Application Report

SLDA035A–June 2015–Revised July 2015

LIN Demonstration Using PGA450Q1EVM Firmware Rev 2.1

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ABSTRACT

This demonstration is intended to illustrate the method of using the internal 8051 MCU firmware of the PGA450-Q1 device to calculate the time of flight (t_{of}) using LIN communication to trigger a distance computation. The settings for short distance measurements have been updated from Rev. 2.0 to Rev 2.1 of the firmware. Differences include an optimized threshold algorithm (optimized for the TI setup) and a decreased blanking time for short distance measurements.

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1 Introduction

Time of flight (t_{of}) is a time estimation of how long the ultrasonic wave transmitted from the transducer takes to travel to the object, and then from the object back to the transducer. Use Equation 1 to calculate the distance between the transducer and object using t_{of}.

$$\text{Distance (meters)} = \left(\frac{t_{of}}{2}\right) \times C_{Air}$$

where

- t_{of} = time of flight in s
- C_{Air} = 343.1 m/s = speed of sound in air at 20°C and absolute pressure 1 bar (1)

To calculate the time of flight, use Equation 2.

$$t_{of}\ (s) = t_{BLANKING} + \left(\text{Location}_{FIFO} \times \text{DOWNSAMPLE} \times \frac{1}{f_S}\right)$$

where

- $t_{BLANKING}$ = 16 µs × (BLANKING_TIME decimal register value)
- Location_{FIFO} = single byte location of interest from the 768 bytes available
- DOWNSAMPLE = downsample rate decimal register value
- f_S = ADC sampling frequency, 1 MHz (2)

2 Setup

The firmware configures the 8051 with the appropriate settings for long and short distance estimation. These operations are initiated by a LIN transmission from the GUI and LIN master on the PGA450Q1EVM to the on-board PGA450-Q1 slave device.

Step 1. Hold the micro in reset and load the firmware into the DEVRAM (OTP programmed to JUMP to DEVRAM so that micro executes instructions from the DEVRAM).

Step 2. Release the micro and send specific LIN transmissions to trigger operations listed in Table 1.

Table 1. LIN Transmit Commands

LIN TX PID	TX DATA	PURPOSE
11	0x(01)	Long distance from 1 m to 5 m
11	0x(00)	Short distance from 15 cm to 1 m
31	7 bytes [D0:D6]	Program 7 bytes of EEPROM data from addresses 0x0400 to 0x0406. These 7 bytes are used to determine the threshold levels during echo detection. The upper nibble of each byte is used for long distance measurement, while the lower nibble is used for short distance measurement.

Step 3. Data can also be retrieved back from the device using specific LIN transmissions as listed in Table 2.

Table 2. LIN Receive Commands

LIN RX PID	BYTES TO BE RECEIVED	PURPOSE
21	2	LIN communication check: data 0x1234 will be received
22	2	Time of Flight data: Data 0xYYYY will be received Data = FFFF implies no object, Data = 0000 implies no burst Time of flight can be determined by converting data into decimal and then multiplying by 1e-6 (timer resolution): t_{of} = hex2dec(YYYY) × 1e-6 s where • YYYY = 0xMSBLSB (MSB at AddrD3 [TX_DATA0] and LSB at AddrD4 [TX_DATA1]) (3)

Step 4. Echo data is stored in an external RAM of 768 bytes (FIFO_DATA from 0 to 767). A valid echo is determined by comparing the FIFO_DATA with the threshold level corresponding to the FIFO_DATA location. The threshold levels typically decrease as the FIFO_DATA location increases as nearer objects produce a stronger echo as compared to objects further away. Figure 1 shows a valid echo compared to the decreasing threshold levels.

