TI Designs
Single Bidirectional Infrared LED Communication Port Reference Design

TEXAS INSTRUMENTS

Description

Infrared (IR) optical ports are still very popular in ultra-low-power metering and sub-metering applications such as heat cost allocators, gas, water, and heat meters. Typical use cases are configuring and activating the meters during manufacturing or field installation as well as manual readout of billing data using handheld readers. Bidirectional communication per IrDA PHY specification with a 9600-bps data rate is quite common. This very low-cost and ultra-low-power implementation is using a single IR LED for transmitting and receiving data with the algorithm implemented inside the sensor controller engine of a CC1350 Wireless MCU.

Resources

TIDA-01212	Design Folder
CC1350	Product Folder
CC1310	Product Folder
TIDA-00848	Design Folder
TIDA-00838	Design Folder

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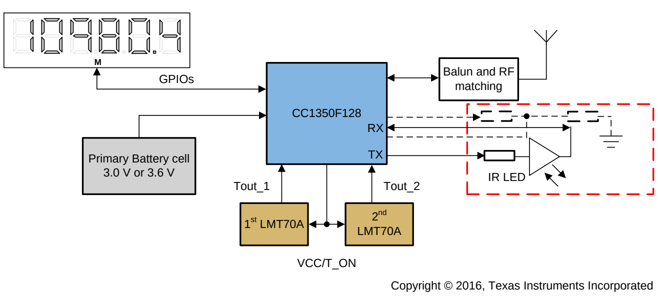
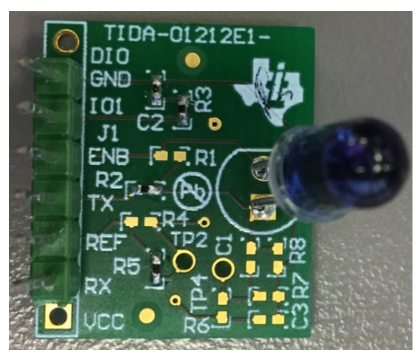
Features

- CC1350 SimpleLink™ Wireless MCU
- Only Two I/Os Required for Bidirectional IR Port Communication With Internal Fixed 1.27-V Reference
- Four I/Os Required (if External Voltage Divider as a Fixed Reference is Used)
- Sensor Controller Engine Controls IR LED to Receive and Transmit IR Data at 9600 bps
- Average Current of 1.73 µA at 3.0 V With CapTouchButton and IR LED Polling Every 1 Second

Applications

- Heat Cost Allocators
- Water Meter
- Heat Meter
- Gas Meter
- Any Metering and Sub-Metering Systems With IrDA 9600-bps Communication Port





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1 System Overview

Many, if not all, metering and sub-metering applications require support for bi-directional infrared (IR) LED communication, which is the dominant low-cost common interface used during manufacturing and later as a maintenance, configuration interface, or for reading out sub-metering data or internal system parameters with a handheld or a mobile device. Some EU standards like EN1434-3 for heat meters require optical interface as per EN62056-21, where two separate IR LEDs are used (one for receive and one for transmit). The IEC62056-21 (also known as EN62056-21 in Europe) IR communication is quite popular with electricity meters throughout the world.

Near field communications (NFC) and *Bluetooth*® Low Energy (BLE) technologies are becoming more and more popular through the integration into smart phones and tablets and can be considered as a possible IR replacement solution; however, the higher component cost, the missing directivity of the RF transmission, and the associated RF certification efforts for these RF technologies limit their mass market deployment as a configuration and maintenance interface in smart metering and sub-metering products so far.

The majority of metering applications (except E-meters) are often powered by primary batteries and thus need a lowest power implementation of IR and RF communications. Gas, water, and heat meters as well as heat cost allocator (HCA) products are widely deployed battery-operated metering and sub-metering products.

There are no fixed requirements for supporting an IR port neither in the EN4064-1 through EN4064-5 (water meter normative documents) nor in EN1434-1 through EN1434-6 (heat meter specifications). Nevertheless, almost all existing water and heat meter products and HCAs provide some type of IR interface, enabling the setup and configuration in the field as well as the readout of the application data, using a handheld unit (HHU). The TIDA-01212 adds an IrDA serial infrared (SIR) optical port implementation inside the sensor controller engine of a CC1350 Wireless MCU. In fact, both CC1350 and CC1310 devices have been tested, so this reference design applies to both (even if only CC1350 is mentioned in this design guide).

