TMS37157 and eZ430-TMS37157 PaLFI

Passive Low Frequency Interface for MSP430
RFID LF HDX, HF & RF Portfolio

Active (Battery powered)
- CC1101-Q1 RF Transceiver (Automotive)
- PaLFI TMS37157

Semi-Active (With and/or Without Battery)
- Packaged RFID Tags
- LF Interface Next

Passive
- HDX+ LF Tags

Device
- Power
- Software
- Tools
- Support

Time
- 2009
- 2010

Texas Instruments
LF Interface Roadmap

Sub Family Overview

1D Passive RF Interface
- TMS37157x
  - 1D LF interface (passive)
  - Half Duplex
  - Battery Charge function
  - Available

3D RF Interface
- TMS37126
  - 3D LF Interface (passive & active)
  - Half Duplex
  - Battery Charge function
  - Available 2010/2011

MSP430 Micro & RF Interface
- TMS37xxx
  - 1D or 3D Interface
  - MSP430 Microcontroller
  - Half Duplex
  - Battery Charge function
  - Available 2010
TMS37157
PaLFI – Passive Low Frequency Interface Device

Basic Parts of TMS37157

- TMS37157 (RFID Tag IC with user memory and SPI interface to Microcontroller)
- Inductor (pickup coil for TMS37157)
- MSP430F2274 (or another suitable MSP430 with similar inputs (analog or digital) for desired sensors)
- Sensor Measurement suggestions for applications:
  - Altitude, 3-Axis accelerometer, Pressure, etc.
  - Temperature (onboard MSP430)
TMS37157
PaLFI – Passive Low Frequency Interface Device

**Key Features**

- Battery-less accessible memory
- Battery charge function (VL, Vanadium Pentoxide)
- Ultra low power
- Microcontroller powered by LF field
- Multi purpose LF interface to a microcontroller
- Stand alone LF-transponder with memory
TMS37157
Benefits / Features

Features

• Battery check and charge function (VL, Vanadium Pentoxide)
• 3-Wire SPI interface
• Integrated passive LF interface
• Ultra low power: 50nA standby, 70µA active
• Half duplex LF communication at 134kHz
• 8kbit/s uplink data rate
• 121 Bytes user EEPROM
• 32 Bit unique serial number
• Supply voltage range: 2 – 3.6V

Applications

• Semi-active transponder
• Ultra low power data logger memory
• Wireless, battery-less sensor interface
• Configuration interface (PLC, CD/DVD Player)
• Stand alone LF-transponder with memory

LF Benefits

• Highest noise immunity due to HDX communication
• 50% higher read range compared to FDX systems
• Ultra reliable EEPROM
• µC access via LF interface

Applications
**TMS37157**

Cross sell examples

Base Station

- CC430 Controller with UHF TX/RX
- TMS3705 LF BASE STATION 134.2kHz

ID Device

- CC430 Controller with UHF TX/RX
- TMS37157 LF Transponder with EEPROM

**DOWNLINK (LF ENERGY)**

**UPLINK (LF DATA)**

- 425μH
- 2.66mH
- 220nF
- 100nF

Base Station

- CC1101-Q1 UHF TX/RX
- MSP430
- TMS3705 LF BASE STATION 134.2kHz

ID Device

- CC1101-Q1 UHF TX/RX
- MSP430
- TMS37157 LF Transponder with EEPROM

- 470pF
- 100nF

**Downlink (LF Energy)**

**Uplink (LF Data)**

- 425μH
- 2.66mH
TMS37157
PaLFI – Passive Low Frequency Interface Device

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
TMS37157
PaLFI – Passive Low Frequency Interface Device

Highlighted Special Features

MSP ACCESS:
• Reader sends a “MSP Access Command” together with 6 byte of data
• TMS37157 detects MSP Access command and wakes up uC by setting VBATI and BUSY
• uC can detect an MSP access command through VBATI or BUSY signal, request the 6 byte of data from the TMS37157, process it and send 6 bytes to the TMS37157
• TMS37157 transmits the received 6 Bytes of data back via the LF interface
• The carrier has to remain on during the complete process

BATTERY CHARGE:
• Reader sends a “Battery Charge Command” to the TMS37157 and leaves the carrier on
• TMS37157 applies a voltage of about 3.4V to VBAT -> battery or a capacitor are charged
TMS37157 PaLFI System Technical Training Agenda

• Hardware
  – 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
# TMS37157

PaLFI – Passive Low Frequency Interface Device

## TMS37157

### User Memory Map

<table>
<thead>
<tr>
<th>Page</th>
<th>Select Address</th>
<th>User Data</th>
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*Texas Instruments*
# TMS37157
PaLFI – Passive Low Frequency Interface Device

## User Memory Map (cont.)

<table>
<thead>
<tr>
<th>USER DATA</th>
<th>PAGE 40</th>
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<tbody>
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</tbody>
</table>
TMS37157
PaLFI – Passive Low Frequency Interface Device

ez430-TMS37157 Target Board
(ID Device)

2.66mH Inductor
(PaLFI Antenna Coil)