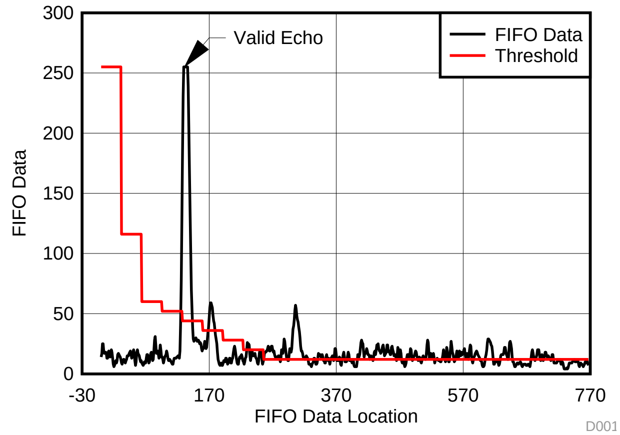


Figure 1. Example of a valid echo logged beyond the threshold

Step 5. For this demonstration to work, ensure that the first 7 bytes of the EEPROM data are programmed with appropriate values to correctly differentiate between valid echoes and noise. Thresholds levels for long distance range can be set up independent to the threshold levels for the short distance range. The upper nibble of EE_DATA[0:6] controls the threshold levels for the long distance instruction, while the lower nibble of EE_DATA[0:6] controls the threshold levels for the short distance instruction.

For short distance instruction, FIFO_CTRL (= 0x07) is set up for Mid-8bit mode with NO ROLLOVER in the firmware. For long distance instruction, FIFO_CTRL (= 0x06) is configured for LSB mode with NO ROLLOVER in the firmware. The relation between FIFO DATA location and threshold value is as stated listed in Table 3.

The EE_DATA[0:6] was programmed with 0x(DC), 0x(6B), 0x(59), 0x(44), 0x(33), 0x(22) and 0x(11) for measurements on the TI set up.

Table 3. FIFO DATA Location of Threshold Ranges

FIFO DATA LOCATION		THRESHOLD LEVEL
START	END	
LONG DISTANCE		
0	31	Ignore echo
32	63	EE_DATA_0[7:4] × 8 + 12
64	95	EE_DATA_1[7:4] × 8 + 12
96	127	EE_DATA_2[7:4] × 8 + 12
128	159	EE_DATA_3[7:4] × 8 + 12
160	191	EE_DATA_4[7:4] × 8 + 12
192	223	EE_DATA_5[7:4] × 8 + 12
224	255	EE_DATA_6[7:4] × 8 + 12
256	767	10
SHORT DISTANCE		
0	3	EE_DATA_0[3:0] × 16 + 4
4	7	EE_DATA_1[3:0] × 16 + 4
8	11	EE_DATA_2[3:0] × 16 + 4
12	15	EE_DATA_3[3:0] × 16 + 4
16	19	EE_DATA_4[3:0] × 16 + 4
20	23	EE_DATA_5[3:0] × 16 + 4
24	63	EE_DATA_6[3:0] × 16 + 4
64	767	4

Step 6. The preferred method of determining the threshold levels is to observe the FIFO DATA for a test set-up with no object (*empty set up*), and then define the appropriate levels. The raw FIFO DATA can be viewed by placing the micro in reset and clicking on the *Read and save FIFO data to file* button (this feature requires MICROSOFT OFFICE 2007 or a later version to be installed). This procedure will need to complete for both long and short distance. Plots for the empty set up on the TI bench are shown in Figure 2 and Figure 3 for reference:

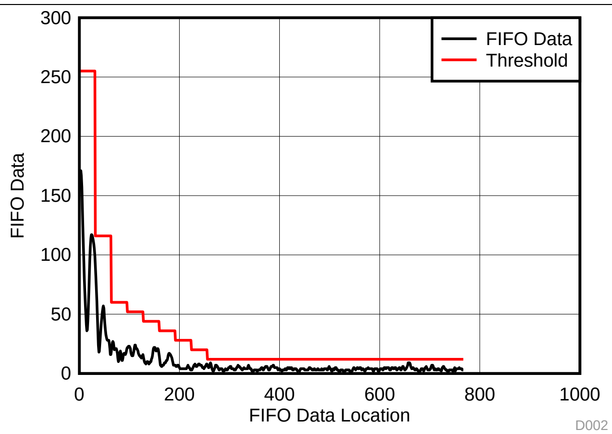


Figure 2. Empty Setup for Long Distance

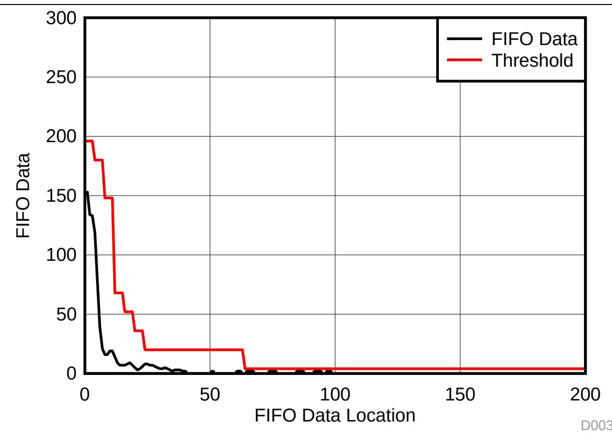


Figure 3. Empty Setup for Short Distance

3 Procedure

Step 1. Supply power to the EVM and open the GUI.