1.1 System Description

There are various solutions for IR communications such as integrated TX/RX IR LED modules with two LEDs, one for TX and one for RX operation, similar to the one described in the TFBS4650 IRDA Module SIR Transceiver product page[10]. The IrDA PHY specification defines multiple data rates, with 9600 bps being the mandatory one. Much faster data rates of up to 16Mbps have been defined, though these are relevant to other applications such as PCs, notebooks, and mobile phones.

Dual LED IR modules are easy to integrate and shorten the development time because they handle the amplification and demodulation of the IR signal. However, this functionality comes at a cost premium. An alternative approach is to handle the modulation and the demodulation within a MCU device, especially for the slower IrDA SIR data rates of up to 115.2 kbps. The few MCU resources such as an ultra-low-power timer and a comparator, which are required for supporting the IR protocol in both transmit and receive, are usually freely available in many MCUs, and having a dedicated LED for each direction makes software implementation easier.

The TIDA-01212 introduces a simpler solution by using a single TSPF6200[7] IR LED instead of the dual LED approach. This is more software demanding, but at the same time the lowest component cost solution. The MCU handles the IR LED control for transmit and receive as well as the proper timings for the bi-directional IR serial port communication. Note that a single IR LED in a smart meter device may also require a single IR LED in the reader (or HHU) to support both transmit and receive modes if the two separate IR LEDs are not sufficiently aligned with the single LED in the sub-metering device. Maximum spectral intensity in transmit is achieved along the axis of the LED. Any misalignment between transmit and receive IR LED reduces the spectral intensity and thus the range of the IR optical link.

The capability of any IR LED to function as a receiver has been known since the 1970s due to Forrest W. Mims publications. Although being primarily a transmitter, an IR LED is sensitive typically to wavelengths slightly below its own peak radiant power wavelength[5]. This fact enables the use of a single IR LED as a bi-directional IR communication port. The TIDA-01212 represents such a bi-directional IR communication subsystem, supporting the mandatory 9600 bps data rate of the IrDA PHY1.4 specification. The TIDA-01212 solution can be integrated in any metering application and due to its simplicity and low-power consumption is aimed at smart gas, water, and heat meters and HCAs. A higher data rate than 9600 bps is possible but has not been tested.

The main components of TIDA-01212 are:

- CC1350 Wireless SoC (includes the sensor controller engine for ultra-low-power implementation)
- TSPF6200 IR LED with 890-nm peak transmit wavelength and maximum spectral sensitivity at 860 to 870 nm

NOTE: TIDA-01212 has been also tested with the NEC infrared protocol for TV remote controls, example software and hardware setup is also documented.

1.2 Key System Specifications

Table 1. Key System Specifications

PARAMETER	SPECIFICATIONS	DETAILS
Operating ambient temperature	–40°C to 85°C (for CC1350/CC1310 and Vishay TSPF6200 IR LED)	Section 1.4.1
IR link data rate	9600 bps	Section 2.5
Current consumption (IrDA 9600 polling 1 per second)	1.7 µA at 3 V	Section 3.6
IR NEC protocol for TV remote	Example RX and TX code provided	Section 3.4

