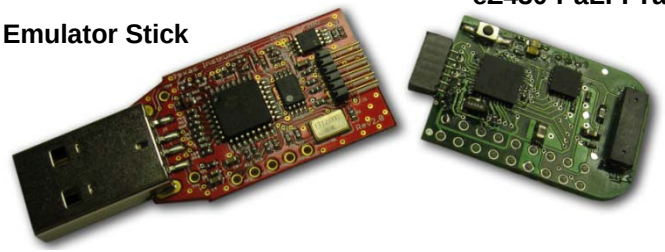
TMS37157

PaLFI – Passive Low Frequency Interface Device

eZ430-TMS37157

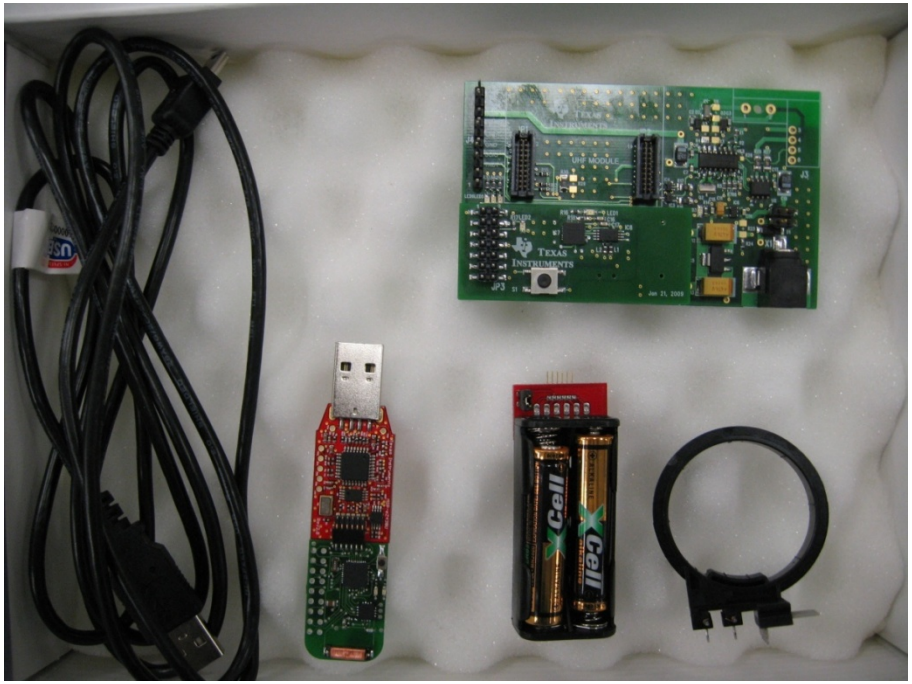
eZ430 Emulator Stick

eZ430-PaLFI Target Board



Development Kit Includes:

- eZ430 Emulator Stick
- eZ430 Battery Board
- eZ430-PaLFI Target Board
- USB RFID Reader with Antenna
- USB cable
- Power Supply Cable (for onboard Amp Circuit)

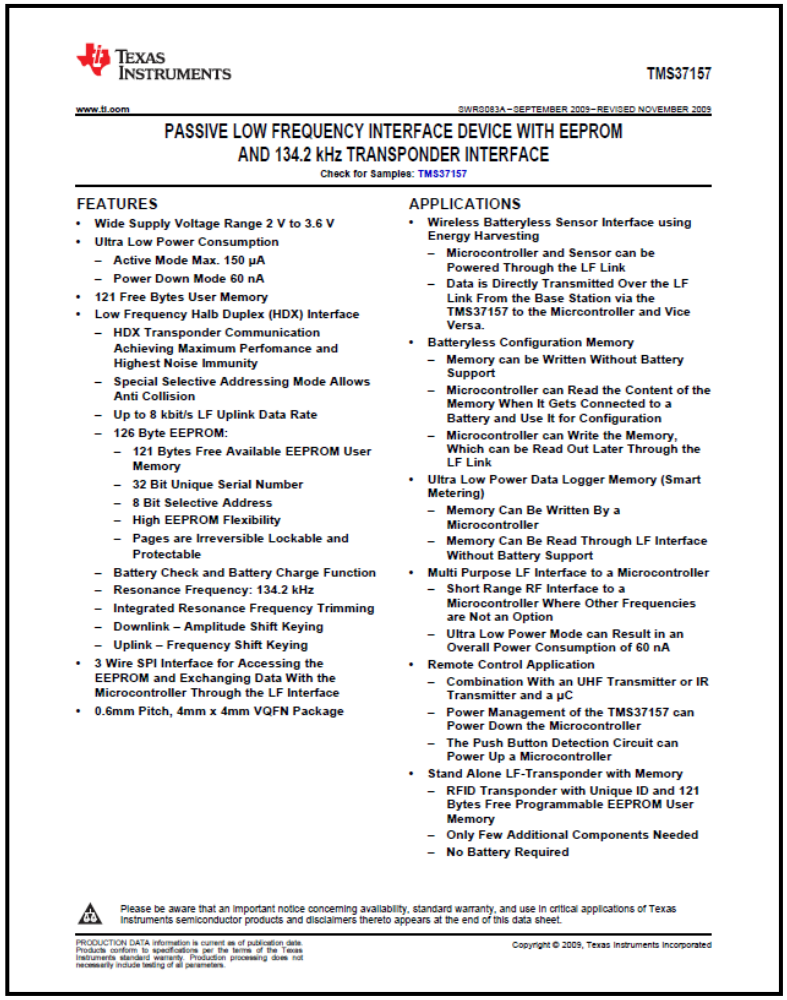


TMS37157

PaLFI – Passive Low Frequency Interface Device

Collateral

- Data Sheet and Manual for PaLFI and MSP430F2274
- Application Reports and example source code in C for all transponder functions
- SPI library for using the TMS37157 with an MSP430
- Reader/writer base station protocol description
- Recommended application circuit for PaLFI with RF guideline



TEXAS INSTRUMENTS TMS37157

www.ti.com SWRS083A–SEPTEMBER 2009–REVISED NOVEMBER 2009

PASSIVE LOW FREQUENCY INTERFACE DEVICE WITH EEPROM AND 134.2 kHz TRANSPONDER INTERFACE

Check for Samples: TMS37157

FEATURES

- Wide Supply Voltage Range 2 V to 3.6 V
- Ultra Low Power Consumption
  - Active Mode Max. 150 µA
  - Power Down Mode 60 nA
- 121 Free Bytes User Memory
- Low Frequency Halb Duplex (HDX) Interface
  - HDX Transponder Communication Achieving Maximum Perfomance and Highest Noise Immunity
  - Special Selective Addressing Mode Allows Anti Collision
  - Up to 8 kbit/s LF Uplink Data Rate
  - 126 Byte EEPROM:
    - 121 Bytes Free Available EEPROM User Memory
    - 32 Bit Unique Serial Number
    - 8 Bit Selective Address
    - High EEPROM Flexibility
    - Pages are Irreversible Lockable and Protectable
  - Battery Check and Battery Charge Function
  - Resonance Frequency: 134.2 kHz
  - Integrated Resonance Frequency Trimming
  - Downlink – Amplitude Shift Keying
  - Uplink – Frequency Shift Keying
- 3 Wire SPI Interface for Accessing the EEPROM and Exchanging Data With the Microcontroller Through the LF Interface
- 0.6mm Pitch, 4mm x 4mm VQFN Package

APPLICATIONS

- Wireless Batteryless Sensor Interface using Energy Harvesting
  - Microcontroller and Sensor can be Powered Through the LF Link
  - Data is Directly Transmitted Over the LF Link From the Base Station via the TMS37157 to the Microcontroller and Vice Versa.
- Batteryless Configuration Memory
  - Memory can be Written Without Battery Support
  - Microcontroller can Read the Content of the Memory When It Gets Connected to a Battery and Use It for Configuration
  - Microcontroller can Write the Memory, Which can be Read Out Later Through the LF Link
- Ultra Low Power Data Logger Memory (Smart Metering)
  - Memory Can Be Written By a Microcontroller
  - Memory Can Be Read Through LF Interface Without Battery Support
- Multi Purpose LF Interface to a Microcontroller
  - Short Range RF Interface to a Microcontroller Where Other Frequencies are Not an Option
  - Ultra Low Power Mode can Result in an Overall Power Consumption of 60 nA
- Remote Control Application
  - Combination With an UHF Transmitter or IR Transmitter and a µC
  - Power Management of the TMS37157 can Power Down the Microcontroller
  - The Push Button Detection Circuit can Power Up a Microcontroller
- Stand Alone LF-Transponder with Memory
  - RFID Transponder with Unique ID and 121 Bytes Free Programmable EEPROM User Memory
  - Only Few Additional Components Needed
  - No Battery Required

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PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of the Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

Click page for TMS37157 Data Sheet ➔

TEXAS INSTRUMENTS

What is a PaLFI?

- **A PaLFI is a Passive Low Frequency Interface to a microcontroller.**
- **It is a Packaged Passive, Low Frequency Transponder IC.**
- **It is a battery charge/power management IC that derives its current from a magnetic field.**
- **It is a Low Frequency Wake Receiver for activating microcontrollers which in turn, can direct other devices (like a UHF radio) to turn on and communicate with other devices.**

What can my customers do with it?

- **Customers can use the PaLFI to:**
  - **Create any classic passive RFID solution, plus:**
    - **Create semi-active devices which are “woken up” when they enter certain areas**
    - **Create systems which facilitate single stream end of line configuration and/or programming of microcontrollers while product is in the box.**
    - **Create Rechargeable Data Logging systems which extract the data over the air**
    - **Etc.**
    - **The possibilities are only limited by the imagination!**

How does it work?

- **The system works by Electromagnetic Induction. (this means it uses the magnetic field to transfer energy and follows the laws of Faraday, Lenz, Gauss, Ampère and Maxwell)**
- **The basic components of the system are comprised of:**
  - **A Base Station (also called a Reader)**
  - **A magnetic dipole (or loop) antenna coil on the Base Station**
  - **A Target Board (also called a Tag or ID Device), which with this device will also be used with a microcontroller (like an MSP430)**
  - **A magnetic dipole (or loop) antenna coil on the Tag.**

Tell Me More!

- **TMS37157 PaLFI System Technical Training**

Agenda

- Hardware Details
  - TMS37157 (PaLFI IC)
  - ez430-TMS37157 (PaLFI + MSP430 Target Board)
  - TMS3705A1DRG4 (LF Reader/Writer IC)
  - RI-ACC-ADR2 (Base Station or Reader/Writer)
- Command/Protocol Details
  - PC to/from GUI level
  - Hardware level (MSP430 to/from TMS3705A1DRG4)
  - Firmware Considerations