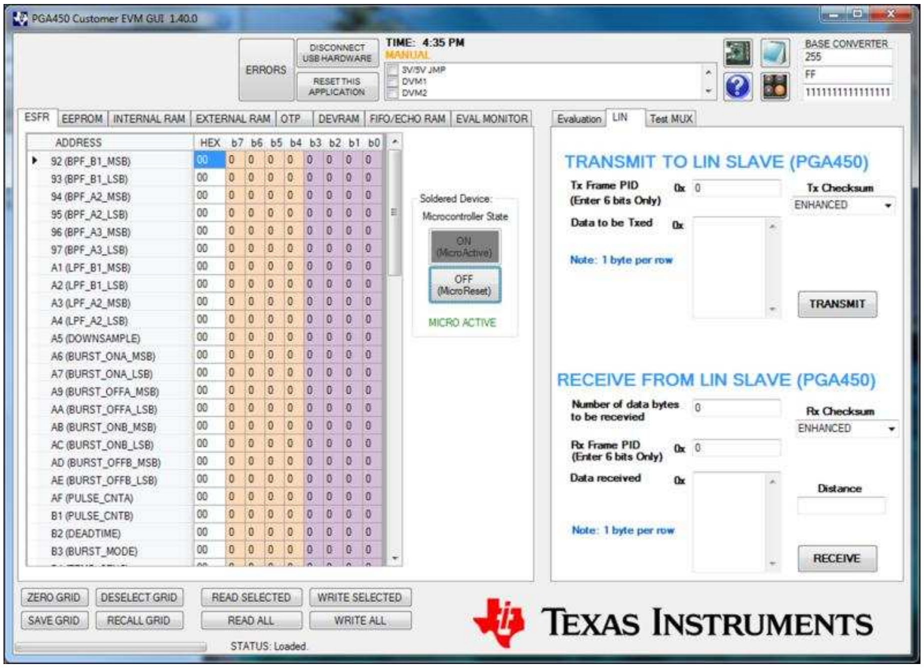


Figure 4. Settings When First Opening GUI

Step 2. Place the micro in reset by clicking *OFF (MicroReset)* from the ESFR tab.