1.3 Block Diagram

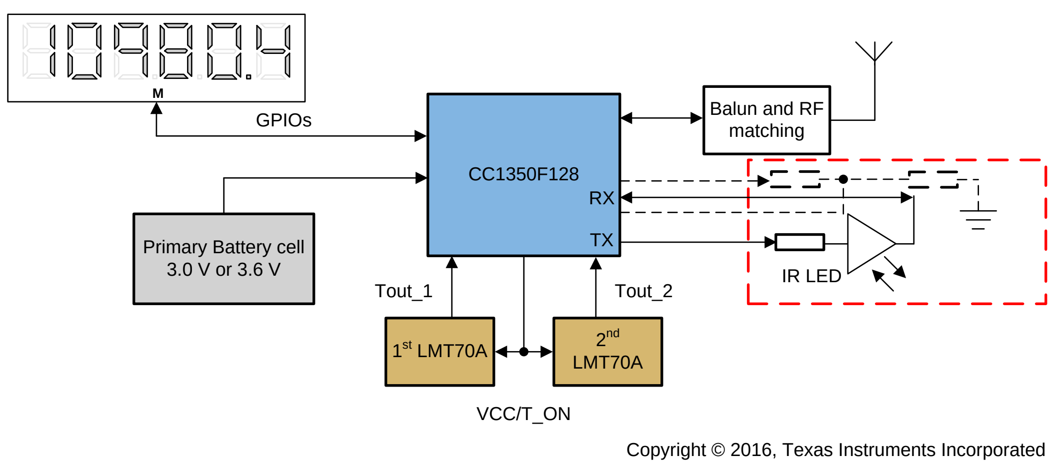

Figure 1. TIDA-01212 Block Diagram

The TIDA-01212 is shown together with the TIDA-00848 HCA design in Figure 1, but it is equally applicable to smart water, heat meters, and gas meters with an IR port.

1.4 Highlighted Products

1.4.1 CC1350

The CC1350 is the first device in the CC13xx and CC26xx family of cost-effective, ultra-low-power wireless MCUs capable of handling both Sub-1 GHz and 2.4-GHz RF frequencies. The CC1350 device combines a flexible, very low-power RF transceiver with a powerful 48-MHz ARM® Cortex®-M3 MCU in a platform supporting multiple physical layers and RF standards. A dedicated radio controller (Cortex-M0) handles low-level RF protocol commands that are stored in ROM or RAM, thus ensuring ultra-low power and flexibility to handle both Sub-1 GHz protocols and 2.4-GHz protocols (for example, BLE; see Figure 2).

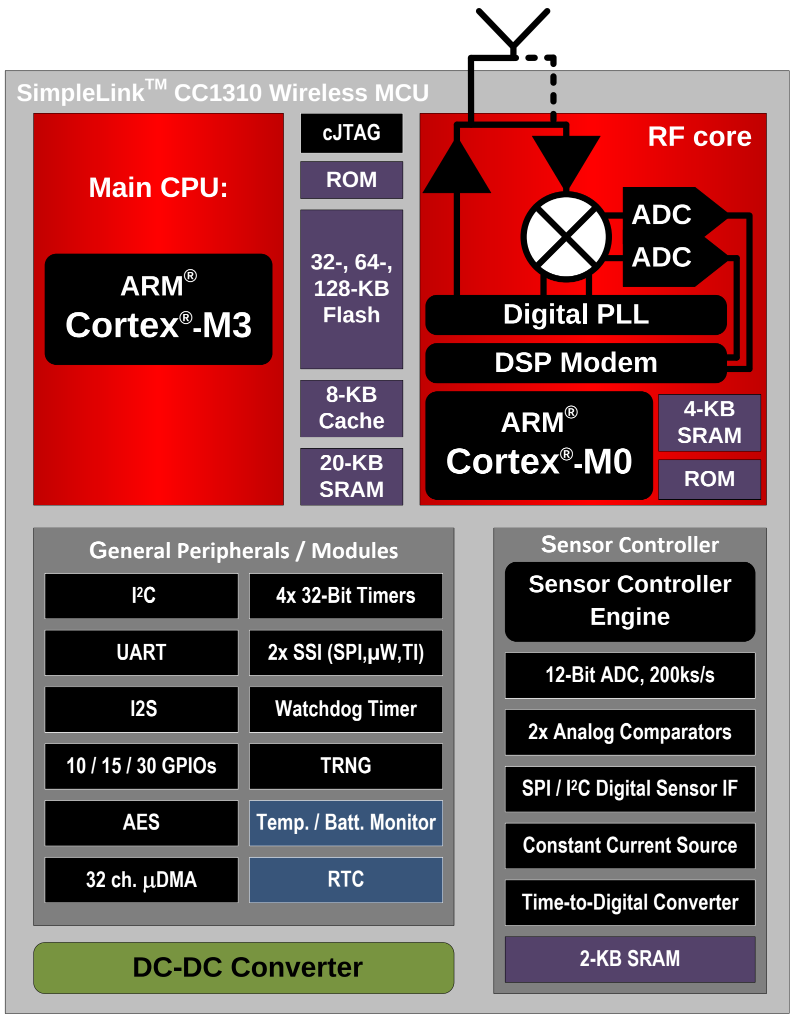

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Figure 2. CC1350 Block Diagram