TMS37157

PaLFI – Passive Low Frequency Interface Device

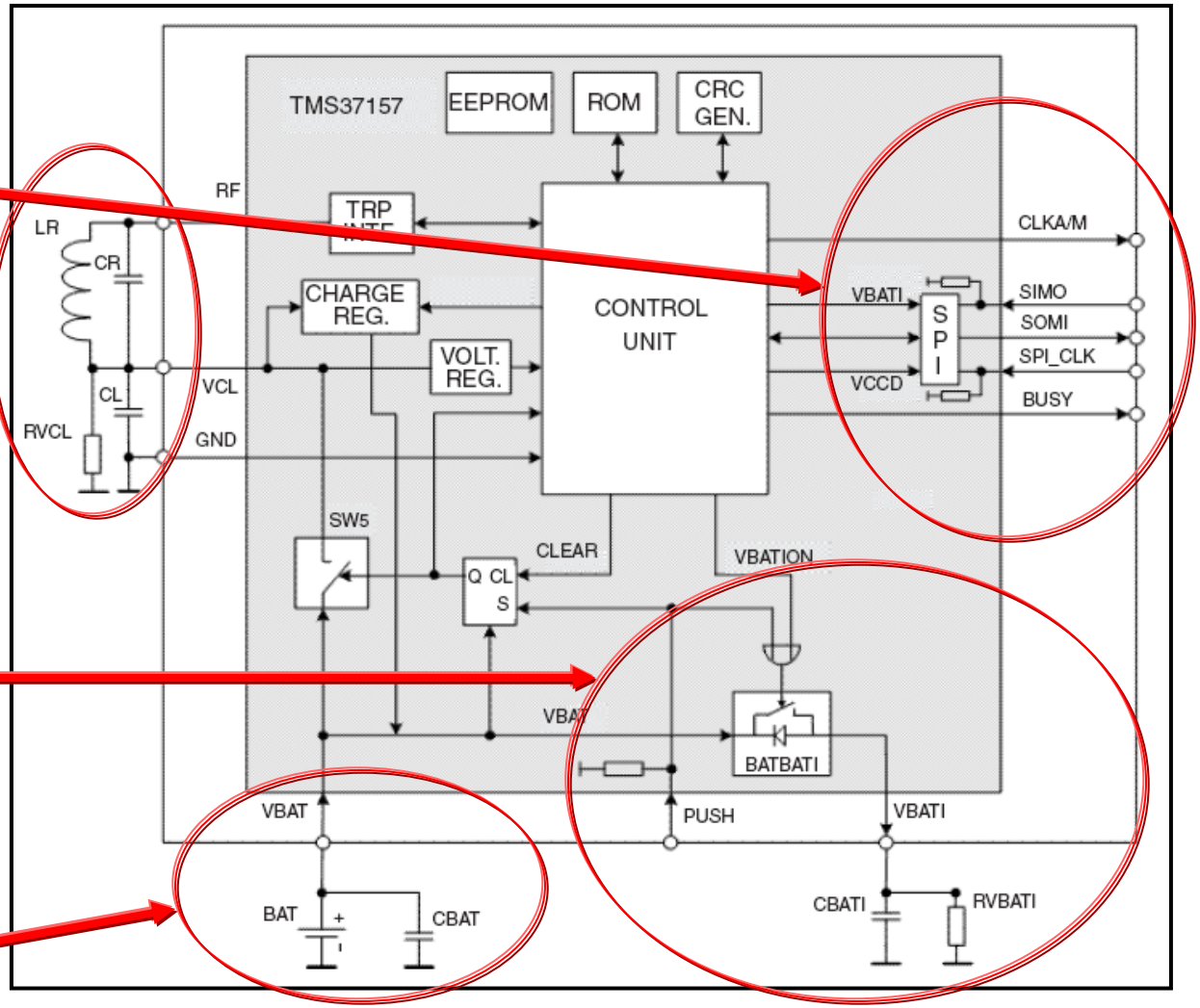
TMS37157
Internal Block Diagram

SPI Interface with Microcontroller

Resonant Tank Circuit and Charge Capacitor

Power for Microcontroller & Battery Charge Management

Battery Connection



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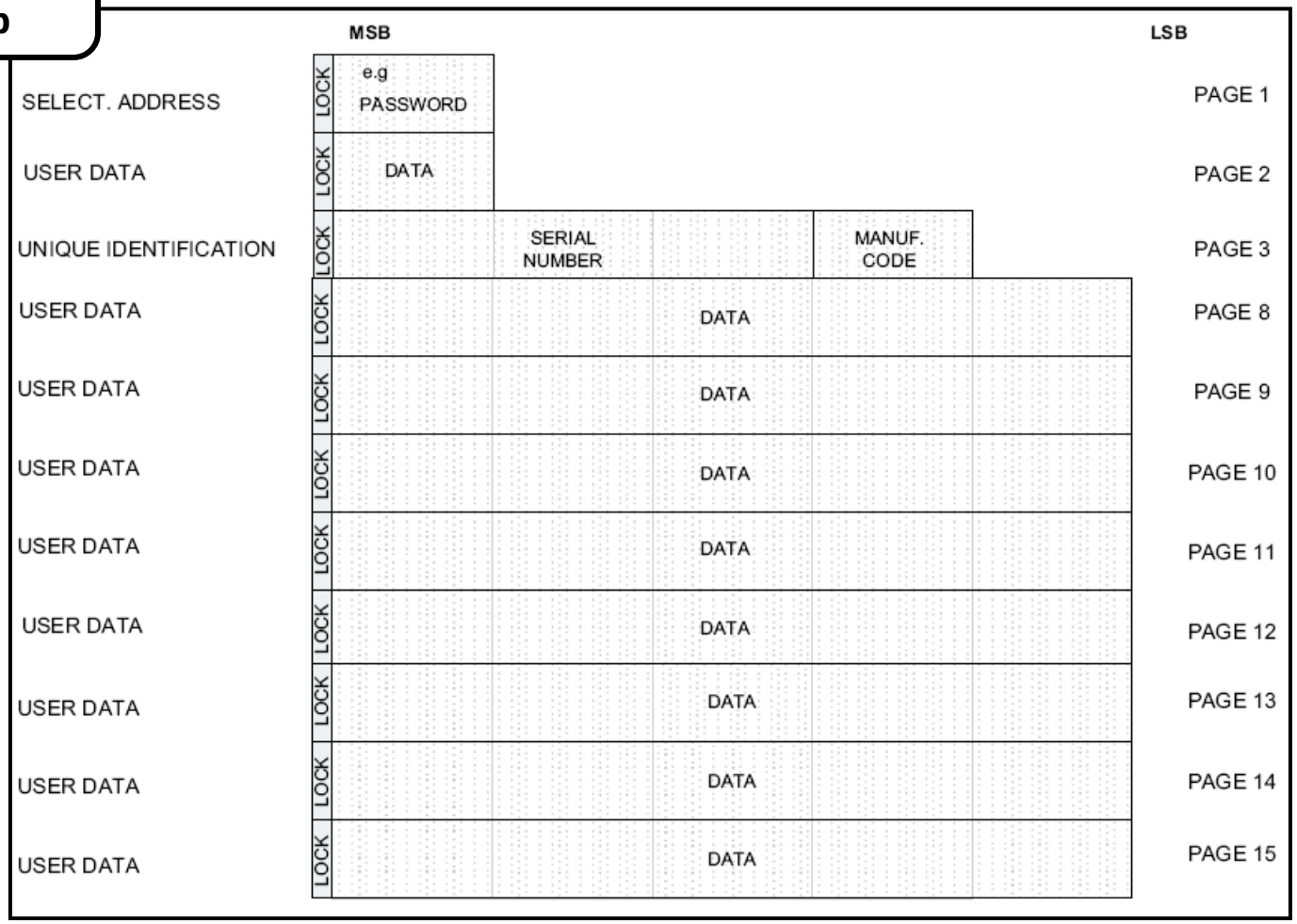
PaLFI – Passive Low Frequency Interface Device

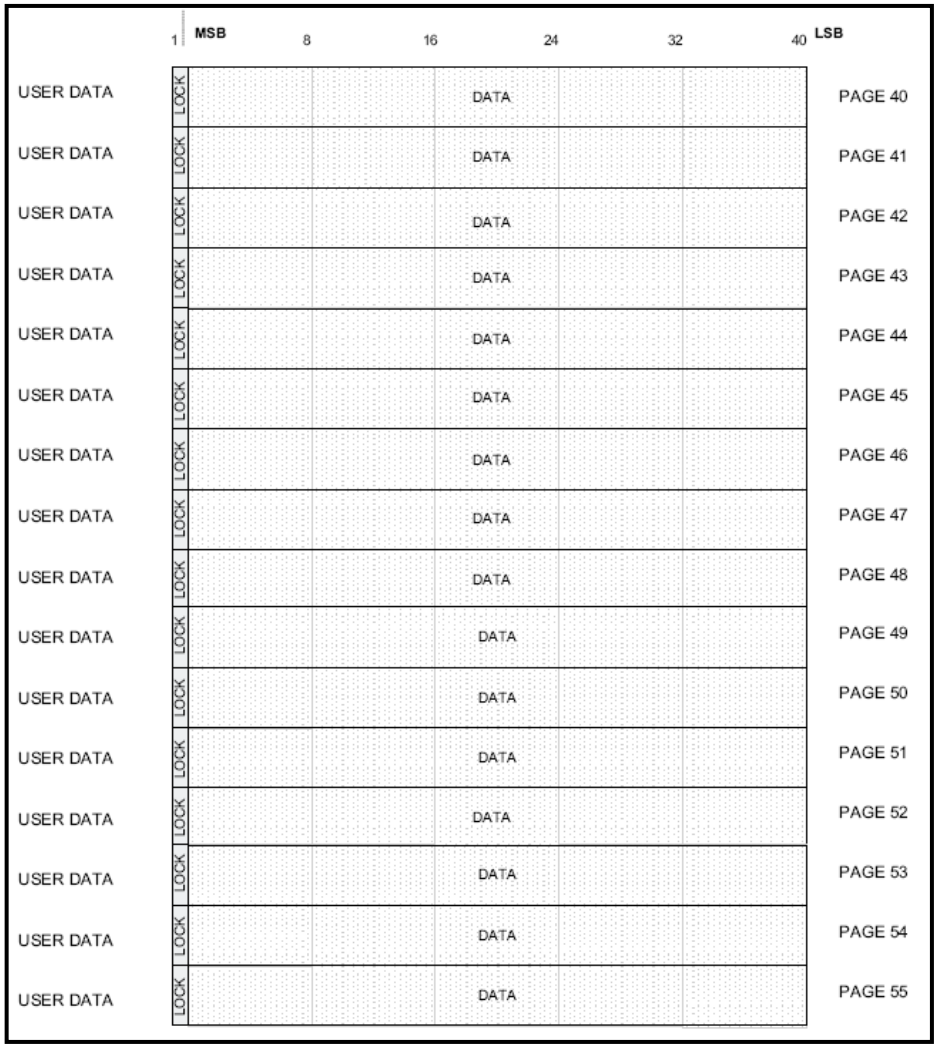
TMS37157
User Memory Map



TMS37157

PaLFI – Passive Low Frequency Interface Device

TMS37157
User Memory Map (cont.)



TMS37157

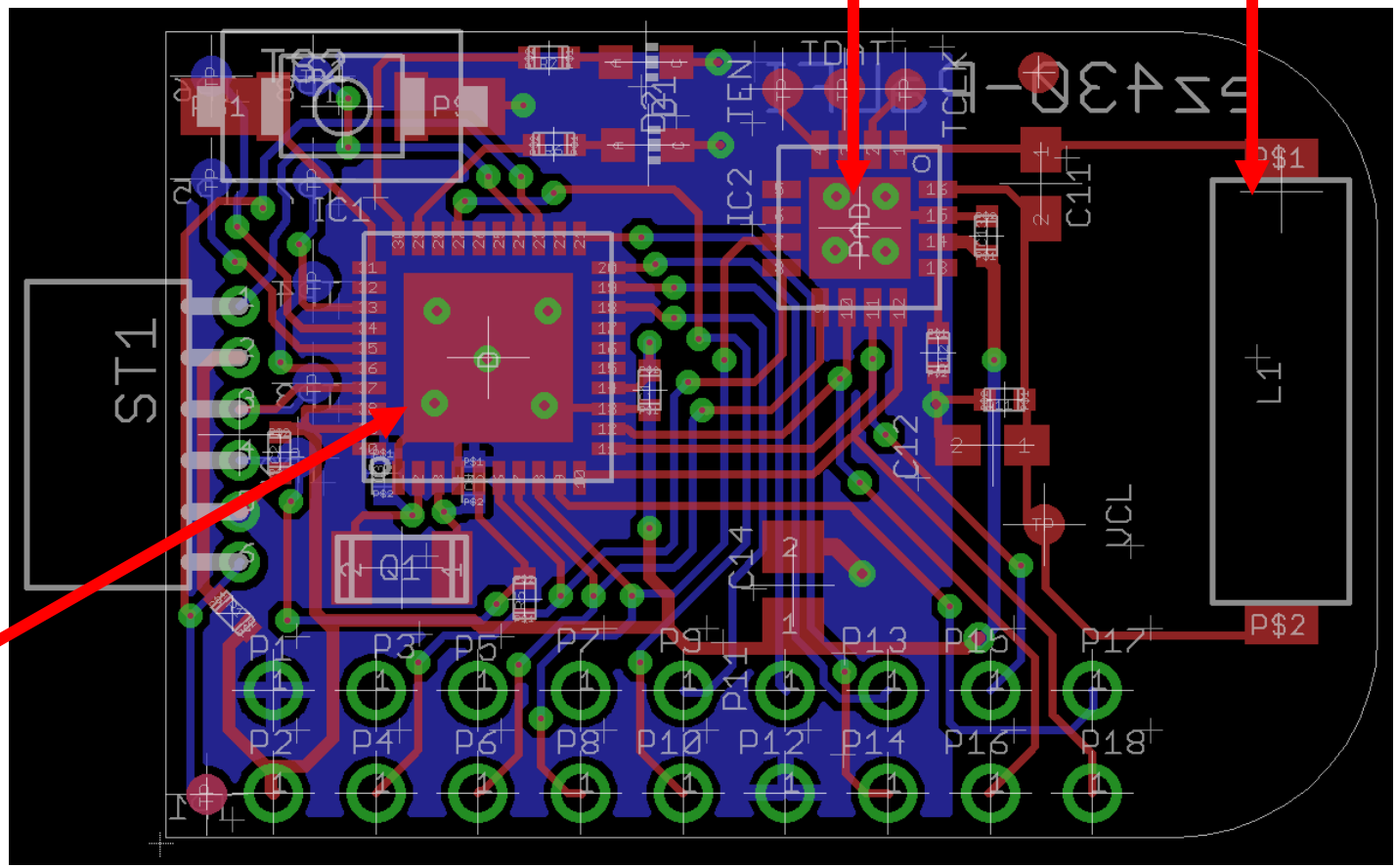
PaLFI – Passive Low Frequency Interface Device

ez430-TMS37157 Target Board (ID Device)

2.66mH Inductor

TMS37157

(PaLFI Antenna Coil)



MSP430F2274

TMS3705A1DRG4

Low Frequency Base Station/Reader IC

- **Key Features**

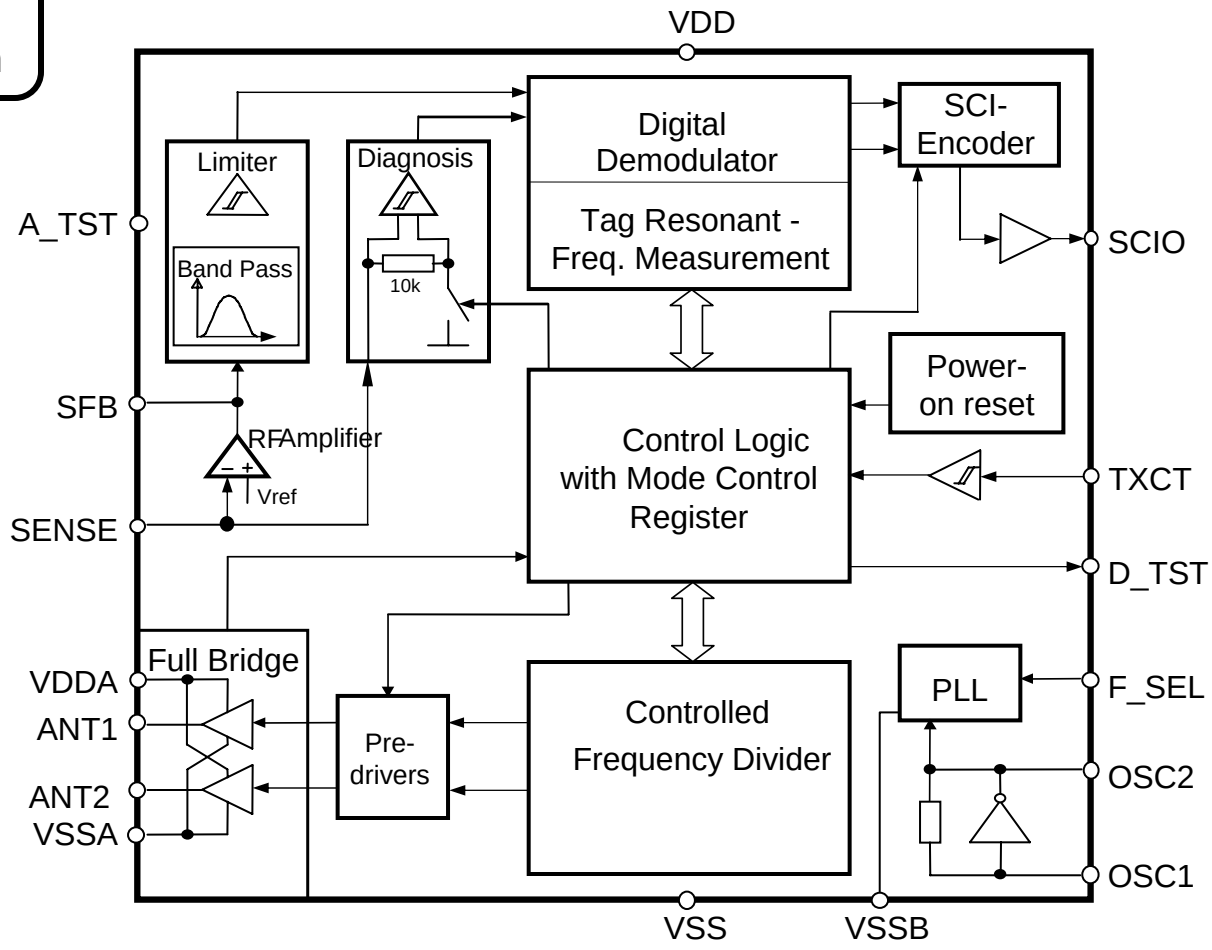
16 Pin SOIC Package

- 5V device
- Automatic sleep mode (TXCT idle for 100 ms)
- Transponder resonance frequency measurement
- Internal Full Bridge antenna driver
- Digital demodulator
- Diagnosis function
- Several operating modes
  - self adapting or fixed frequency charge-up
  - automatic or fixed demodulator threshold
  - asynchronous or synchronous data to µP
- Reduced additional component count
- PLL for internal clock generation
- 2/4 MHz crystal or low cost ceramic resonator can be used