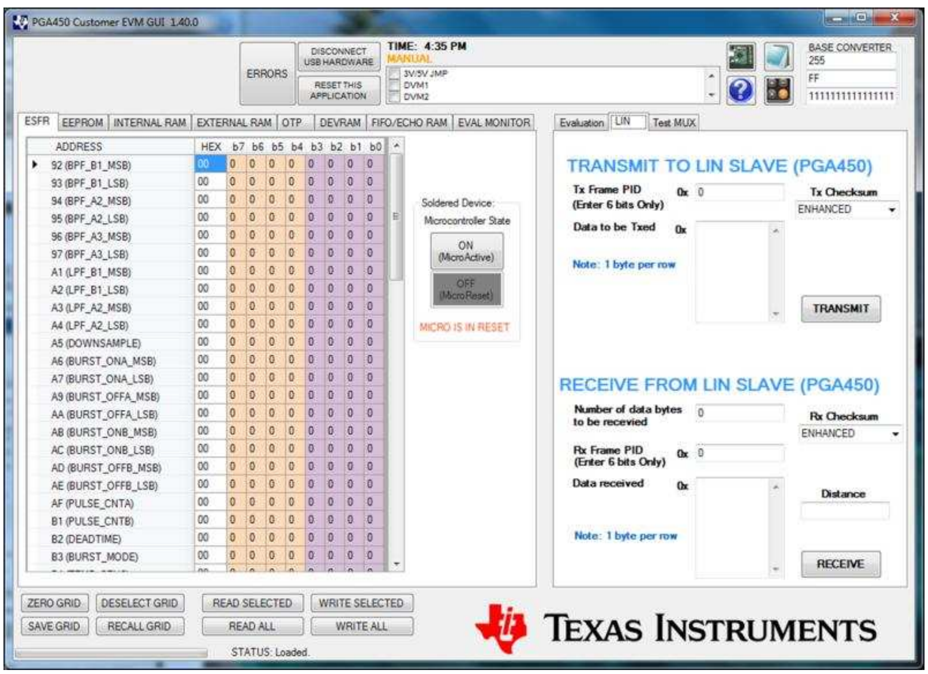


Figure 5. Placing Microcontroller in Reset State Under ESFR Tab

Step 3. Check status of OTP by clicking *Check OTP Status* from the OTP tab. Verify the response reads *PROGRAMMED to jump to DEVRAM* or *EMPTY*). If the response reads *PROGRAMMED*, replace the PGA450-Q1 device on the EVM with a new unit.

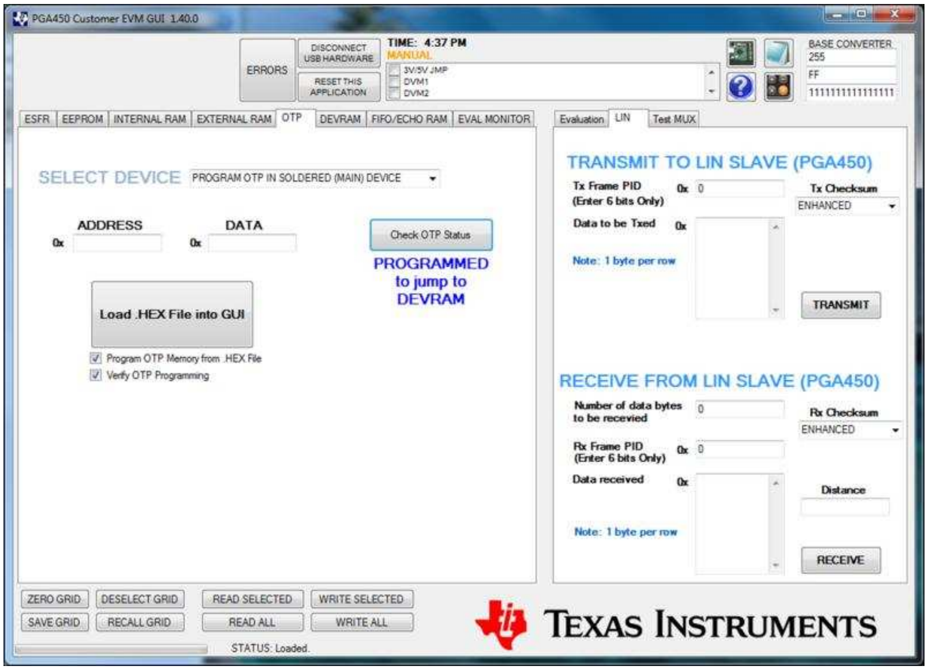


Figure 6. Checking OTP Status Under OTP Tab

Step 4. Load the program into the DEVRAM by clicking *Load .HEX File into GUI* from the DEVRAM tab. If the OTP status was *PROGRAMMED to JUMP to DEVRAM* in the previous step, then checking the *PROGRAM OTP Memory Also* box is not required (as shown in Figure 7). If the OTP status was EMPTY, then this box must be checked and 8 V must be supplied on the VPROG OTP pin. A provision on the EVM provides 8 V to the VPROG_OTP pin through jumper settings.