The ARM Cortex-M3 runs with up to 48 MHz, and there is also 128KB of in-system programmable Flash, 8KB of SRAM for cache (or as general-purpose RAM), and 20 KB of ultra-low leakage SRAM in the device. The sensor controller has been optimized for ultra-low power and can run autonomously from the rest of the system at 24 MHz, using only 0.4 mA + 8.2 µA/MHz. The sensor controller has a 16-bit architecture, controls the 12-bit ADC hardware block, and has its dedicated 2KB of ultra-low leakage SRAM for code and data. The CC1310 standby current is typically 0.8 µA at 3.6 V when using XOSC_LF (with RTC running and RAM and data CPU retention). The sensor controller seamlessly interfaces to the IR LED and uses its internal TDC and COMPA (Comparator A) hardware blocks to deliver outstanding low-power consumption while executing various tasks.

2 Getting Started Hardware and Software

2.1 Hardware

The TIDA-01212 hardware is simple: R2 = 62 Ω and D1 = TPSF6200, which are the minimum required components. Optionally, components R3 = 511 kΩ and C2 = 1.00 MΩ build up an external voltage divider of a 1.87-V reference level (when VDD is 3.3 V, as is the case when the SRF06EB board powers the TIDA-00848 HCA board). The 1.87-V reference is fed into the REF pin of the COMPA module inside the sensor controller engine. The rest of the discrete components are not populated except for either R4 or R5 if the external voltage divider R3/C2 is used.

NOTE: The component values for C1, C3, R6, R7, and R8 are NOT properly selected. All these components have been added as simple passive component placeholders and no RC filter development has been done.