TMS3705A1DRG4

Low Frequency Base Station/Reader IC

TMS3705A1DRG4
Internal Block Diagram



TMS37157

PaLFI – Passive Low Frequency Interface Device

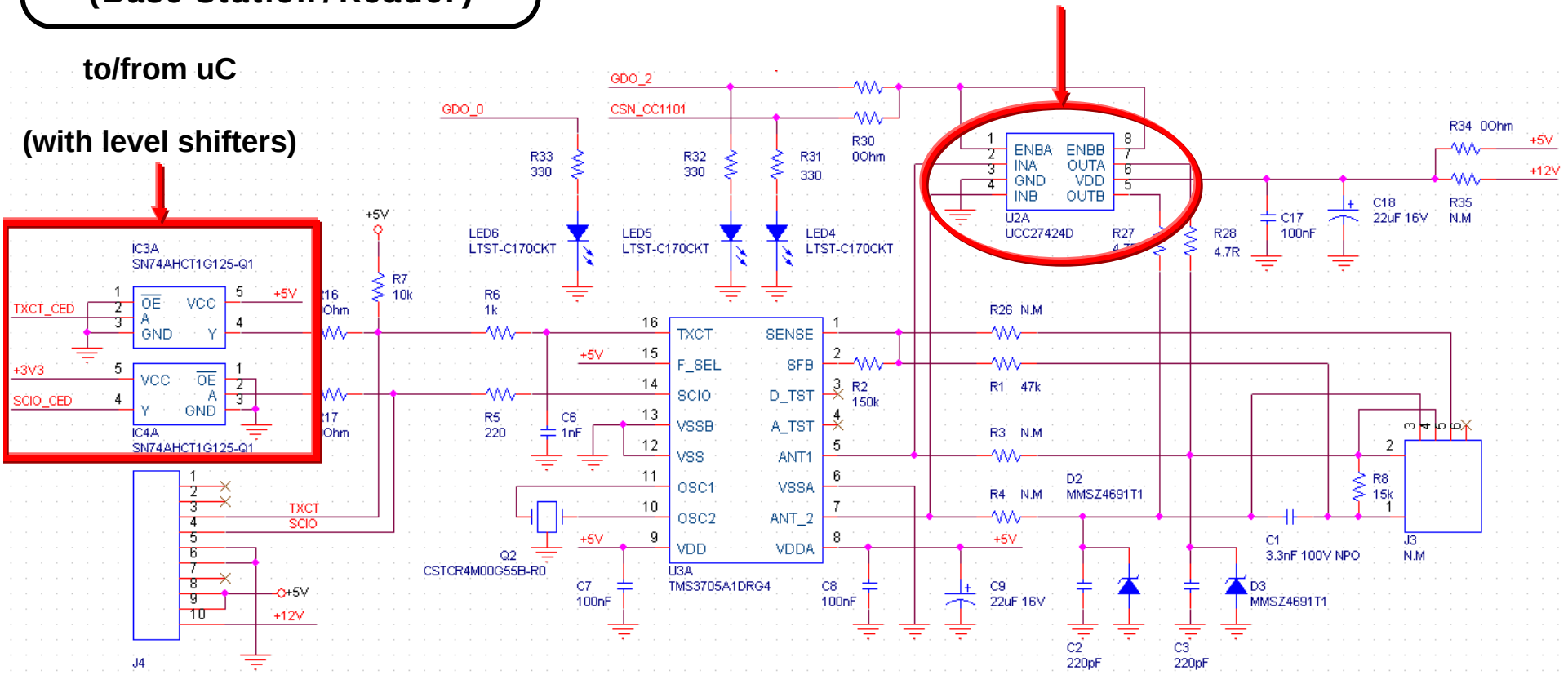
TMS3705A1DRG4
Application Circuit
(Base Station / Reader)

Optional Dual

MOSFET Amp IC

to/from uC

(with level shifters)



TMS37157

PaLFI – Passive Low Frequency Interface Device

- **Technical Training Module:**
  - **Base Station and PaLFI communication basics**
    - **Pulse Position Modulation format details**
    - **PaLFI response format details**

Base Station / PaLFI Communication Basics

- **ez430-TMS37157 Base Station currently uses Pulse Position Modulation (PPM) scheme to interface over the air with the ez430-TMS37157 target board. (Downlink)**

TRANSPONDER TIMING USING PPM

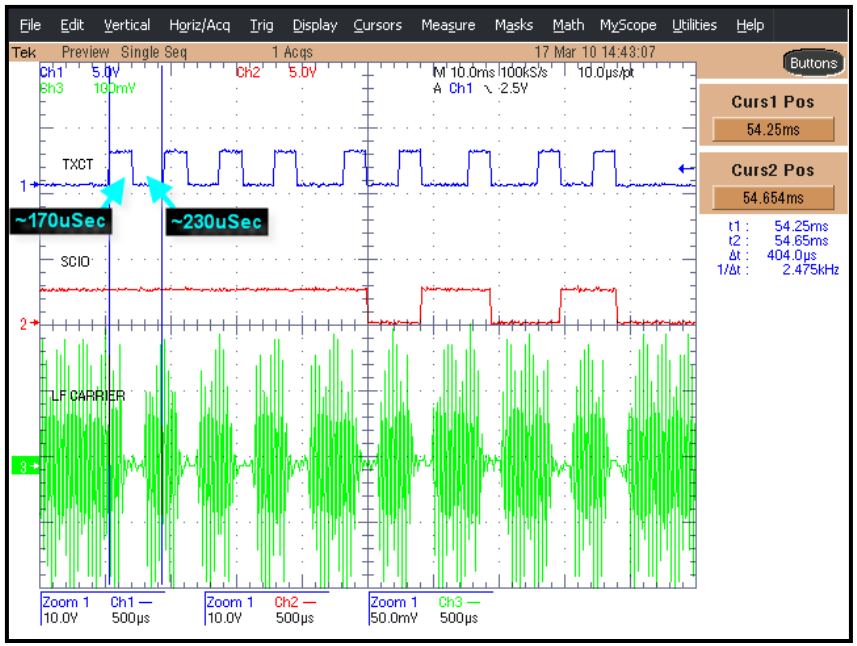
PARAMETER		MIN	TYP	MAX	UNIT
PPM - Pulse Position Modulation					
t_{offtrp}	Write pulse pause (PPM)(1)		170		µs
t_{ontrpL}	Write pulse activation/ low bit (PPM)(1)		230		µs
t_{ontrpH}	Write pulse activation/ high bit (PPM)(1)		350		µs
$t_{bittrpL}$	Write low bit period(1)		400		µs
$t_{bittrpH}$	Write high bit period(1) (2) (3)	510	520	1730	µs

- **The transponder will respond back over the air using FSK, with the demodulated and digitized response indicated here using the relationship of the signals between the TXCT and SCIO pins.**
- **In the response string, it should be noted that the bytes are handled a certain way in order to interpret them.**
- **For example, they come in LSB first and need to have one's complement performed on them in order to translate them correctly.**

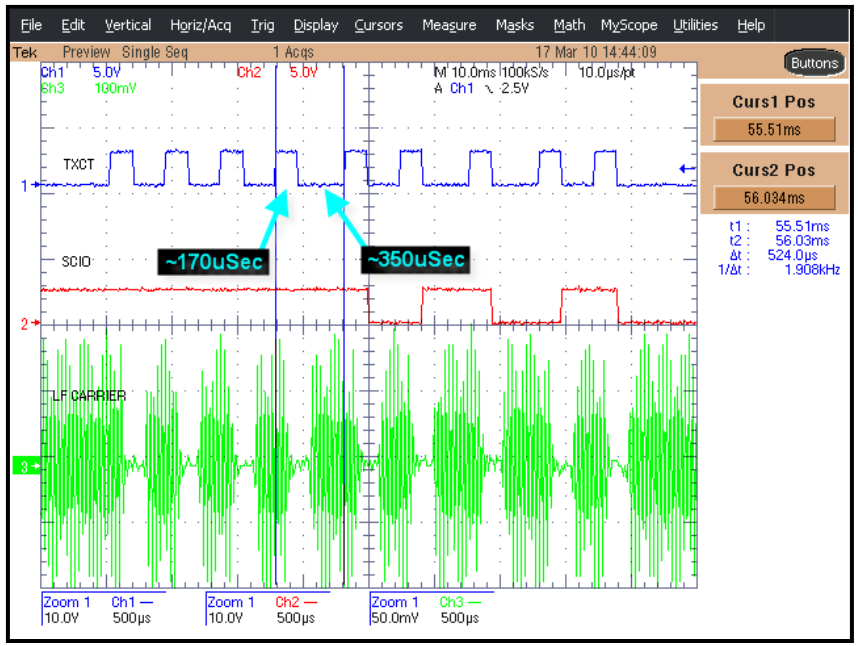
Base Station Communication Basics (PPM Low and High Bits)

- Blue trace is TXCT line on the TMS3705A1DRG4
- Green trace is the actual Low Frequency field generated by the reader IC being amplitude modulated

Low Bit

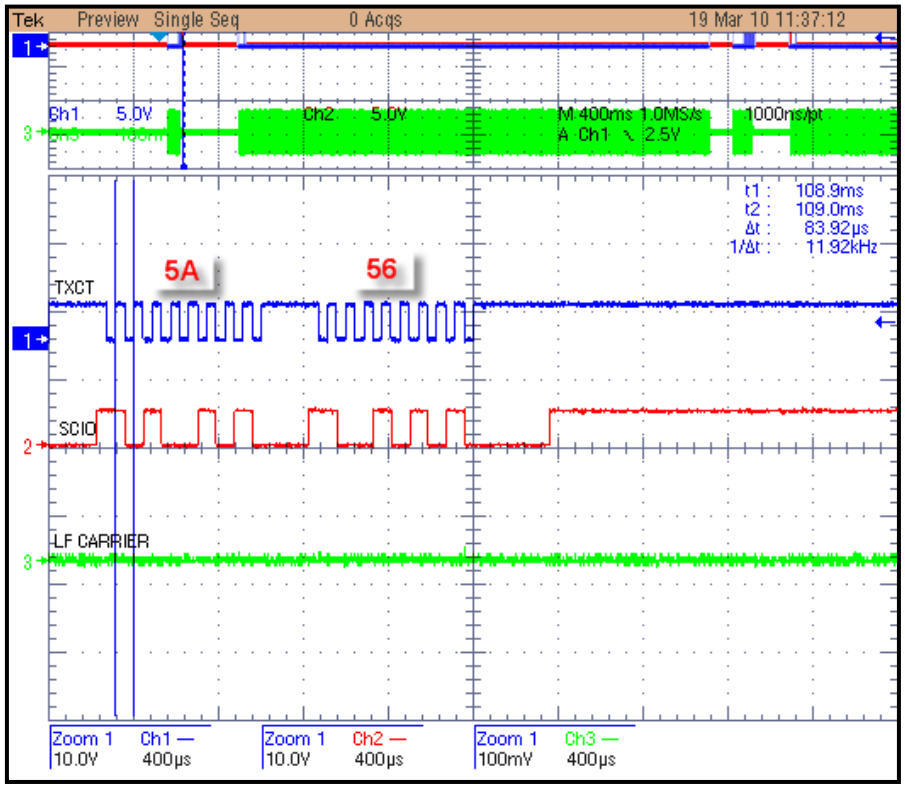


High Bit



PaLFI Communication Basics
(Demodulated and Digitized PaLFI Response Low and High Bits)

- Logic 1 = TXCT going high while SCIO line high
- Logic 0 = TXCT going high while SCIO line low
- Example 0x5A byte below shows LSB first bit string of 10100101_2. When rotated (to become MSB first) it becomes 10100101_2, then one's complement is performed on the binary string, yielding 01011010_2 or $0x5A_{16}$.



TMS37157

PaLFI – Passive Low Frequency Interface Device

- **Technical Training Module:**
  - **General Read of Page 3 (Command 0x0C)**
    - **Reading Page 3 returns pages 1, 2 and 3, which are the tag 8 bit Password/Selective Address, 8 bit User ID, 8 bit Manufacturing ID and Unique 24 Bit Serial Number Fields.**
      - **Note: A read either of the Pages 1 or 2 will also result in these data fields being returned but with different CRCs and BCCs because the Page Requests are different.**

TMS37157

PaLFI – Passive Low Frequency Interface Device

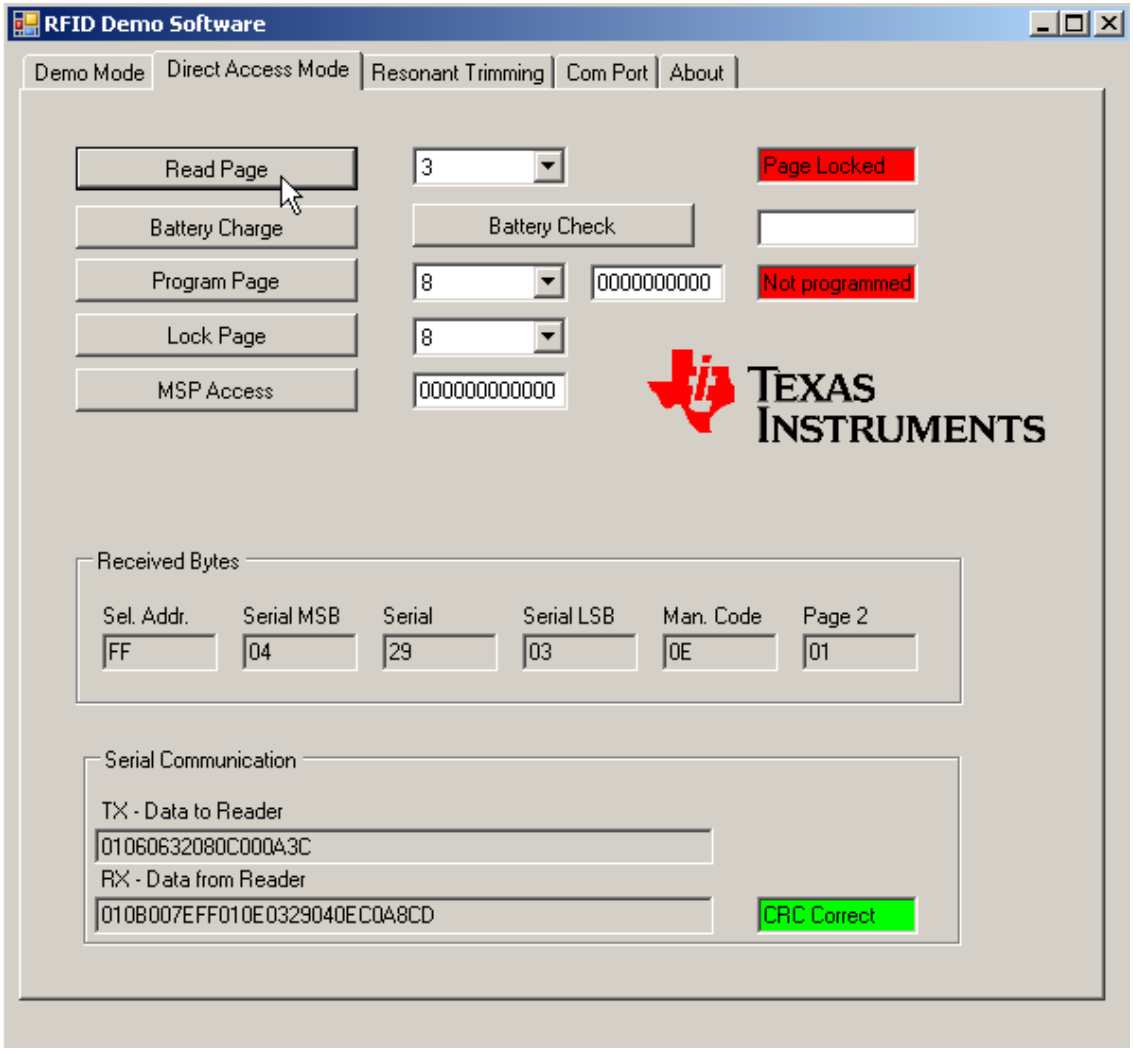
- **In order to send commands to the TMS37157 LF interface, the user sends a Write Address byte comprising a 2-bit Command field and a 6-bit Page field. The Command field, which is transmitted first, determines the function to be executed and whether the command comprises additional data bytes that must also be sent. The Page field specifies the target of the command. The table below shows which additional data bytes must be included with each command type. The elements for each command are sent from left to the right of this table.**

FUNCTION	WRITE ADDRESS		SELECTIVE ADDRESS	WRITE DATA	FRAME BCC
	COMMAND FIELD	PAGE FIELD			
	MSB LSB				
General read page, battery check	00	X			
Selective read page	11	X	X		X
Program page; MSP access	01	X		X(1)	X
Selective program page	01	X	X	X(1)	X
Lock page	10	X			X
Selective lock page	10	X	X		X
Protect page	11	X			X
Selective protect page	11	X	X		X

WRITE ADDRESS

	MSB P P P P P P | PAGE FIELD MSB LSB	LSB C C | COMMAND FIELD MSB LSB	HEX VALUE	
Page 3	000011	00	0Ch	General Read Page 3

Command Implementation
PaLFI General Read of Page 3 (Command 0x0C)
[Using the GUI]



