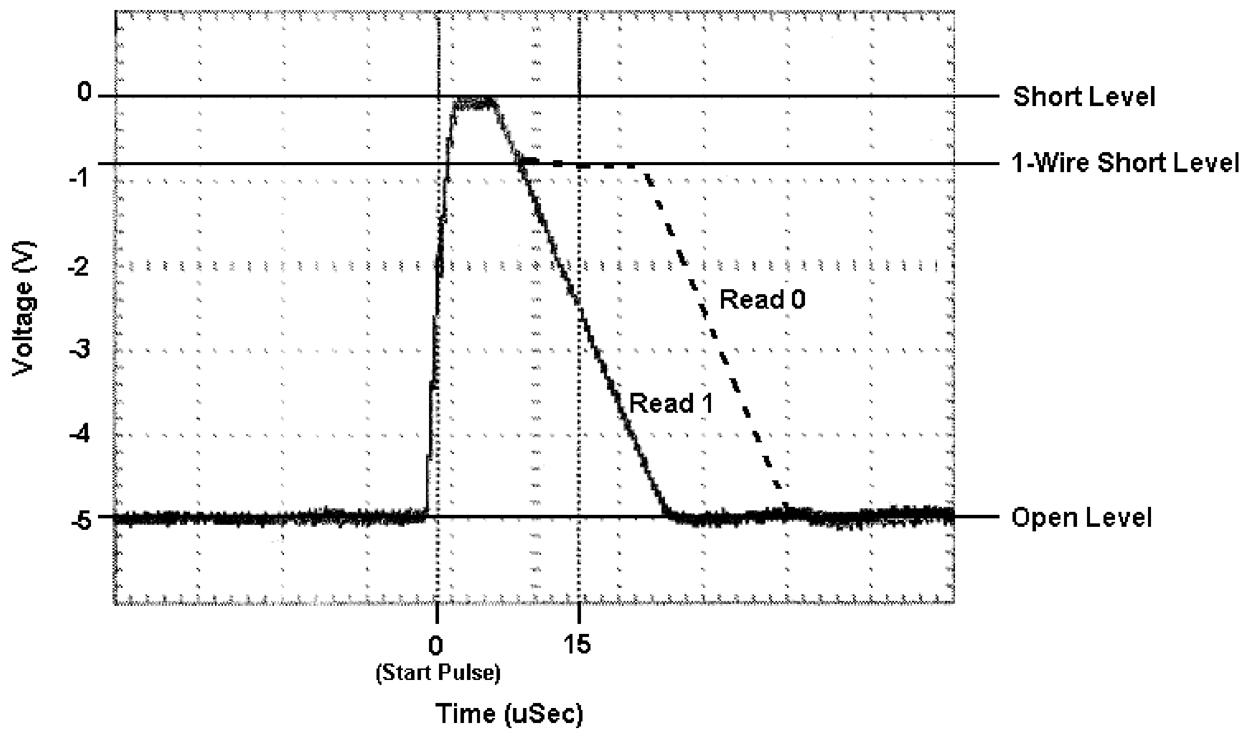

Figure 4: *TEDS Read Waveforms with 500' of RG58 Coaxial Cable*

LONG DISTANCE TEDS

Long Distance TEDS (LDTEDS) communication requires that new methods of detection be utilized by the TEDS reader in the signal conditioner in order to differentiate whether the 1-wire device in the transducer is sending a "1" or a "0". In the discussion above, it is clear that the 4mA current source limits the amount of cable capacitance that is permitted for error free communication. Unfortunately, the only way to send a pulse over a long cable without distorting its width is to provide a higher drive current. We can provide this higher drive current when the TEDS reader must signal to the 1-wire device, but when receiving a signal from the 1-wire device, we must limit the charging current to 4mA to be compliant with DS2430A specifications.

Figure 5 shows the waveforms for reading a 0 and 1 with 47000pF capacitance. When reading back data, a time-based detector would sample the voltage approximately 15µsec after the leading edge of the pulse, and if the voltage were below the detector threshold, it would assume that a zero was being transmitted. If we assume that the detector threshold was -2V (-1.2V for the 1-wire device minus 0.8V for the blocking diode), we would classify both waveforms as a 0. Although the two waveforms are clearly different, we can't tell a 1 from a 0 by sampling at 15µsec.