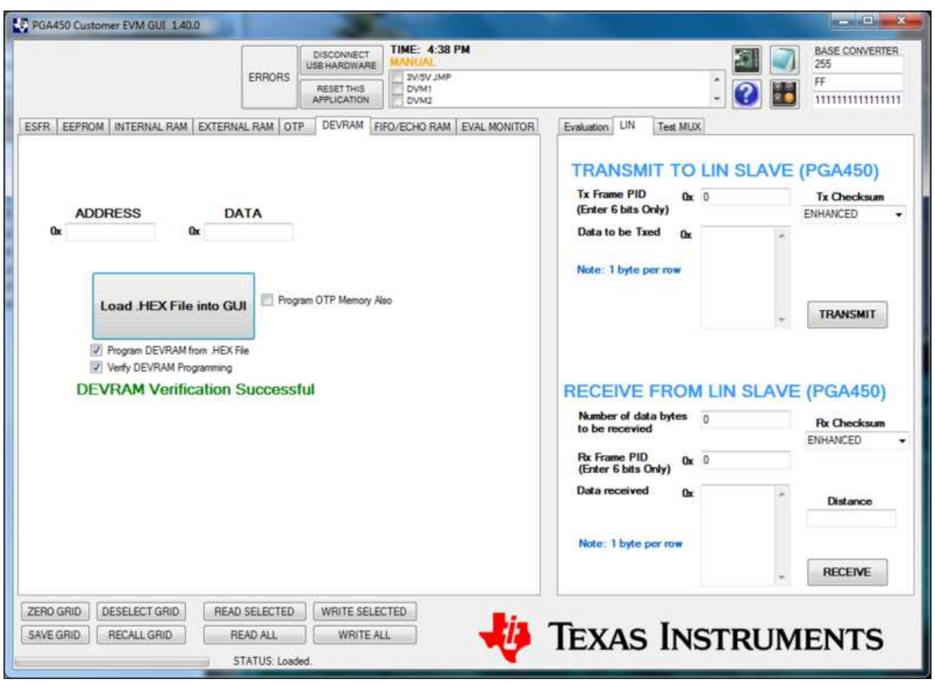


Figure 7. Loading .HEX File if OTP is Programmed to Jump to DEVRAM

Step 5. Release the micro out of reset by clicking *ON (MicroActive)* from the ESFR tab.

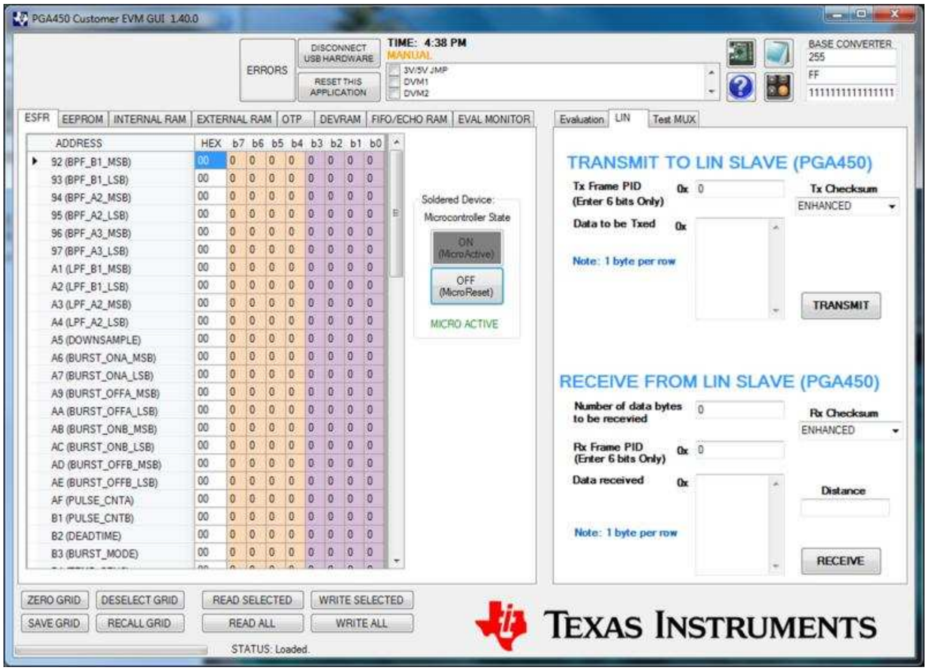


Figure 8. Placing the Microcontroller to the Active State After Loading .HEX File

Step 6. Send a LIN transmission by clicking the *RECEIVE* button with a PID = 21 and the number of bytes to be received = 2. As shown in Figure 9, 0x1234 should be received, verifying that the LIN communication is working.