Example Command/Response Sequences

General Read of Page 3 Command

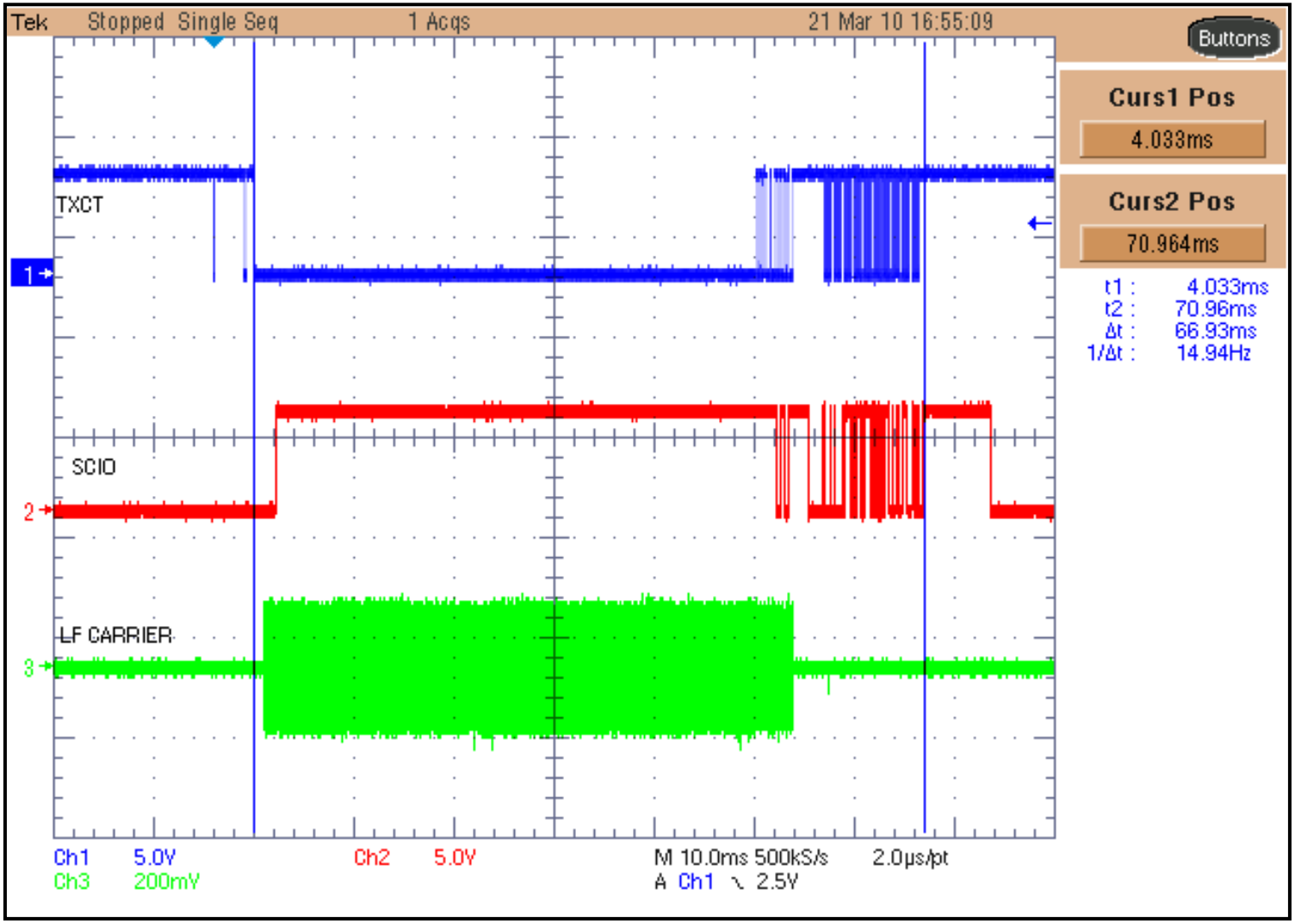
➔ 01060632080C000A3C

➔ 010B007EFF010E0329040EC0A8CD

Command Implementation

PaLFI General Read of Page 3 (Command 0x0C)

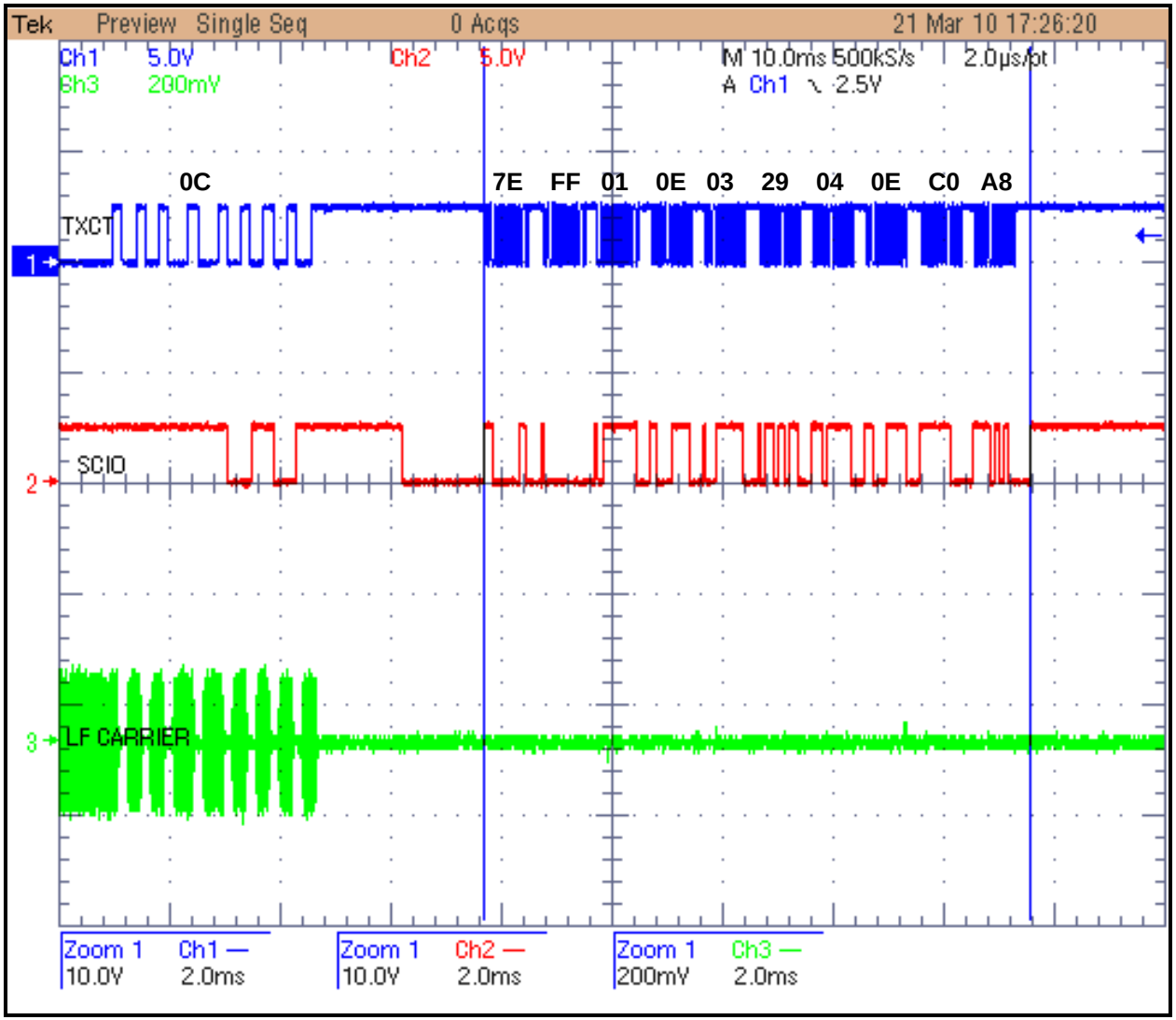
Overall Sequence (LF Charge Burst, Modulated Command, Tag Response)



Command Implementation

PaLFI General Read of Page 3 (Command 0x0C)

(Zoom on End of LF Charge Burst, Modulated Command, Tag Response)

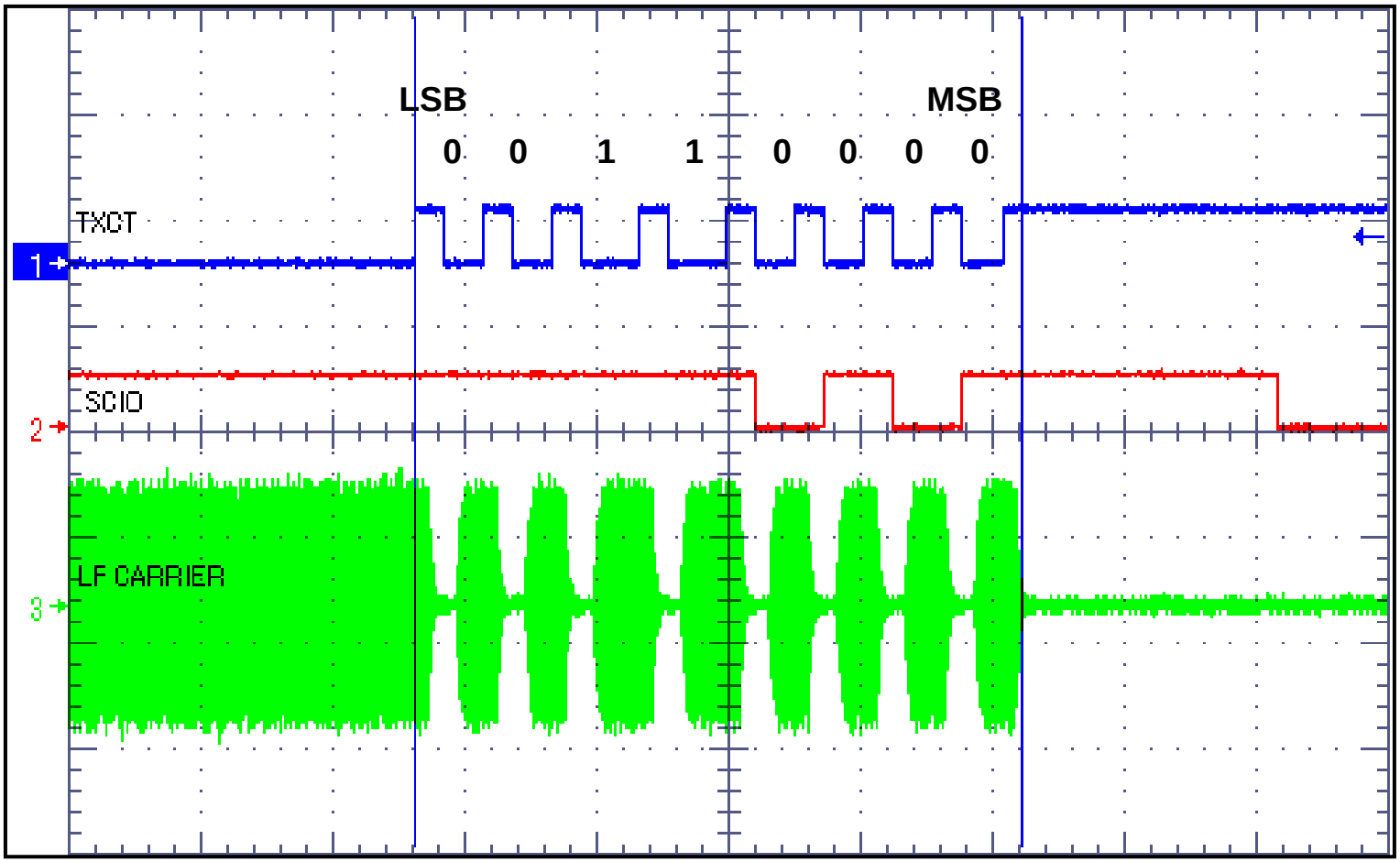


Command Implementation

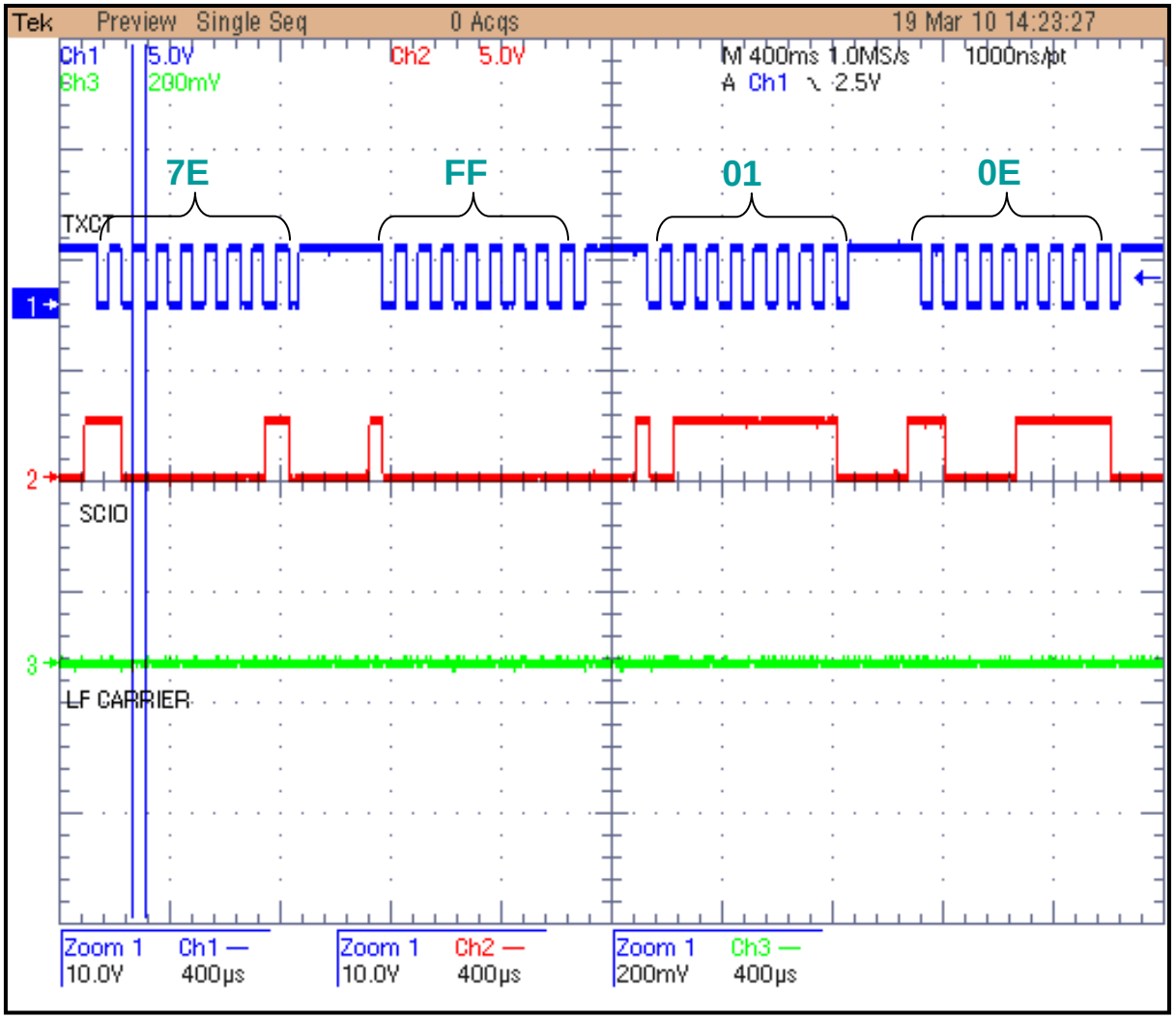
PaLFI General Read of Page 3

(Zoom on End of the LF charge burst and General Read Command 0x0C)

[00110000 (rotated) = 00001100 = 0x0C]