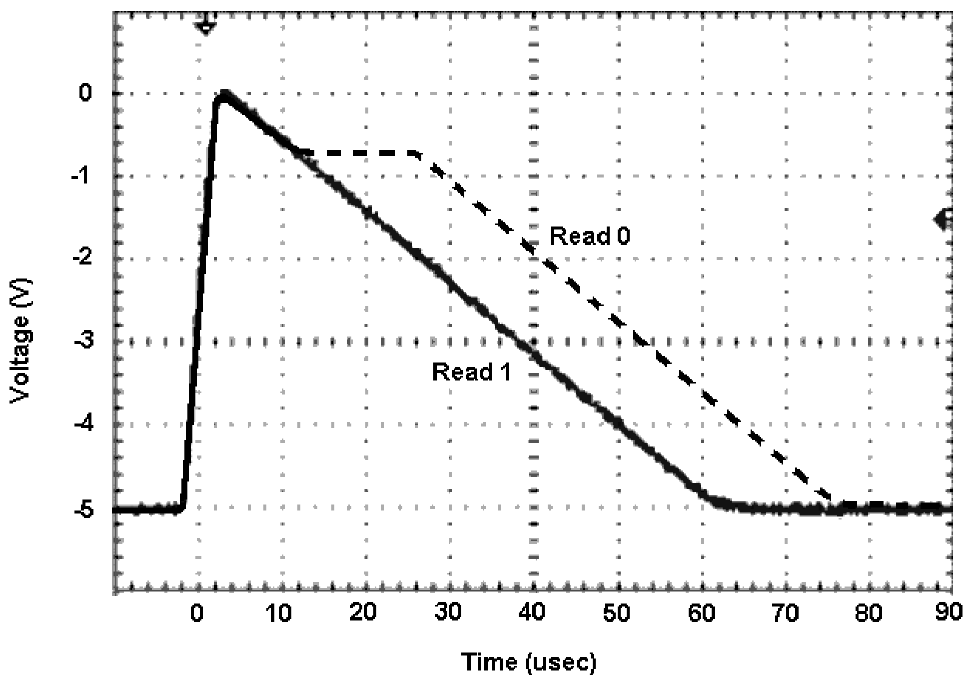

Figure 5: *LDTEDS Read "0" and "1" Waveforms with 47000pF of Load Capacitance*

To make long distance communications possible, an analog-to-digital converter (ADC) and a digital signal processor (DSP) are introduced to sample the communications interface as shown in **Figure 6.** We use an ADC to digitize the waveform, and DSP techniques to analyze the data. Referring to **Figure 7**, after the TEDS reader discharges the cable to the short level, we compute the slope and Y intercept of the voltage versus time line as the cable capacitance charges back to the open level. We use the slope and intercept to compute the 1-wire release time where the line crosses the 1-wire short level. If the release time is less than 15µsec, then a 1 is read from the 1-wire device and if it is greater than 15µsec, then a 0 is read.

To improve noise immunity, we calculate a detection threshold that is unique to each 1-wire device by evaluating the release times associated with the 64-bit ROM in the 1-wire device. The ROM consists of a device ID, device serial number and CRC that contains a mix of 1's and 0's. From the data we set the detection threshold to the midpoint of the computed minimum and maximum release times. Subsequently, we evaluate the release time of each bit against the computed detection threshold to determine if the 1-wire data is a 0 or 1.