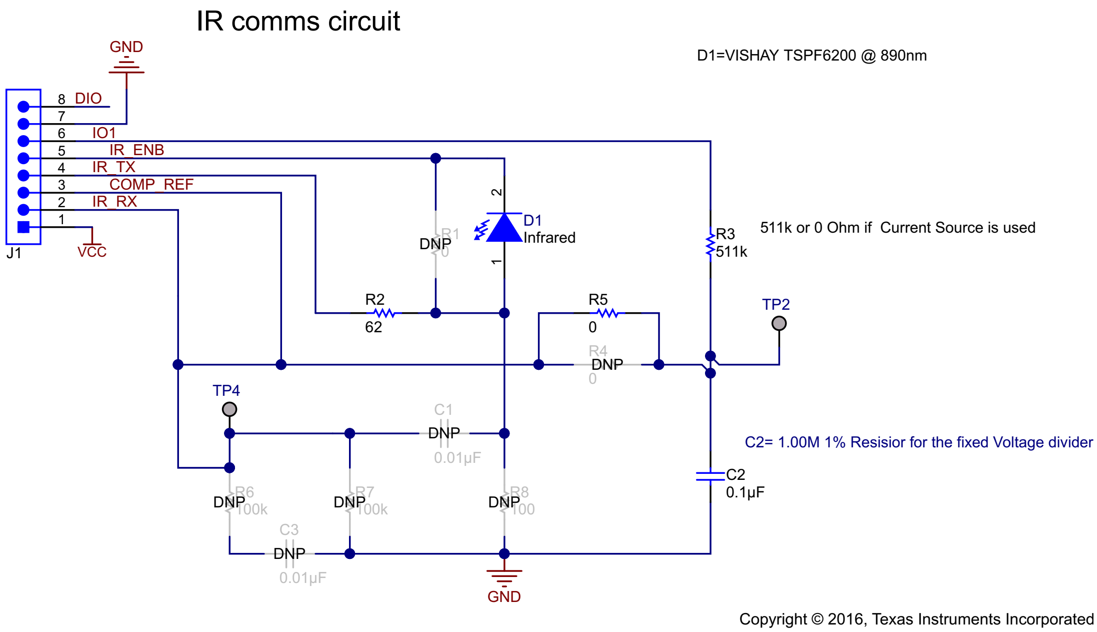

Figure 3. TIDA-01212 Schematic

The TIDA-01212 can connect to multiple TI boards such as the SRF06EB or the TIDA-00848 HCA reference design. The minimal configuration requires only two IOs and just two wires that are connected to TX and IR_ENB on the 8-pin header J1 in Figure 3. The CC1350 Wireless MCU on the EM mounted on top of the SmartRF06EB board, which also includes the XDS100v3 Debugger for programming the CC1350, controls the IR LED operation. The MSP430FR4133LP with the TIDA-01212 is used as an IrDA PHY transmitter with 9600 bps. Here, the IR_TX line is wired to Pin 8.3 on the MSP430FR4133LP while the LED cathode = IR_ENB line connects to the GND on J2 connector (see the left side of Figure 4). The red EVM and the TIDA-01212 on the left operate as the transmitter unit while the receiving unit, consisting of SRF06EB+CC1350EM with another TIDA-01212, sits to the right. The distance between the two IR LEDs in the photo is about 2 cm (see black ruler with a cm scale).

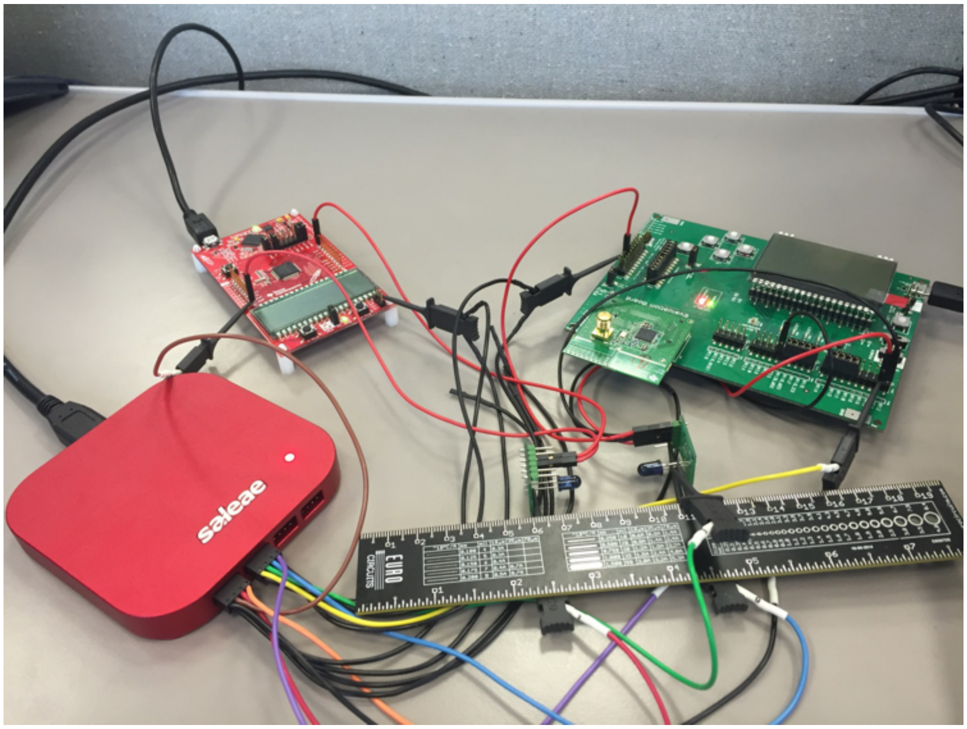

Figure 4. Test Setup With Two TIDA-01212 Boards "Face-to-Face" (TX and RX)

2.2 Software

The first IrDA PHY standard was released in 1994 and describes the transmission in an IrDA-compatible mode, which sometimes is also called SIR. The concept behind is to reuse the RS-232 port, which was a standard peripheral interface in all IBM compatible PCs, for enabling an optical data transmission. The shortening of the bit length to a maximum of 3/16 of its original length (details in Table 2) is done for power saving, which is helpful in battery operated smart metering and sub-metering devices. An IR transmitting LED is driven to transmit an optical signal to the receiver with a simple pulse sequence. This type of transmission covers the data range up to 115.2 kbit/s, which is the maximum data rate supported by standard UARTs. The minimal required transmission speed for IrDA is only 9600 bps. All transmissions must be started at 9600 bps to enable device compatibility; after establishing the bi-directional IR link, higher data speeds can be negotiated[4].