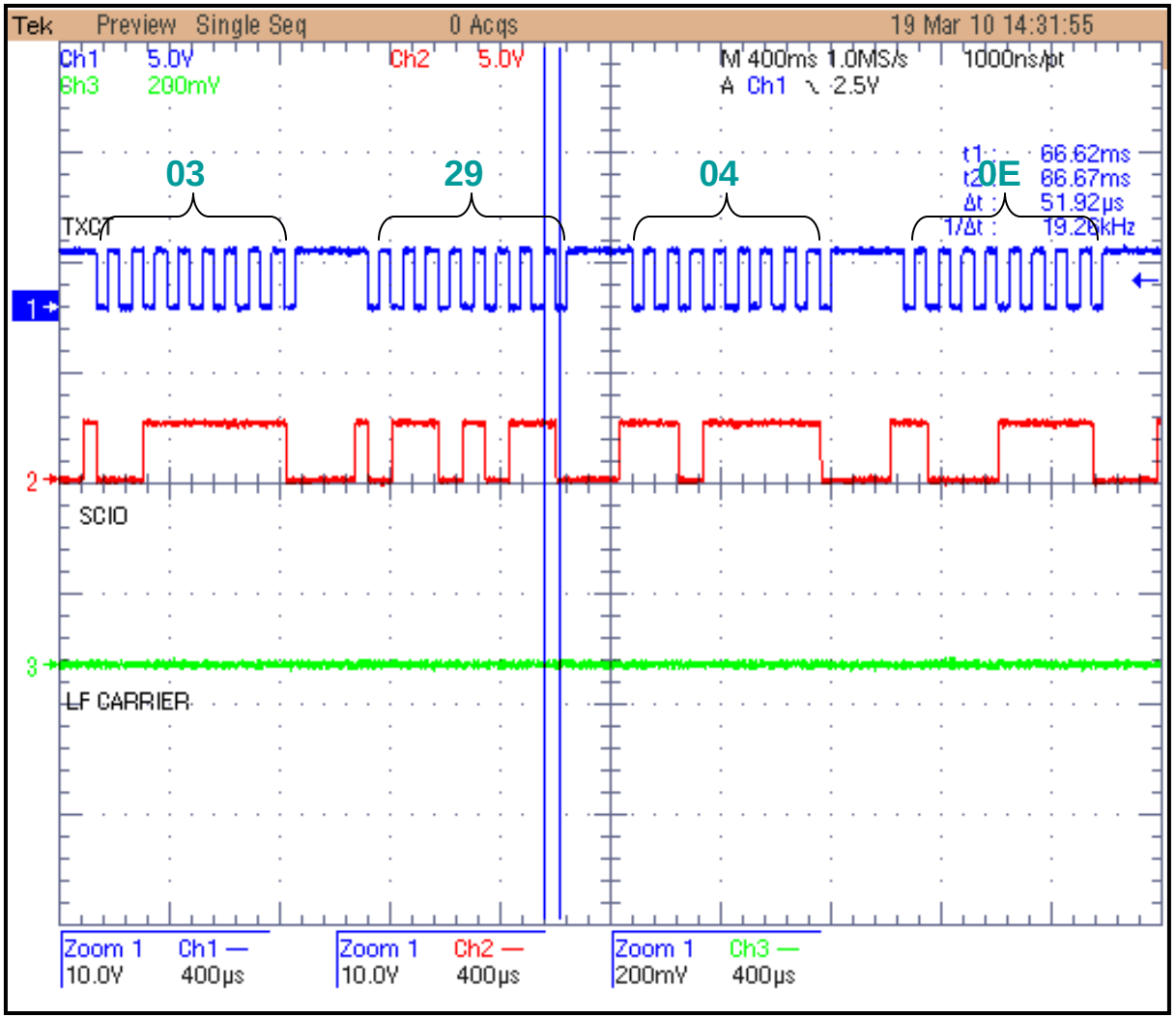


Command Implementation
PaLFI Read Page 3 Tag Response Example
[Password, User ID and Manufacturing ID]



- 7E = Start Byte
- FF = Page 1 (Password)
- 01 = Page 2 (User Data)
- 0E = Part of Page 3 (Manufacturer ID byte)

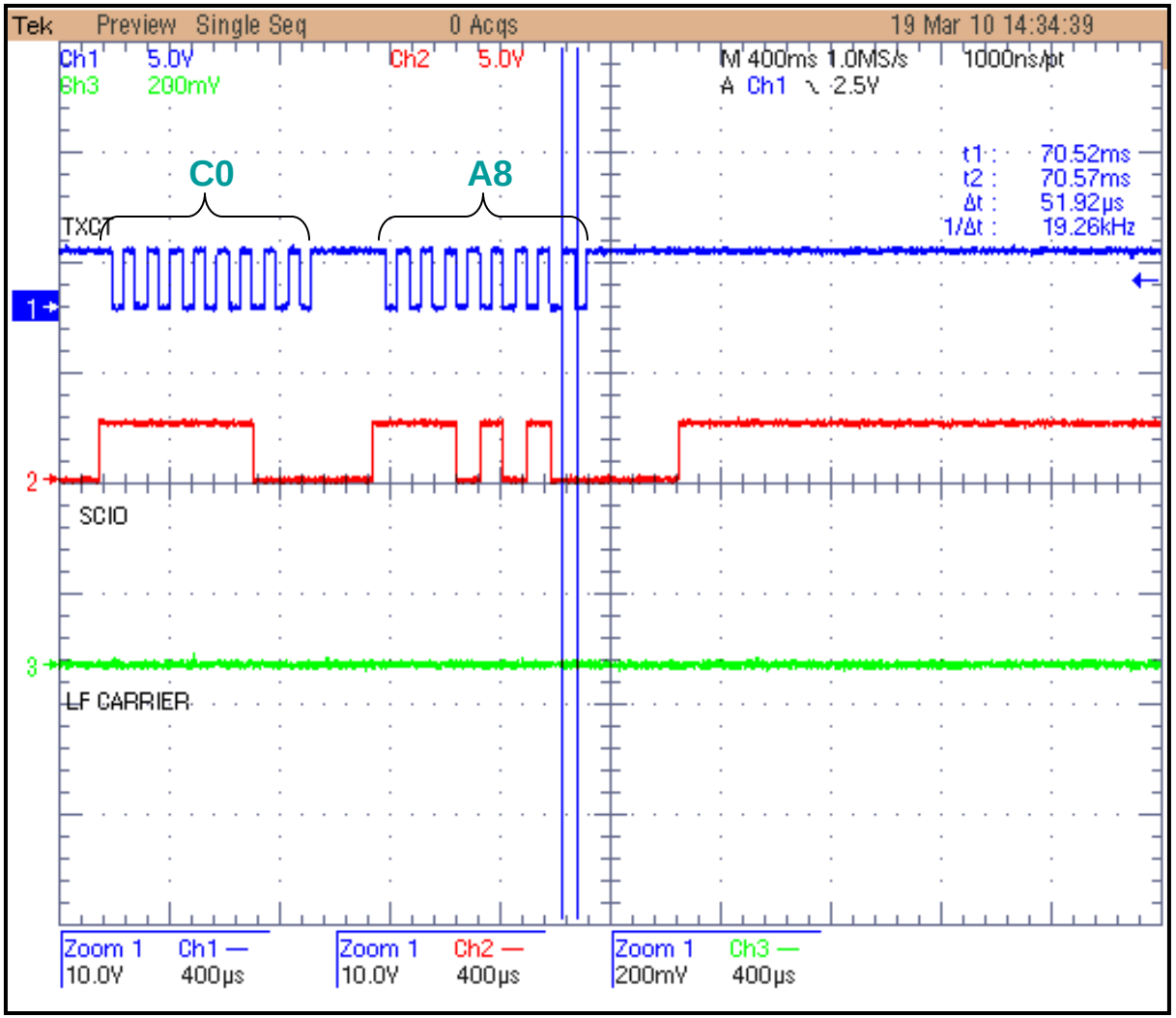
Command Implementation
PaLFI Read Page 3 Tag Response Example
(Serial # and Page Address)



- 03 = Page 3 (Serial # LSB)
- 29 = Page 3
- 04 = Page 3 (Serial # MSB)
- 0E = Page 3 (Page Address)

Command Implementation

PaLFI Read Page 3 Tag Response Example (CRC)



- **C0 = CRC (LSB)**
- **A8 = CRC (MSB)**

Note:

The CRC is calculated (with this device) over the string: **FF010E0329040E** using reverse CCITT, with a start value of 0x3791

- BCC (0xCD) (not shown here, but in the GUI) is XOR result taken over the entire response string: **0B007EFF010E0329040EC0A8** which is minus the SOF byte seen in the GUI.

TMS37157
PaLFI – Passive Low Frequency Interface Device

- Technical Training Module:
  - Battery Charge Command is:
    - Used to power attached microcontroller (without using battery)
    - Used to charge an attached system battery
  - When a Battery Charge Command has been received the TMS37157 applies a voltage of about 3.4 V to VBAT.
  - The charge current depends mainly on the antenna of the LC Tank Circuit and the Field Strength of the Base Station.
  - The TMS37157 does not answer to a Battery Charge Command.
  - The LF Field has to remain on after transmitting the telegram. The telegram format corresponds to a Read Page 26 Command.
  - The charging of the battery can be ended by any other command.

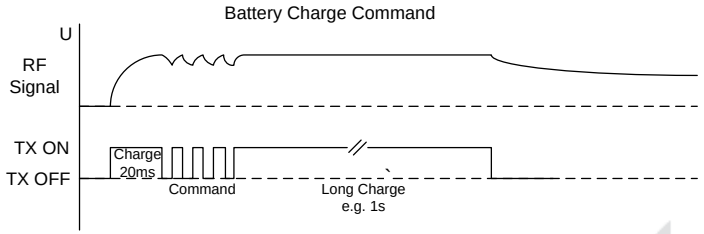
TMS37157

PaLFI – Passive Low Frequency Interface Device

Command Implementation

Battery Charge command

(Page26, 68h)



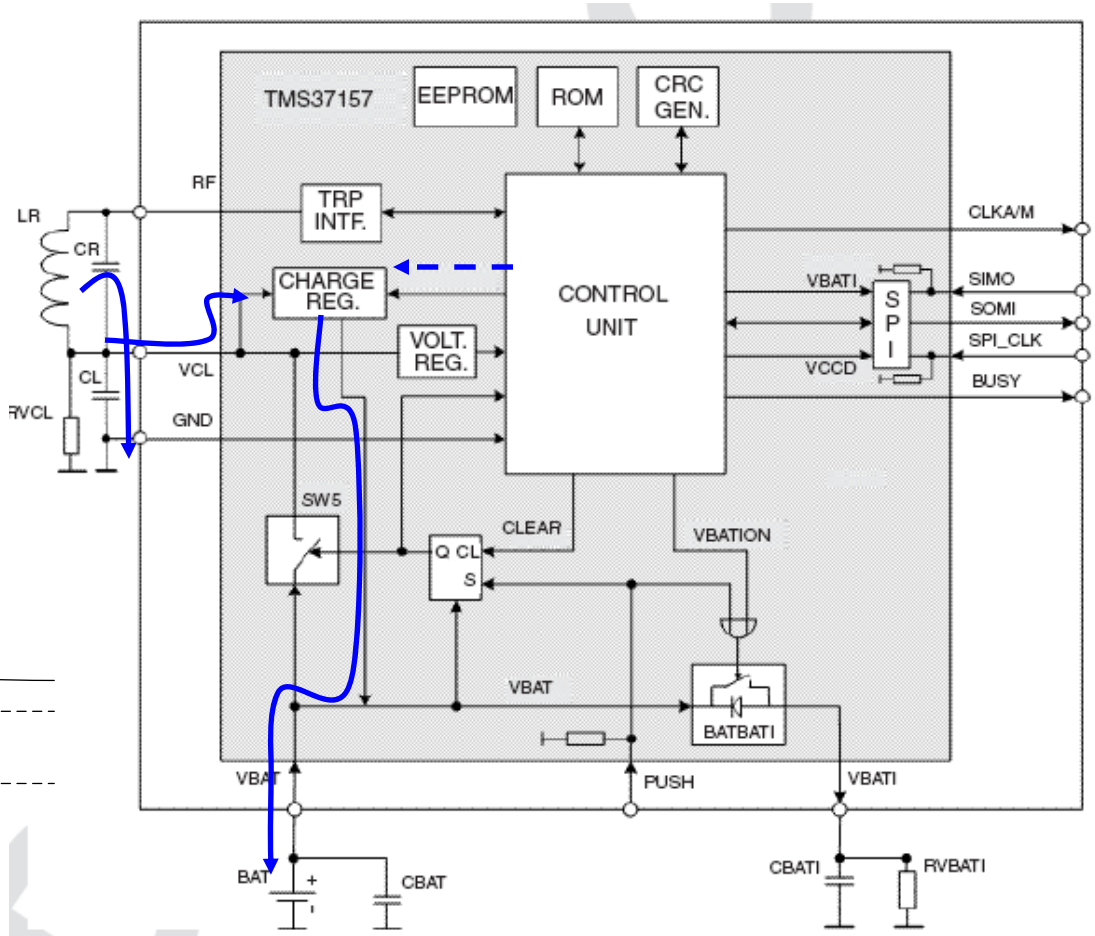
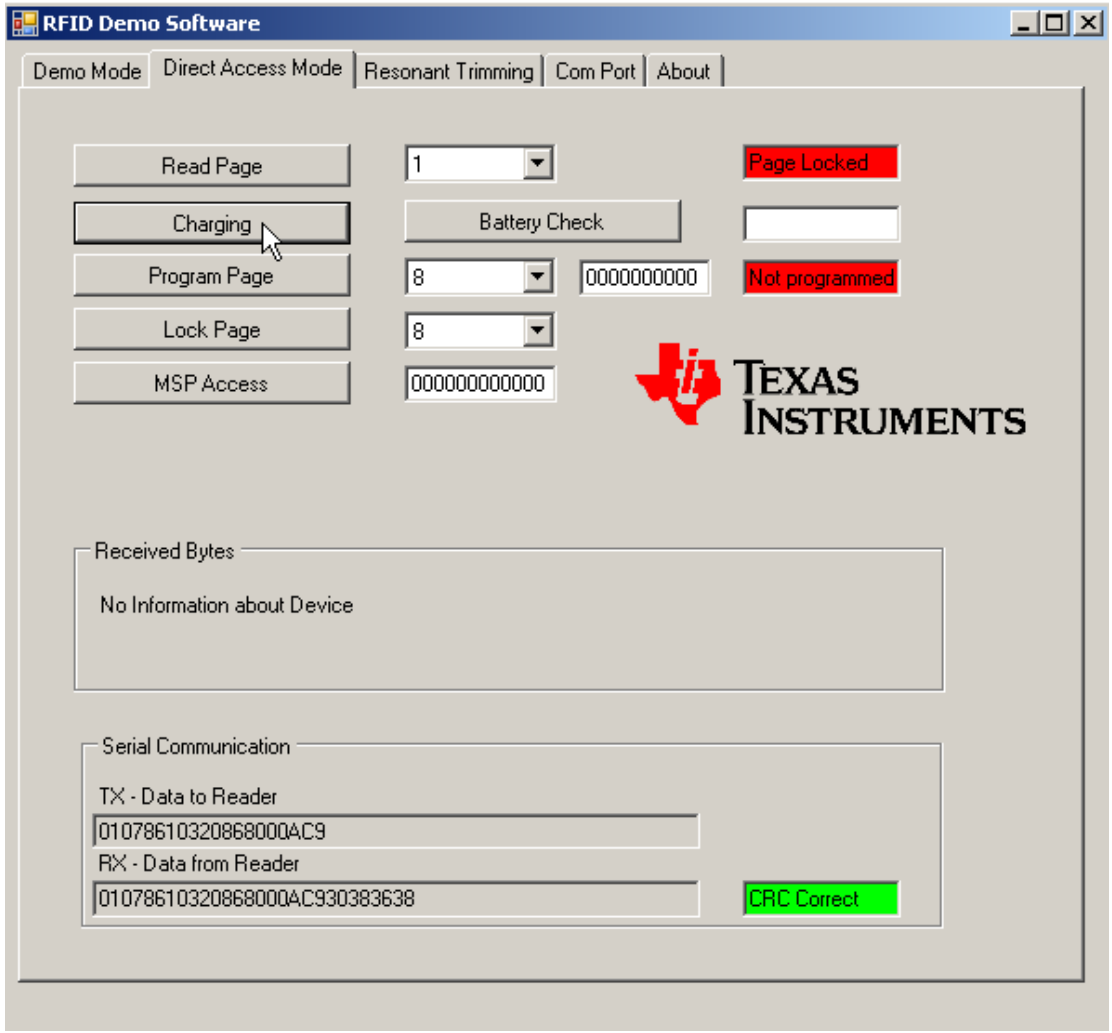