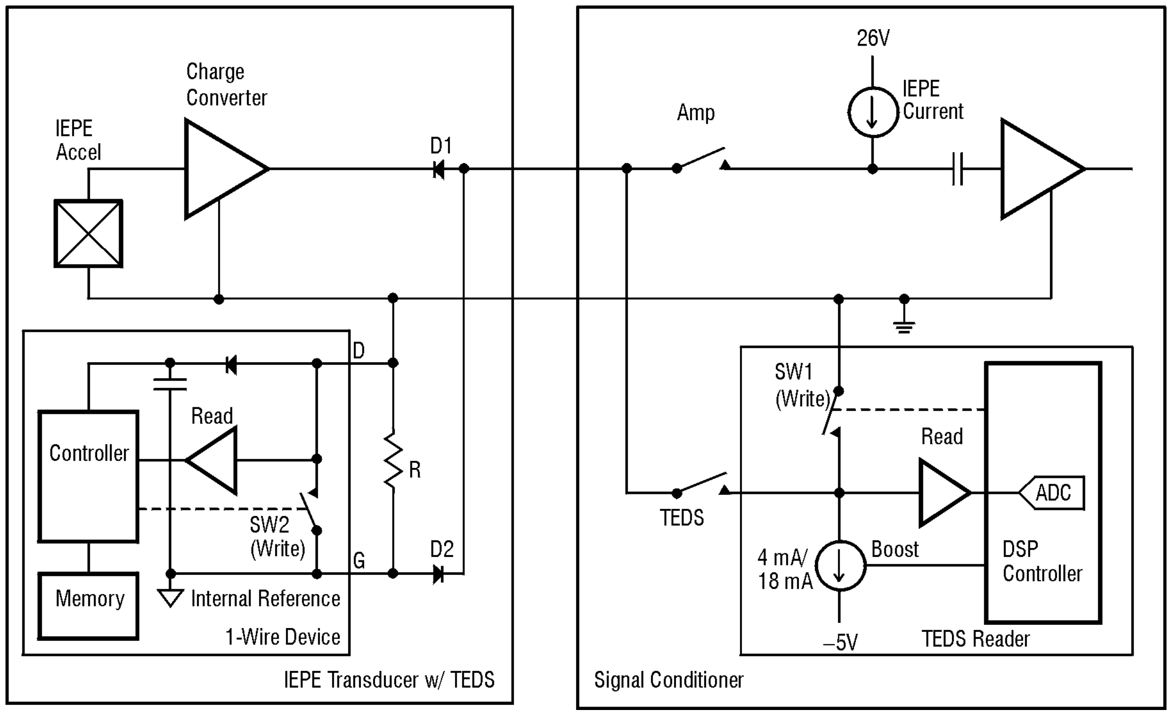

Figure 6: *LDTEDS 1-Wire Communication between Signal Conditioner and Sensor*

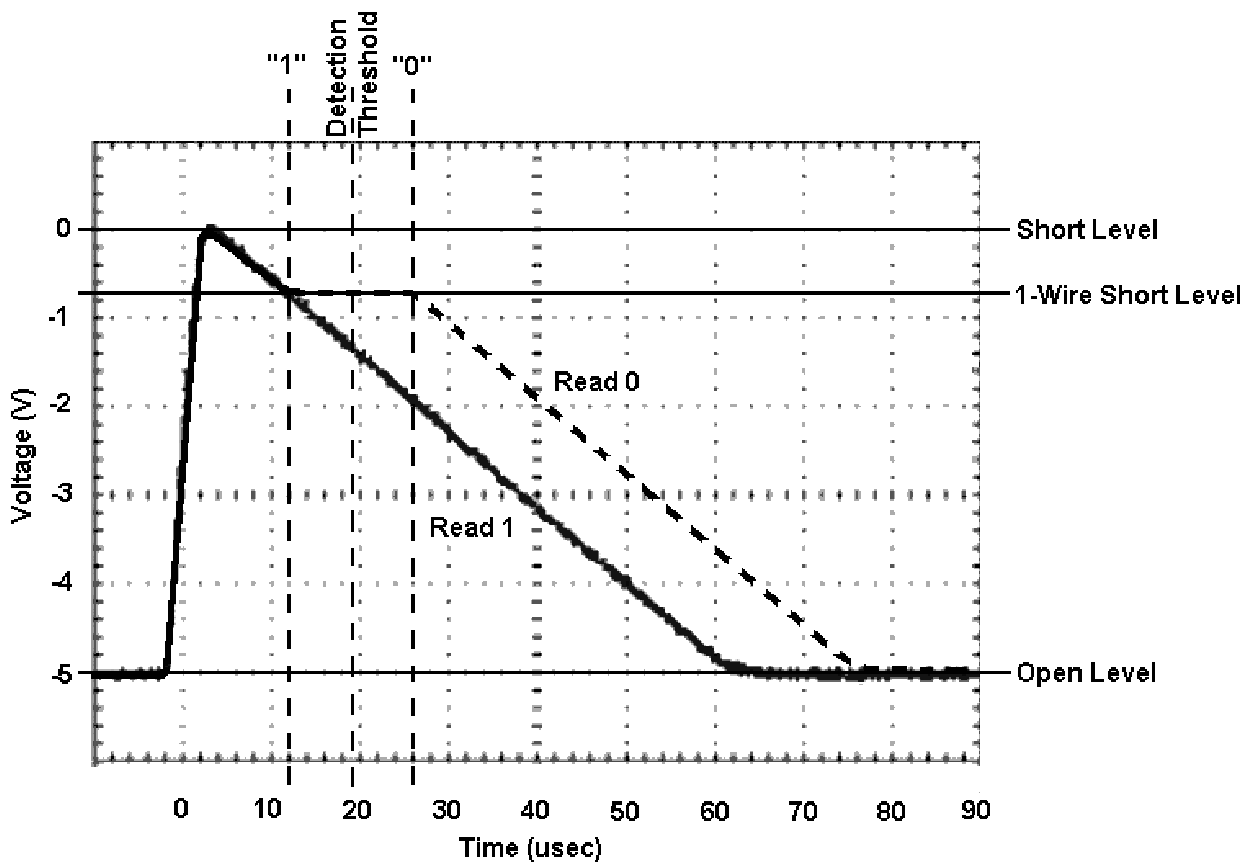

Figure 7: *LDTEDS Read "0" and "1" Waveforms with 47000pF of Load Capacitance*

In order to write data to the 1-wire device over long cable runs, we can provide a current source boost to improve the 1-wire charging time. In our design, the boosted current level is 18mA, which is more than sufficient to drive 1500 feet of 30pF/ft cable to the required logic levels. Assuming that the detection threshold in the 1-wire device is -2.2V, then the Write 1 trailing edge must reach approximately -3V within 15μsec of the leading edge of the pulse. Examining **Figure 8**, we see that this is the case, so there will be no problem writing data to a 1-wire device over a 1500 feet cable.