Table 2. IrDA PHY Definition[1]

SIGNALING RATE	MODULATION	RATE TOLERANCE % OF RATE	PULSE DURATION MIN	PULSE DURATION TYP	PULSE DURATION MAX
2.4 kbit/s	RZI	±0.87	1.41 µs	78.13 µs	88.55 µs
9.6 kbit/s	RZI	±0.87	1.41 µs	19.53 µs	22.13 µs
19.2 kbit/s	RZI	±0.87	1.41 µs	9.77 µs	11.07 µs
38.4 kbit/s	RZI	±0.87	1.41 µs	4.88 µs	5.96 µs
57.6 kbit/s	RZI	±0.87	1.41 µs	3.26 µs	4.34 µs
115.2 kbit/s	RZI	±0.87	1.41 µs	1.63 µs	2.23 µs
0.576 Mbit/s	RZI	±0.10	295.2 ns	434.0 ns	520.8 ns
1.152 Mbit/s	RZI	±0.10	147.6 ns	217.0 ns	260.4 ns
4.0 Mbit/s (single pulse) (double pulse)	 4 PPM 4 PPM	 ±0.01 ±0.01	 115.0 ns 240.0 ns	 125.0 ns 250.0 ns	 135.0 ns 260.0 ns
16.0 Mbit/s	HHH (1,13)	±0.01	38.3 ns	41.7 ns	45.0 ns

2.3 IrDA PHY With 9600-bps Implementation

The ultra-low-power software implementation of the IrDA receive and transmit operations is handled inside the sensor controller engine (SCE) of the CC1350. The latter periodically enables and checks the IR LED for incoming signal when in receive mode. Typically, this is the default operational mode, where the metering node (for example, a water meter or HCA device) will be polling the IR LED for incoming wake-up command bytes. The polling period can be adjusted through the CCS open source code project by modifying the TI RTOS period of the TRXIRLED task or by using a different tick sleep period in the SCE command: fwScheduleTask(1); //reschedule the task in 1 TI RTOS tick.

Typically, this polling period will be no longer than 2 to 3 seconds; in order to avoid such a long wake-up period, the TIDA-01212 example code uses 1 second for realistic duty cycle and power consumption estimation. The 1-second period is also used for the CapTouchButton task (copied from the TIDA-00848 design guide[2]) and allows the SCE to execute both tasks sequentially every second as a compromise between low-power consumption and acceptable IR response delay and CapTouch detection delay.

In addition, a separate SCE example code project additionally supports the popular NEC IR protocol, widely used in consumer electronic products such as TVs, SAT receivers, and so on. A short summary of this NEC IR protocol is found in the *NEC Infrared Transmission Protocol*[7].

2.4 Sensor Controller Code Project

The SCE example code in the file "HCACapTouch_IRLED.scp" consists of three tasks required in an HCA device. Figure 5 shows that in total 66.4% of the 2KB RAM resources are used, which leaves some headroom for adding code or some data buffering for the IR port communication in both transmit and receive directions.