Figure 3. TMS37157 Power Management

Command Implementation
Battery Charge Command (0x68)
[Using the GUI]



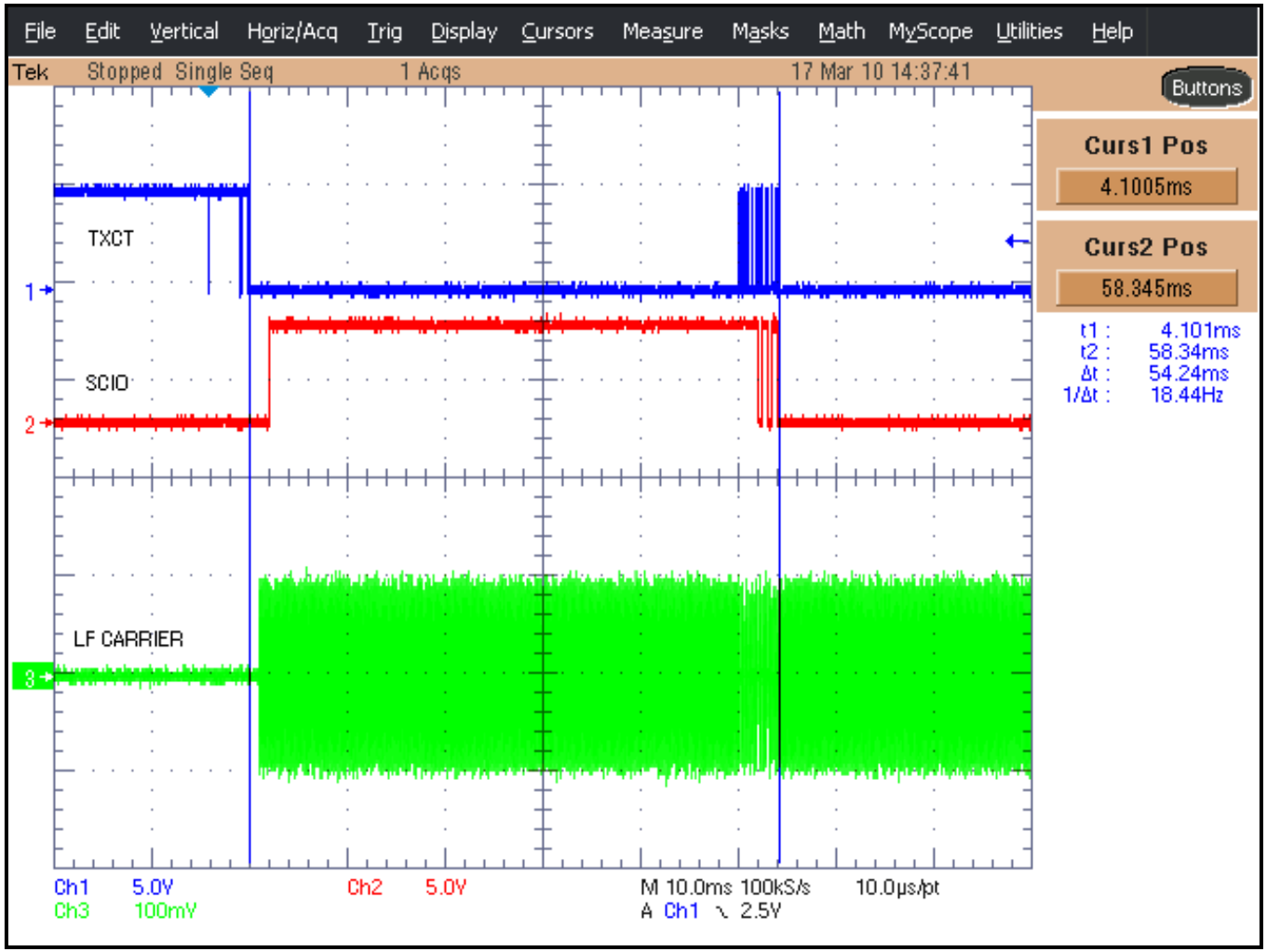
Example Command/Response Sequences

Battery Charge Command

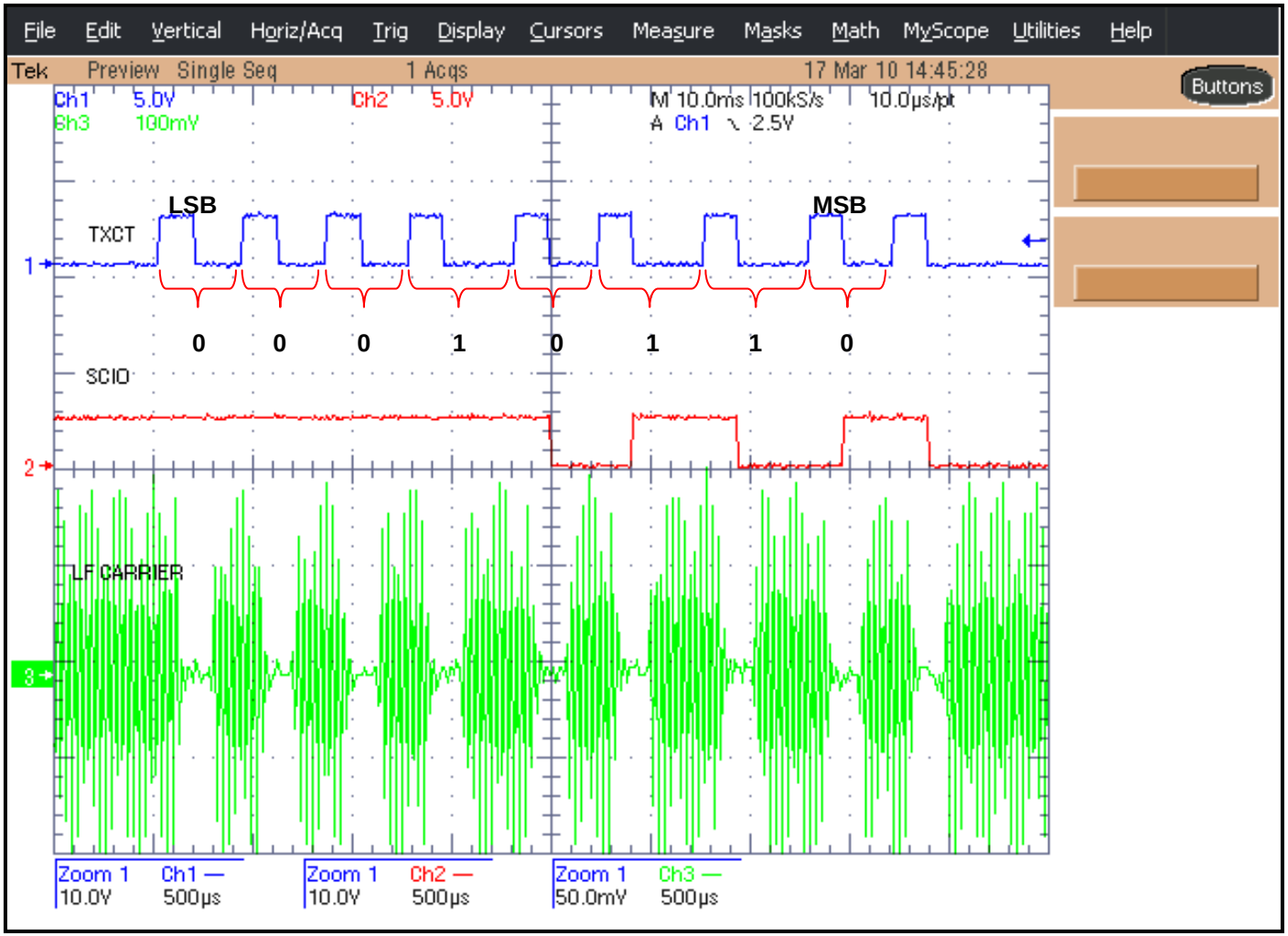
➔ 01078610190868000AE2

➔ 01078610190868000AE230383638

Command Implementation
Battery Charge command
(Overall Sequence)



Command Implementation
Battery Charge
(Command 0x68, using PPM)



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TMS37157

PaLFI – Passive Low Frequency Interface Device

- **Technical Training Module:**
  - **Microcontroller Access/Program Command (with and without a battery or other DC power source)**
    - **The MSP Access command allows transfer of LF data to/from a microcontroller (i.e. MSP430) via the TMS37157 Analog Front End.**
    - **The microcontroller handles data transfers using the following SPI commands:**
      - **MSP Read Data From PCU (Data In)**
      - **MSP Write Data To PCU (Data Out)**

TMS37157

PaLFI – Passive Low Frequency Interface Device

- **MSP Access Data Handling Flow:**

  The following sequence is needed to implement an MSP Access command:

  - **The TMS37157 detects that an MSP Access command has been received and wakes the Microcontroller (e.g. MSP430).**
  - **The Microcontroller reads the status using the SPI command *Get Status*.**
  - **The *MSP* access request is detected and the data are requested by the Microcontroller. Data bytes are transferred to the Microcontroller using the SPI command *MSP Read Data from PCU*.**
  - **The data bytes are processed and actions executed, as necessary.**
  - **If necessary, the Microcontroller sends response data bytes back to the TMS37157, using the SPI command *MSP Write Data to PCU*.**
  - **After the TMS37157 has detected removal of LF power, the response data bytes are sent back to the base station (i.e. TMS3705A1DRG4 based reader).**

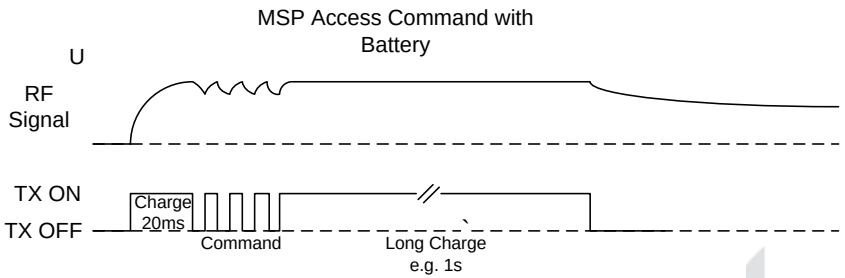
  NOTE:

  - **The LF field must be present throughout the above sequence (except the last step), otherwise a malfunction of the TMS37157 may occur.**

TMS37157

PaLFI – Passive Low Frequency Interface Device

Command Implementation
MSP Access / Program command
with a Battery
(Page31, 7Dh)



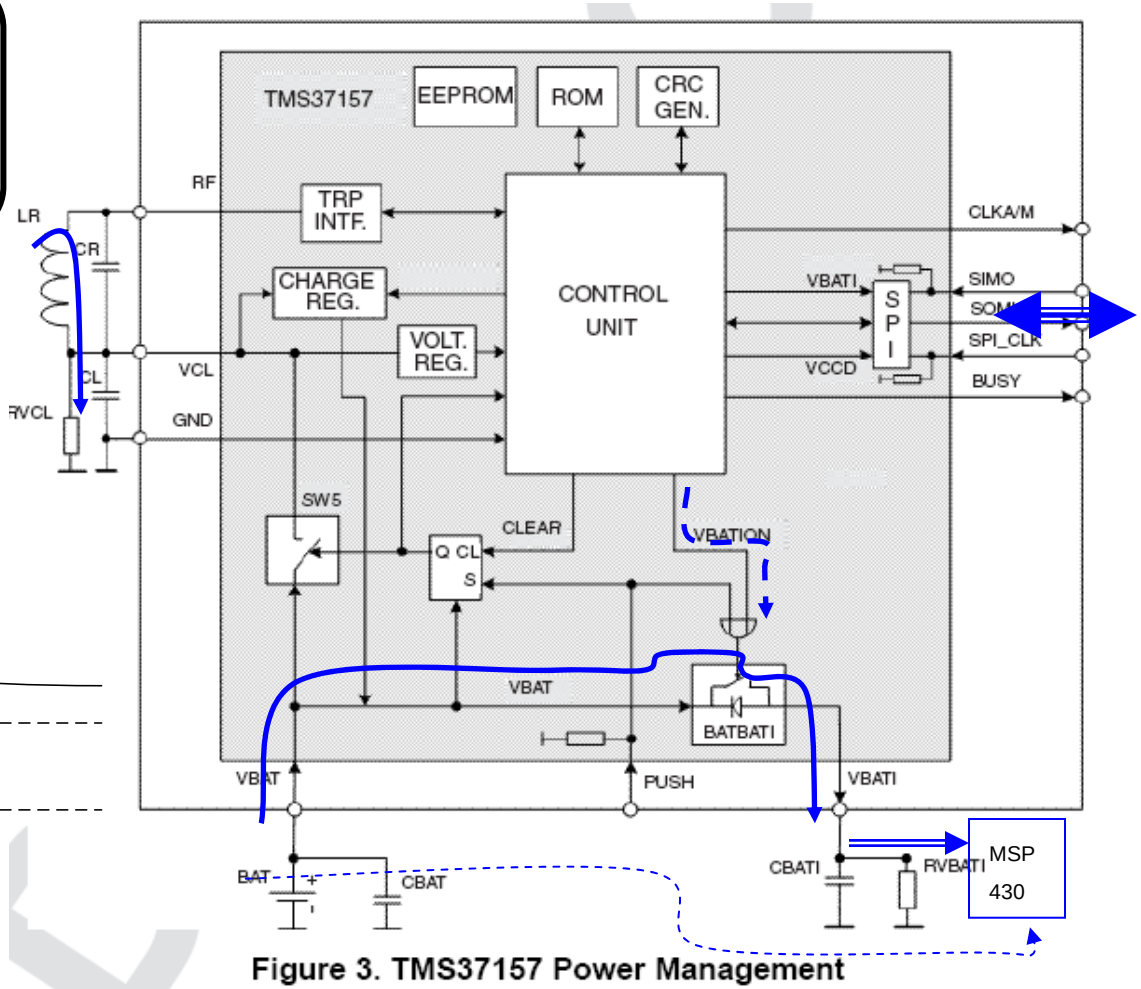
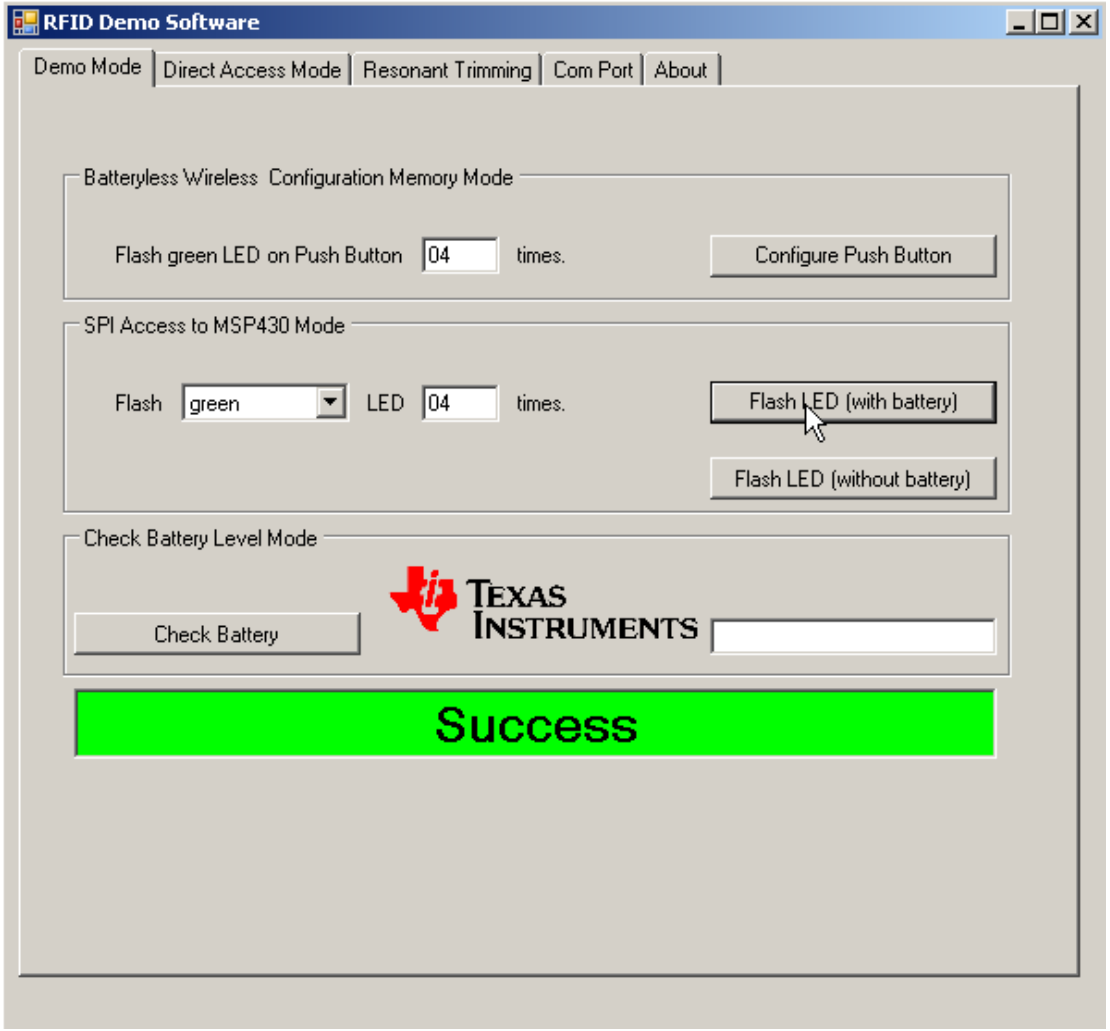