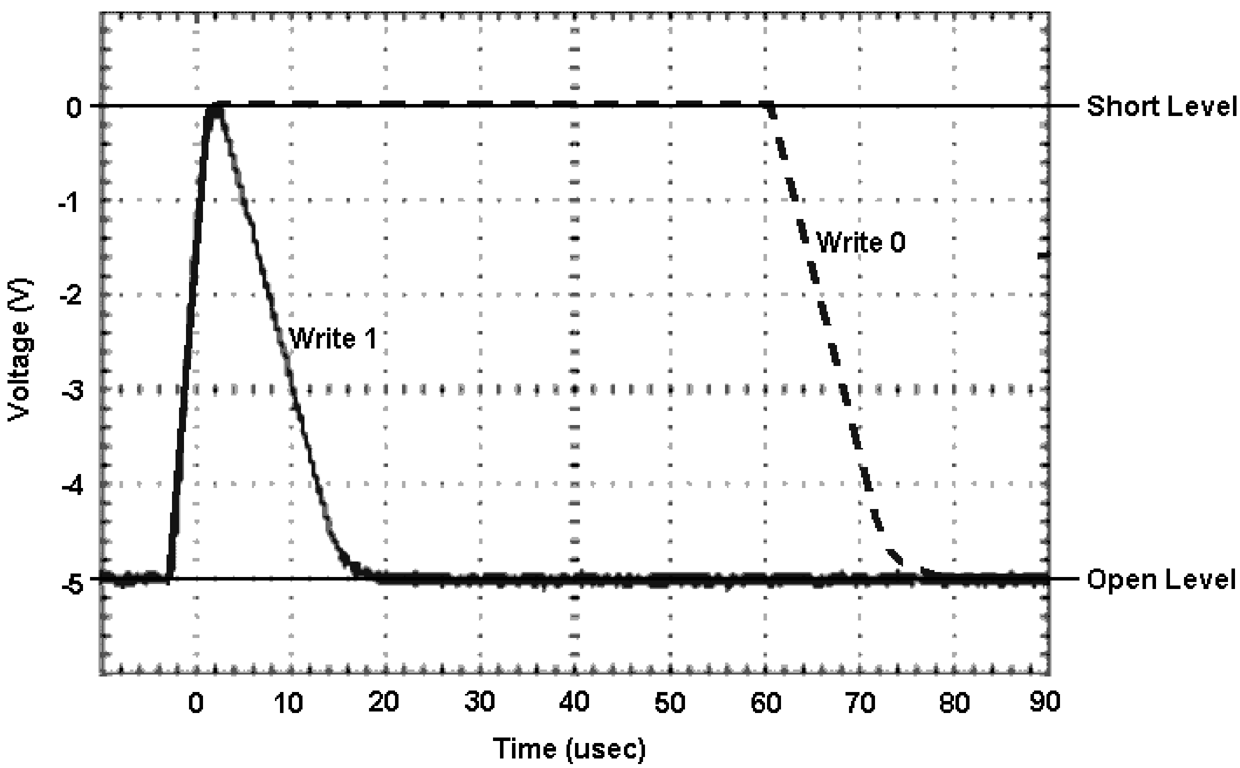

Figure 8: *LDTEDS Write Waveforms with 47000pF of Load Capacitance*

SUMMARY

In this paper we demonstrate the fundamental communication distance limitations of conventional IEEE 1451.4 TEDS hardware. We propose a model for the limitation and compute a maximum communication distance of 444 feet. We introduce Long Distance TEDS (LDTEDS) as a method of extending communication distances for TEDS sensors. The LDTEDS circuitry uses an analog to digital converter to digitize the 1-wire read waveforms and utilizes a digital signal processor to determine if the 1-wire device transmits a 0 or 1. We propose a current source boost circuit to enable writing of data to the 1-wire device at long distance. Our circuit can communicate with TEDS sensors at distances out to 1500 feet.