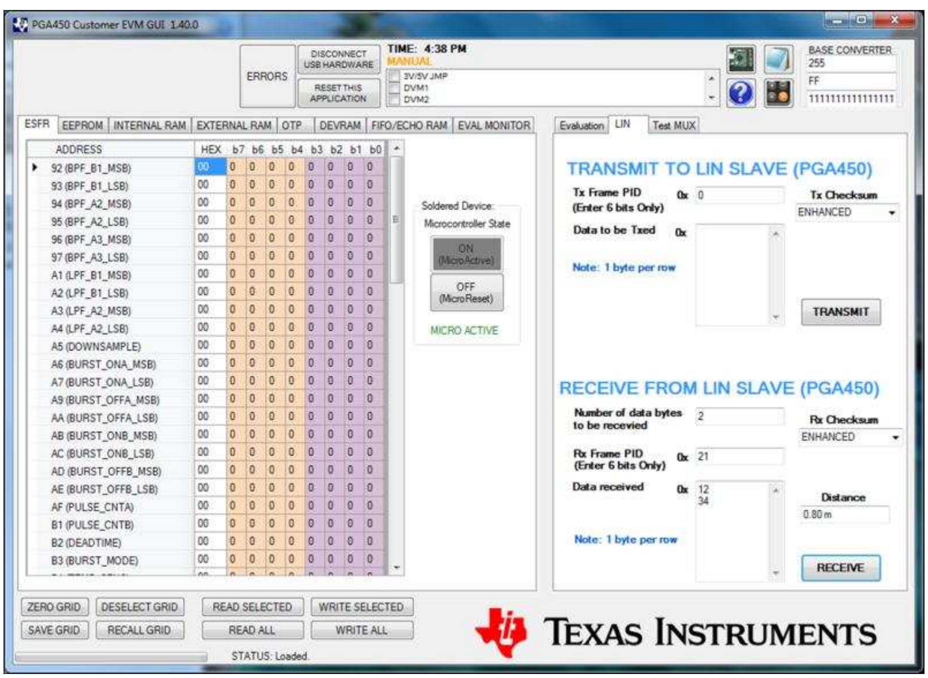


Figure 9. LIN Receive Command Verifying Communication

Step 7. Send a LIN transmission by clicking the *TRANSMIT* button with a PID = 11 and the *Data to be Txed* = 0x01 which triggers a long distance measurement.

Step 8. Next, send a LIN transmission by clicking the RECEIVE button with PID = 22 and bytes to be received = 2. The time of flight in micro seconds in the format of 0xYYYY and distance in meters is provided.

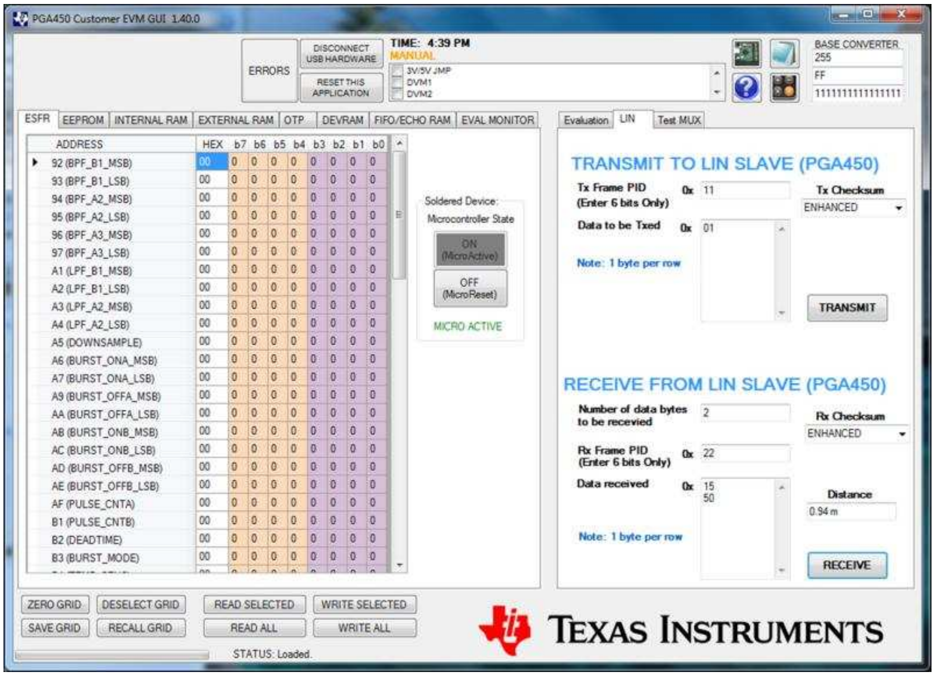


Figure 10. LIN Transmission Example of a Long Distance Measurement

Step 9. If the EEPROM must be programed for echo threshold comparison, send a LIN transmission by clicking the *TRANSMIT* button with a PID = 31 and the *Data to be Txed* with the seven data bytes. This command programs EEPROM locations 0x0400 to 0x0406 with the transmitted data.