Figure 3. TMS37157 Power Management

Command Implementation

MSP430 Access/Program Command Flash Green LED 4 Times with a Battery [Using the GUI]



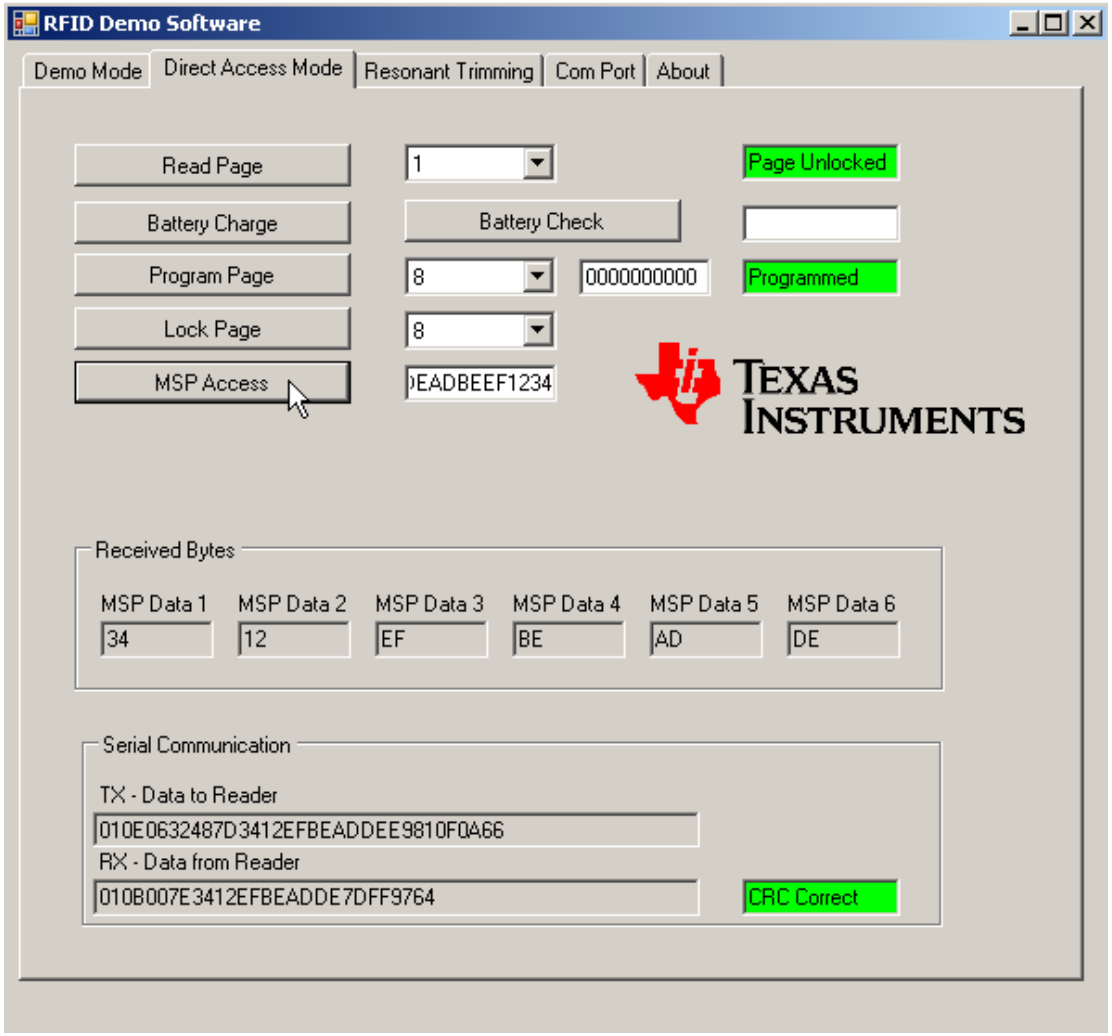
Example Command/Response Sequences
(happening behind the scenes)

MSP430 Access Command
➔ 010E0632487D040000000000AF58050AF3
➔ 010B007E0400000000007D14B0A8

MSP430 Access Command (for Red LED)
➔ 010E0632487D040100000000EB53050ABD
➔ 010B007E0401000000007D3FB486

Command Implementation

MSP430 Program / Access Command DEADBEEF1234 with a Battery [Using the GUI]



Example Command/Response Sequences

MSP430 Access Command

➔ 010E0632487D3412EFBEADDEE9810F0A66

➔ 010B007E3412EFBEADDE7DFF9764

Command Implementation

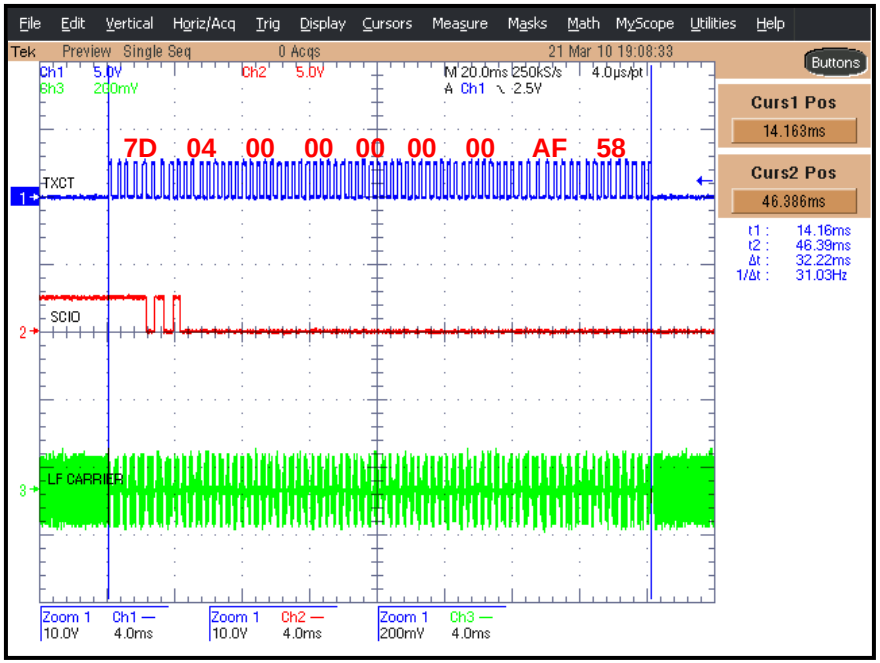
MSP430 Access / Program Command with a Battery [Overall]

Command Implementation

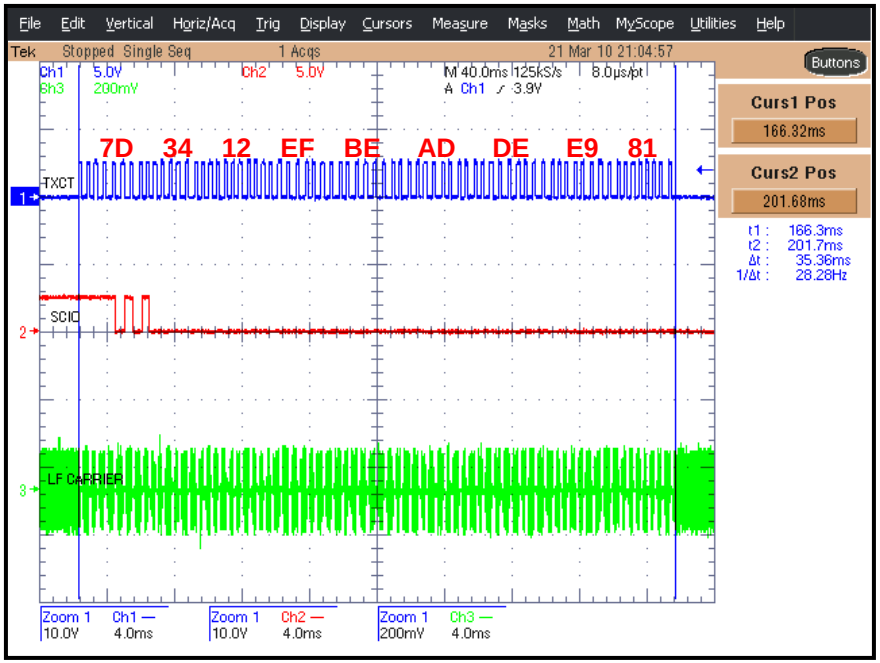
MSP430 Access/Program Modulated Commands

Flash Green LED 4 times and DEADBEEF1234 with a Battery

[Overall]

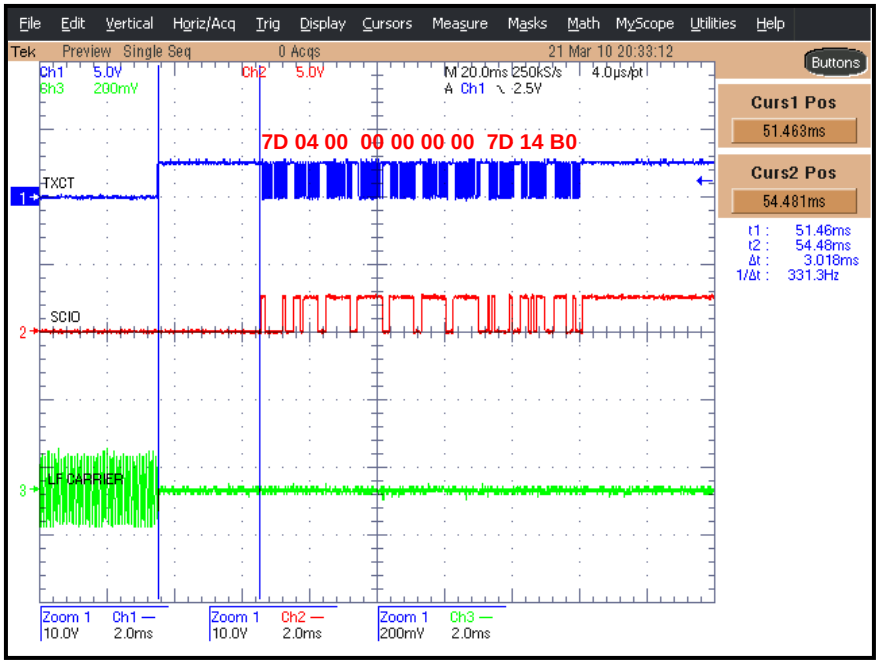


Modulated Command for flashing Green LED 4 times



Modulated Command for sending DEADBEEF1234

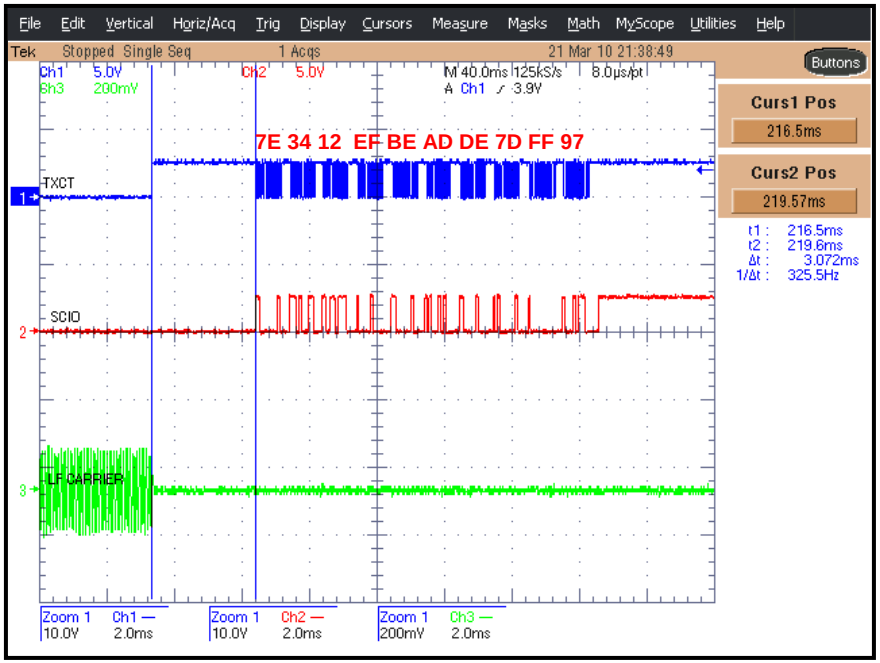
Command Implementation
MSP430 Access/Program TMS37157 Responses
Flash Green LED 4 times and DEADBEEF1234 with a Battery
[Overall]



MSP430 thru TMS37157 response from

flashing Green LED 4 times

(with CRC)



MSP430 thru TMS37157 response from

sending DEADBEEF1234

(with CRC)

TMS37157

PaLFI – Passive Low Frequency Interface Device

Command Implementation

MSP Access / Program command

without a Battery

(Page31, 7Dh)