LDTEDS is commercially available in two Precision Filters products. The 28334A is a 4-channel dual mode charge/IEPE amplifier and the 28316B is a 16-channel IEPE amplifier/filter. Both products are designed for the company's 28000 Signal Conditioning System.

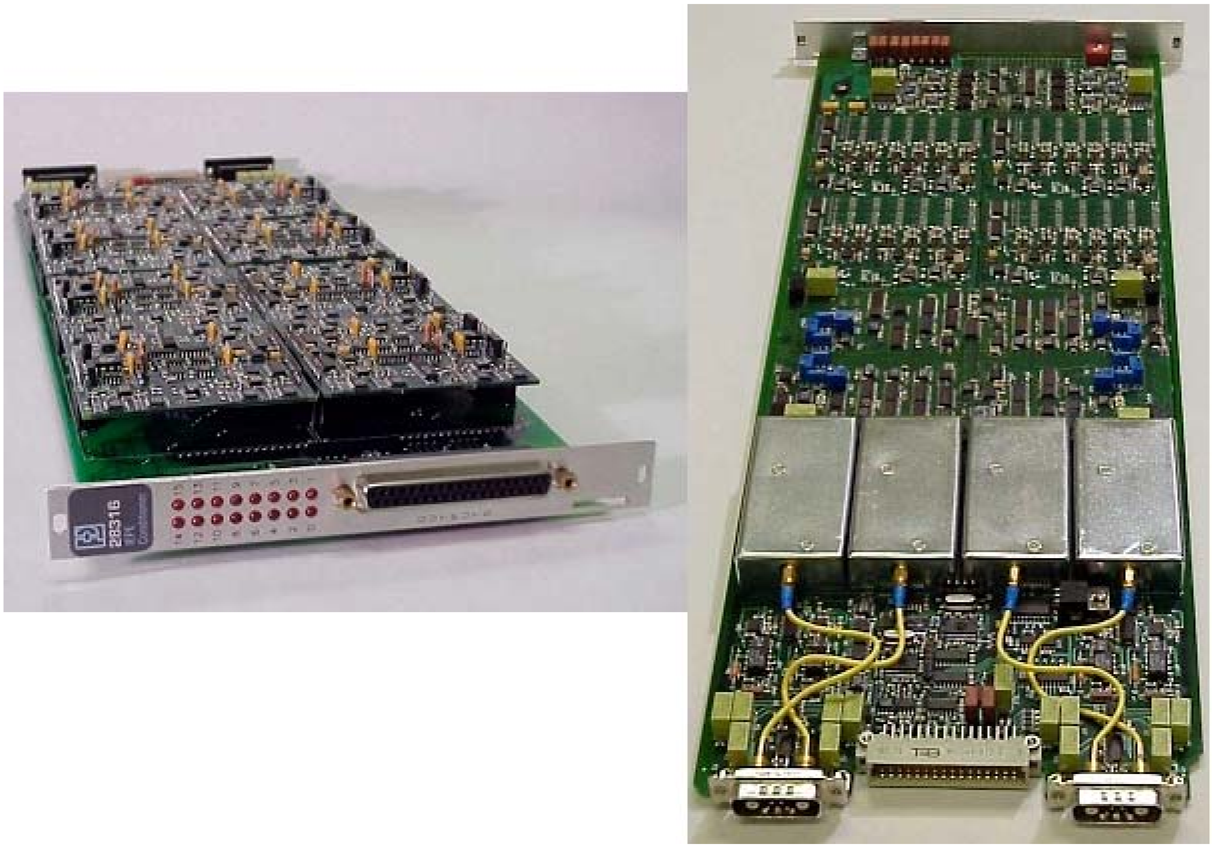

Figure 9: *Precision Filters, Inc. 28316B 16-Channel IEPE Amplifier/Filter and 28334A 4-Channel Dual Mode Dynamic Charge Conditioner with LDTEDS Capability*

ACKNOWLEDGEMENTS

The authors wish to acknowledge Mr. Alan Szary for his contributions toward the development of LDTEDS.

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