MSP430F2274
TMS3705A1DRG4
Low Frequency Base Station/Reader IC

• Key Features

– 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

16 Pin SOIC Package
TMS3705A1DRG4
Low Frequency Base Station/Reader IC
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
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

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>t_{onmp} Write pulse pause (PPM)(^{(1)})</td>
<td>170</td>
<td></td>
<td></td>
<td>(\mu s)</td>
</tr>
<tr>
<td>t_{onmPL} Write pulse activation/ low bit (PPM)(^{(1)})</td>
<td>230</td>
<td></td>
<td></td>
<td>(\mu s)</td>
</tr>
<tr>
<td>t_{onmPH} Write pulse activation/ high bit (PPM)(^{(1)})</td>
<td>350</td>
<td></td>
<td></td>
<td>(\mu s)</td>
</tr>
<tr>
<td>t_{bttPL} Write low bit period(^{(1)})</td>
<td>400</td>
<td></td>
<td></td>
<td>(\mu s)</td>
</tr>
<tr>
<td>t_{bitrPH} Write high bit period(^{(1)}) (^{(2)}) (^{(3)})</td>
<td>510</td>
<td>520</td>
<td>1730</td>
<td>(\mu s)</td>
</tr>
</tbody>
</table>

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.
• Blue trace is TXCT line on the TMS3705A1DRG4
• Green trace is the actual Low Frequency field generated by the reader IC being amplitude modulated
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 10100101₂. When rotated (to become MSB first) it becomes 10100101₂, then one’s complement is performed on the binary string, yielding 01011010₂ or 0x5A₁₆.
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.
    • 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.

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>WRITE ADDRESS</th>
<th>SELECTIVE ADDRESS</th>
<th>WRITE DATA</th>
<th>FRAME BCC</th>
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<tbody>
<tr>
<td></td>
<td>COMMAND FIELD</td>
<td>PAGE FIELD</td>
<td></td>
<td></td>
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<tr>
<td>General read page, battery check</td>
<td>00</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Selective read page</td>
<td>11</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Program page; MSP access</td>
<td>01</td>
<td>X</td>
<td>X(1)</td>
<td>X</td>
</tr>
<tr>
<td>Selective program page</td>
<td>01</td>
<td>X</td>
<td>X(1)</td>
<td>X</td>
</tr>
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<td>Lock page</td>
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<td>Selective lock page</td>
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<tr>
<td>Protect page</td>
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<td>X</td>
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<tr>
<td>Selective protect page</td>
<td>11</td>
<td>X</td>
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WRITE ADDRESS

<table>
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<tr>
<th>MSB</th>
<th>LSB</th>
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<td>PAGE FIELD</td>
<td>MSB</td>
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Page 3 000011

<table>
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<tr>
<th>MSB</th>
<th>LSB</th>
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<tr>
<td>C</td>
<td>C</td>
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<tr>
<td>COMMAND FIELD</td>
<td>MSB</td>
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</tbody>
</table>

HEX VALUE 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
→ 0106032080C000A3C
← 01B007EFF010E0329040EC0A8CD
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)

LSB MSB
0 0 1 0 1 1 0
• 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.
**Command Implementation**

MSP Access/Program command with a Battery

(Page31, 7Dh)

**TMS37157**

PaLFI – Passive Low Frequency Interface Device

---

**Figure 3. TMS37157 Power Management**

- MSP Access Command with Battery
- TX ON
- TX OFF
  - Charge 20ms
  - Long Charge e.g. 1s
  - RF Signal

---

**MSP 430**

- VBAT
- BUSY
- SIMO
- SCK
- SP тт CLK
- CLK/I/M

---

**Texas Instruments**
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**

→ 01E0632487D040000000000AF58050AF3

← 01B007E0400000000000D14B0A8

**MSP430 Access Command (for Red LED)**

→ 01E0632487D0401000000000EB53050ABD

← 01B007E0401000000000D3FB486
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)

MSP Access Command w/o Battery

RF Signal

LED ON

LED OFF

TX ON

TX OFF

Charge 20ms
Command Bat CHRG
Command MSP ACC
Command Bat CHRG
Long Charge e.g. 10s

Figure 3. TMS37157 Power Manage

MSP430

MSP430
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
⇐ 010B007EFF010E329040EC0A8CD

Battery Charge Command
⇒ 01078610190868000AE2
⇐ 01078610190868000AE230383638

MSP430 Access Command
⇒ 010E0632487D0400000000AF58050AF3
⇐ 010B007E0400000000007D14B0A8

Battery Charge Command
⇒ 01078610190868000AE2
⇐ 01078610190868000AE230383638

Read Page 3 Command
⇒ 01060632080C000A3C
⇐ 010B007EFF010E329040EC0A8CD
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
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
void SPI_Read_SerialNum(void)
{
    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
}
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

```
<table>
<thead>
<tr>
<th>CHARGE</th>
<th>WRITE ADDRESS</th>
<th>Charge.....</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSB</td>
<td>MSB</td>
<td>00 010110</td>
</tr>
</tbody>
</table>
```

Page 26
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.
#include "msp430x22x4.h"
#include "PaFI_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
    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);
}