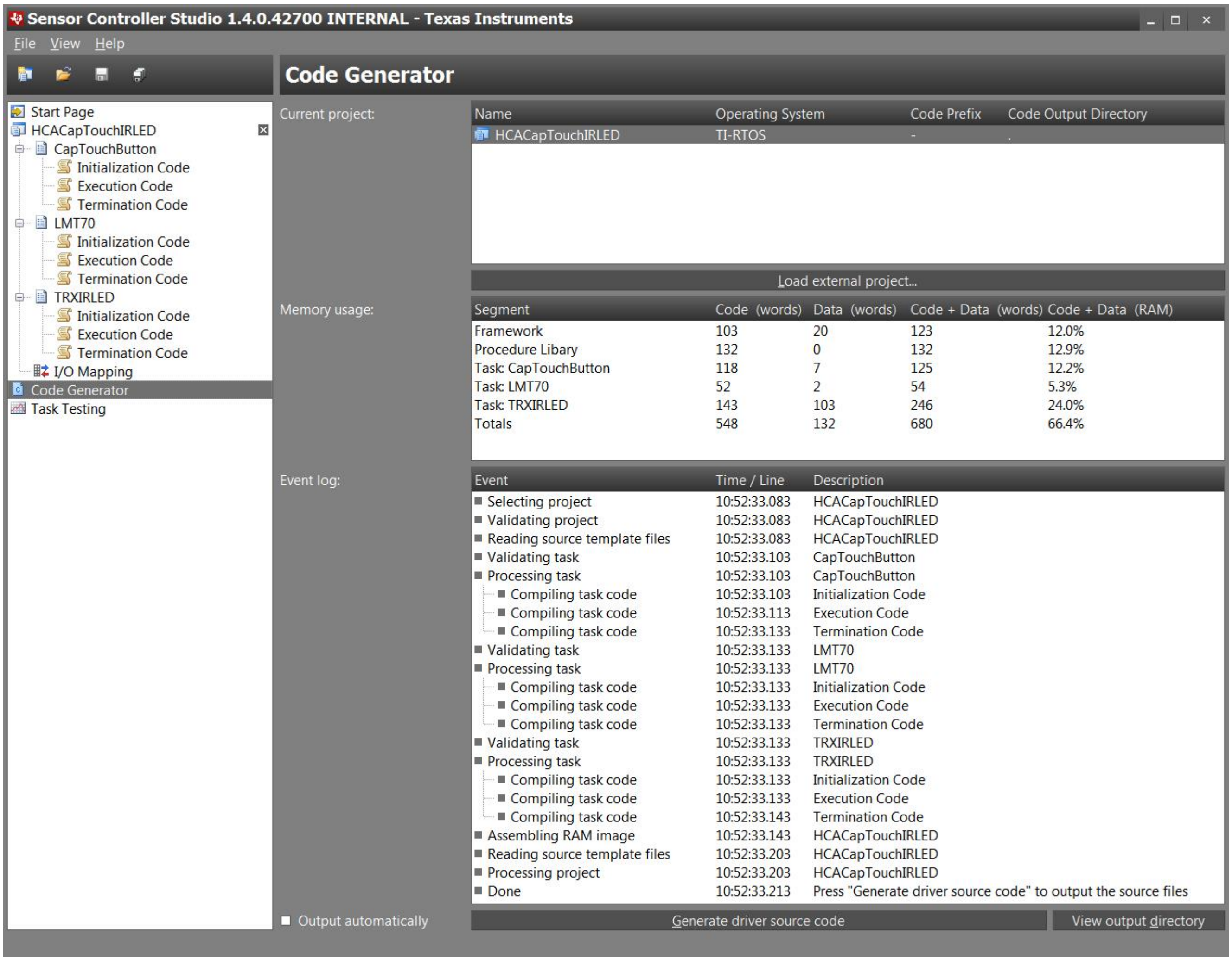

Figure 5. SCE Project for HCA (CapTouchButton, LMT70A Readout, and IR LED Comm Port)

The bi-directional IR code is inside the TRXIRLED task and is explained in Section 2.5. The task itself is split into two sections: the initialization code (which is run only once) and the execution code (which is run periodically, each time the task has been started; here every second).

The other two tasks are not reviewed here; these have been tested and documented in the TIDA-00646 (LMT70) and TIDA-00848 (CapTouchButton). The code for both of these SCE tasks is copied and reused without any change. It is also relevant for implementing an HCA, where all these functions are required and must be supported.