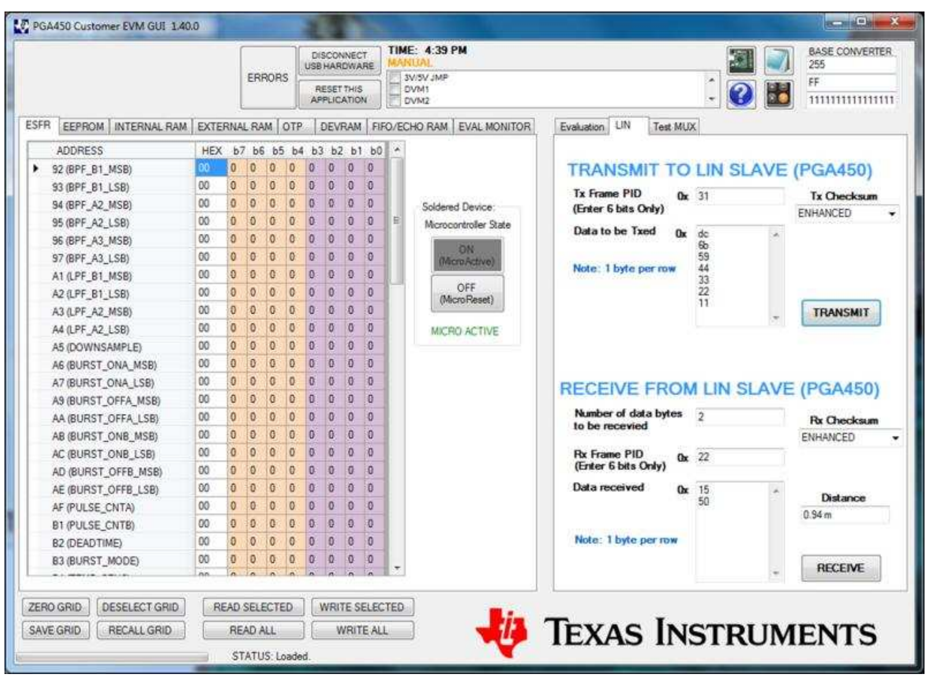
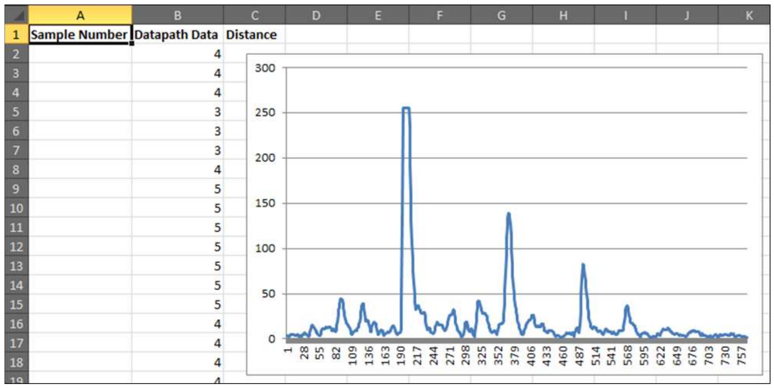


Figure 11. LIN Transmit to Program EEPROM-Based Thresholds

Step 10. To retrieve the echo data, put the micro in reset and click on the *Read and Save FIFO data to File* button from the FIFO/ECHO tab which opens an Excel® file with the data.

NOTE: Microsoft® Office 2007 or newer version is needed.



This is example snippet showcases results from a different experiment, but was exported using the same GUI.

Figure 12. Example Snippet of FIFO Data Exported to Excel Spreadsheet

Revision History

Changes from Original (#IMPLIED) to A Revision **Page**

- Changed the units for time of flight (t_{of}) 2

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

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