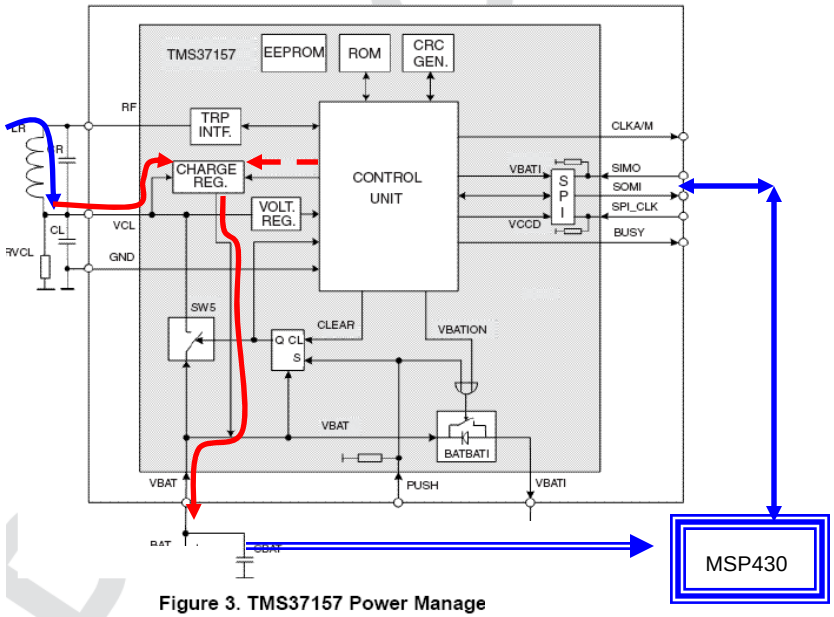
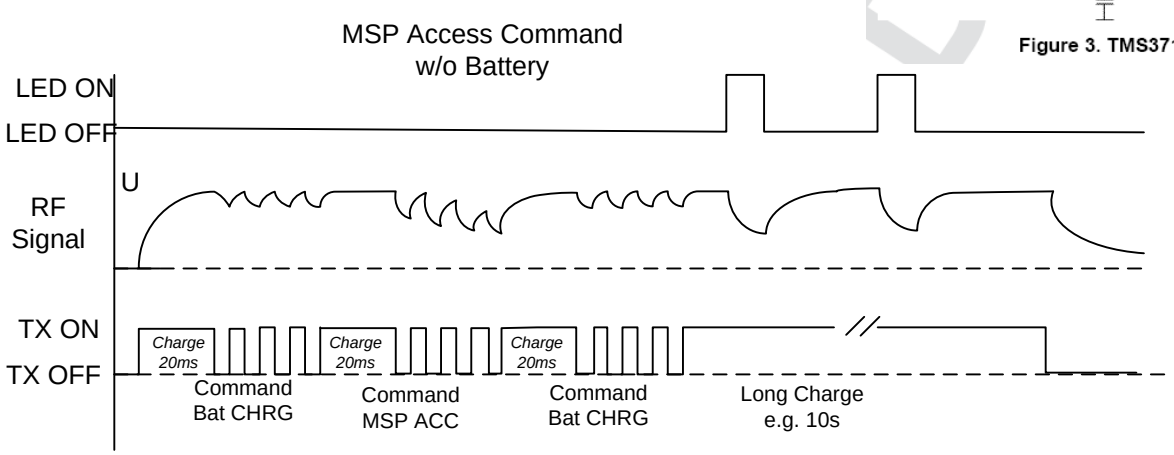
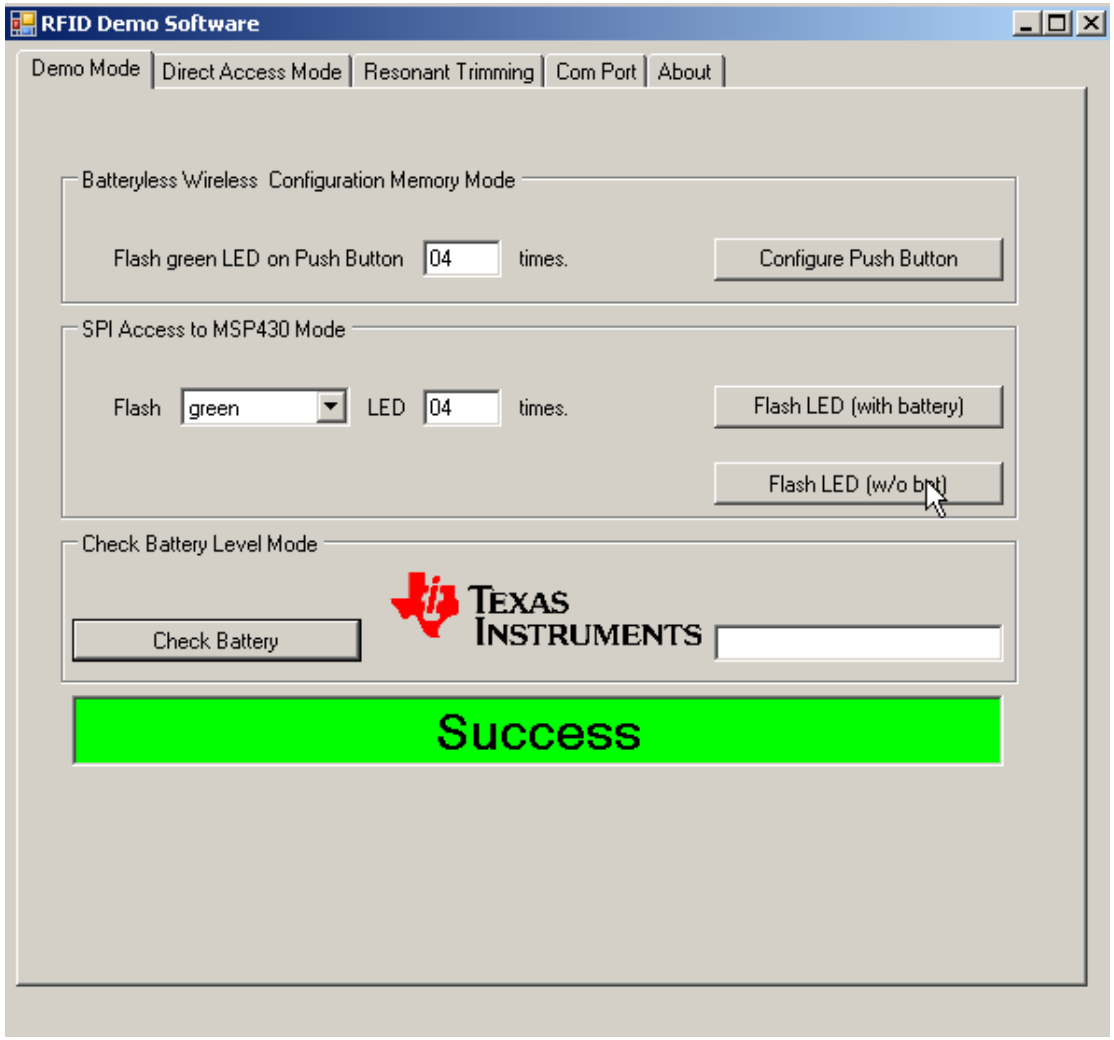


Figure 3. TMS37157 Power Manage



Command Implementation

MSP430 Access/Program Command Flash LED 4 Times without a Battery [Using the GUI]



Example Command/Response Sequences
(happening behind the scenes)

Read Page 3 Command
➔ 01060632080C000A3C
➔ 010B007EFF010E0329040EC0A8CD

Battery Charge Command
➔ 01078610190868000AE2
➔ 01078610190868000AE230383638

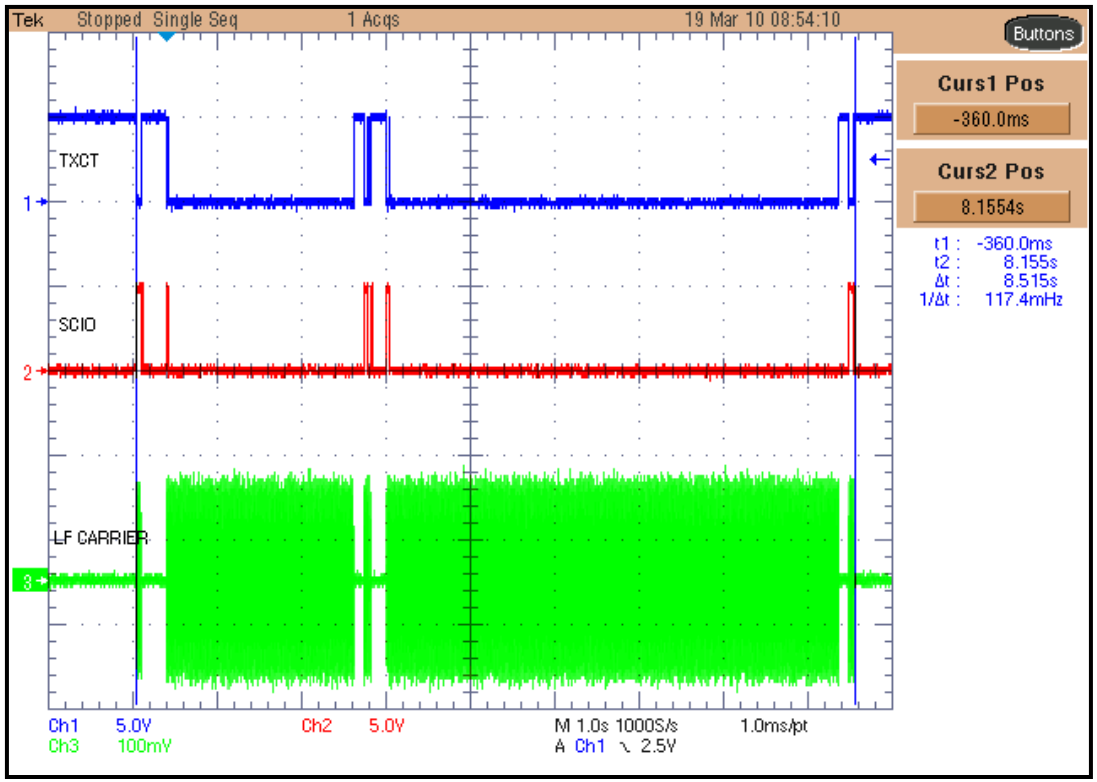
MSP430 Access Command
➔ 010E0632487D040000000000AF58050AF3
➔ 010B007E0400000000007D14B0A8

Battery Charge Command
➔ 01078610190868000AE2
➔ 01078610190868000AE230383638

Read Page 3 Command
➔ 01060632080C000A3C
➔ 010B007EFF010E0329040EC0A8CD

Command Implementation
Overall MSP430 Access Command without Battery
(Program MSP430 and Flash LED four times example)

- **This is a combination of the previous commands described in this training module.**
  - **Read Page 3, Battery Charge and MSP Access**



TMS37157

PaLFI – Passive Low Frequency Interface Device

- **Technical Training Module:**
  - **Firmware Considerations**
    - **Read Page 3**
    - **Battery Charge**
    - **MSP Access**

TMS37157

PaLFI – Passive Low Frequency Interface Device

- **Read Page 3**
  - **The Transponder Memory comprises a total of 126 bytes, organized in pages.**
  - **Memory space is apportioned as follows:**
    - **User Data 121 bytes**
    - **Serial Number (3 bytes) + Manufacturer ID (1 byte) = 4 bytes**
    - **Selective Address 1 byte**
  - **A read of Page 3 returns three pages of data**
    - **Page 1 = Password**
    - **Page 2 = User Data 1**
    - **Page 3 = Serial Number and Manufacturer ID**

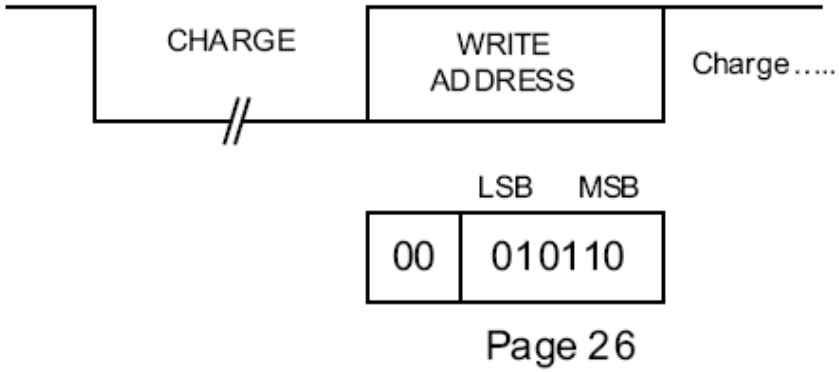
Read Page Command Firmware Code Snippet

```
void SPI_Read_SerialNum(void)
 /*****************************************************************************************
  *  Read out Serial Number, MID, User Data 1 and Password (Pages 1, 2 and 3)
  *****************************************************************************************/
{
  SPI_Set_Up_Telegram();
  SPI_Buf_Set_Output_Byte(Page3);
  SPI_Buf_Set_Telegram_Length();

  SPI_Buf_Send();

  if (MSP430_SPI_Rx(SPI_Stack.ucInput,7))
    ErrorMode();

  TRP_Data.SelectiveAddress = SPI_Stack.ucInput[0];
  TRP_Data.KeyNumber        = SPI_Stack.ucInput[1];     // equal to User data 1
  TRP_Data.SerialNumber[0]  = SPI_Stack.ucInput[2];// Manu Code / Page 3
  TRP_Data.SerialNumber[1]  = SPI_Stack.ucInput[3];// Ser. Nr. / Page 3
  TRP_Data.SerialNumber[2]  = SPI_Stack.ucInput[4];// Ser. Nr. / Page 3
  TRP_Data.SerialNumber[3]  = SPI_Stack.ucInput[5];// Ser. Nr. / Page 3
}
```

TMS37157

PaLFI – Passive Low Frequency Interface Device

- **Battery Charge**
  - **When a Battery Charge Command has been received the TMS37157 applies a voltage of about 3.4 V to VBAT.**
  - **The charge current depends mainly on the antenna of the LC Tank Circuit and the Field Strength of the Base Station.**
  - **The TMS37157 does not answer to a Battery Charge Command.**
  - **The LF Field has to remain on after transmitting the telegram. The telegram format corresponds to a Read Page 26 Command.**
  - **The charging of the battery can be ended by any other command.**
  - **The write data format of the Battery Charge Command is shown below**



TMS37157

PaLFI – Passive Low Frequency Interface Device

- **MSP Access**
  - **The MSP Access Commands are special cases; they work only if the TMS37157 receives an MSP Access Command through its RF Interface.**
  - **The MSP Access Commands are used to transfer data through the RF Interface directly to the MSP and back.**
  - **In the normal application the MSP is in LPM4 waiting for an Interrupt and the TMS37157 is in Standby mode, resulting in overall ultra low power consumption.**
  - **If the TMS37157 receives an MSP Access Command, it sets Busy high. This can be used as an Interrupt for the MSP430.**
  - **The TMS37157 shows its readiness by resetting busy. Now the MSP can request the data from the TMS37157.**
  - **The TMS37157 waits until the MSP send 6 Bytes of data back to the TMS37157.**
  - **During this time, the field of the RFID reader has to stay on, supplying the TMS37157 with Energy.**
  - **The TMS37157 sends the Data back to the RFID reader, when the RFID reader switches off the field.**
  - **The following code snippet shows how to use the MSP Access Commands in connection with a Busy Interrupt.**
    - **It is assumed that Busy Pin is connected to P2.1 of the MSP.**

MSP Access Command Firmware Code Snippet

```
#include "msp430x22x4.h"
#include "PaLFI_Transponder.h"
void main (void)
{
unsigned char MSP_Access_Data[6] = {0};
P2OUT = 0; //
P2DIR &= ~CU_BUSY; // Busy Input P2.1 CU_BUSY = 0x002
P2IFG &= ~CU_BUSY; // reset busy Interrupt
P2IE |= CU_BUSY; // busy Interrupt enabled
While(1)
{
if((P2IFG & CU_BUSY) == CU_BUSY)); // Test for Interrupt
{
While ((P2IN & CU_BUSY) == CU_BUSY); // wait until TMS37157 ready
SPI_Read_CU_Data(MSP_Access_Data); // read Data from TMS37157
MSP_Access_Data[1] = MSP_Access_Data[2] + MSP_Access_Data[3]; // change data
SPI_Write_CU_Data(MSP_Access_Data); // Write Data to TMS37157
P2IFG &= ~CU_BUSY; // reset Interrupt Flag
P2IE |= CU_BUSY; // set Interrupt enabled
}
__bis_SR_register(LPM4_bits + GIE); // Enter LPM4, global Interrupts Enabled
}
}
#pragma vector=PORT2_VECTOR
__interrupt void PORT2_ISR(void)
{
P2IE &= ~CU_BUSY;
__bic_SR_register_on_exit(LPM4_bits+GIE);
}
```