2.5 Initialization and Execution Code of TRXIRLED Task

The initialization part defines all signals that will be used to detect the IR light and sets the CC1350 IO pins as appropriate. The AXS_prefix to the IR_ENB pin means analog, open-source; allowing driving the pin high, which is needed for reverse biasing the IR LED in receive mode. In the minimum IO pin configuration, when DCOUPL = 1.27-V internal voltage reference is used, only IR_ENB and TX signals are needed. If an external resistor divider is used (allowing to extend the IR link range), then the REF and the IO1 lines are necessary. AUXIO_A_REF is chosen as the analog function IO pin of the CC1350, which will be the reference input to the COMPA block in the sensor controller (see Figure 6). In the initialization part, the AUXIO_O_IO1 defines the digital output pin, named IO1, and which is then set HIGH for generating the reference voltage through the divider R3/C2. In Figure 7, the receive part of the execution code is shown. Only the variable n can be used to implement a for() loop in Sensor Controller Studio (SCS), thus adding another execution code loop requires the use of while() statement, here implemented with the index variable k.

The value for k is an important parameter because it sets the number of 1/9600 = 104,166-µs periods, during which the IR LED will be activated to detect an incoming IR light pulse. Normally, the time for 1 byte + Start and Stop bits should be sufficient to reliably detect an IR signal (instead of noise). Different wake-up byte patterns are possible, depending on customer's preference. The shortest IR LED on-time will be achieved if a transmit pattern of "11111 00000" to the IR LED is used, corresponding to a byte = 0x0F with leading "1" as a Start bit and trailing "0" as the Stop bit. Note that the transmit data bits are inverted through the RZI coding, means "0" is when IR pulse is being sent out. This pattern can be detected with a minimum duration of 7 bits times in receive mode and will deliver 2 or more subsequent bits with IR pulse detected.

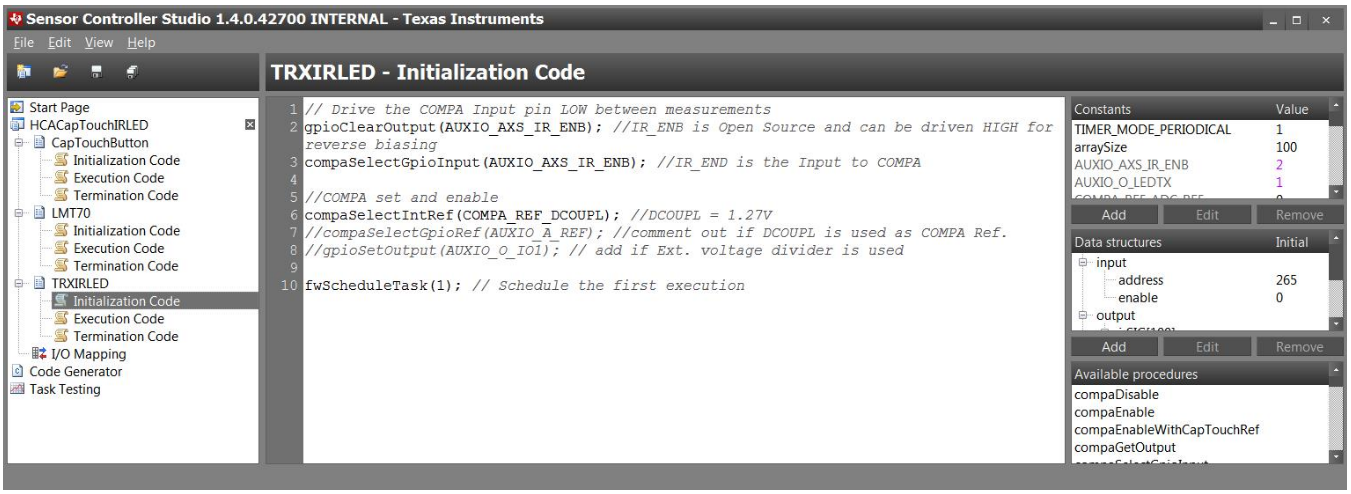

Figure 6. Initialization Code for TRXIRLED Task

In the code in Figure 7, k < 20 is an example to show the functionality of the implementation. For lowest average current consumption in the HCA or any other sub-metering device, depending on the transmit wake-up pattern, the shortest possible IR LED detection period is selected. In the measurement in Section 3.6, *k < 7* has been used.

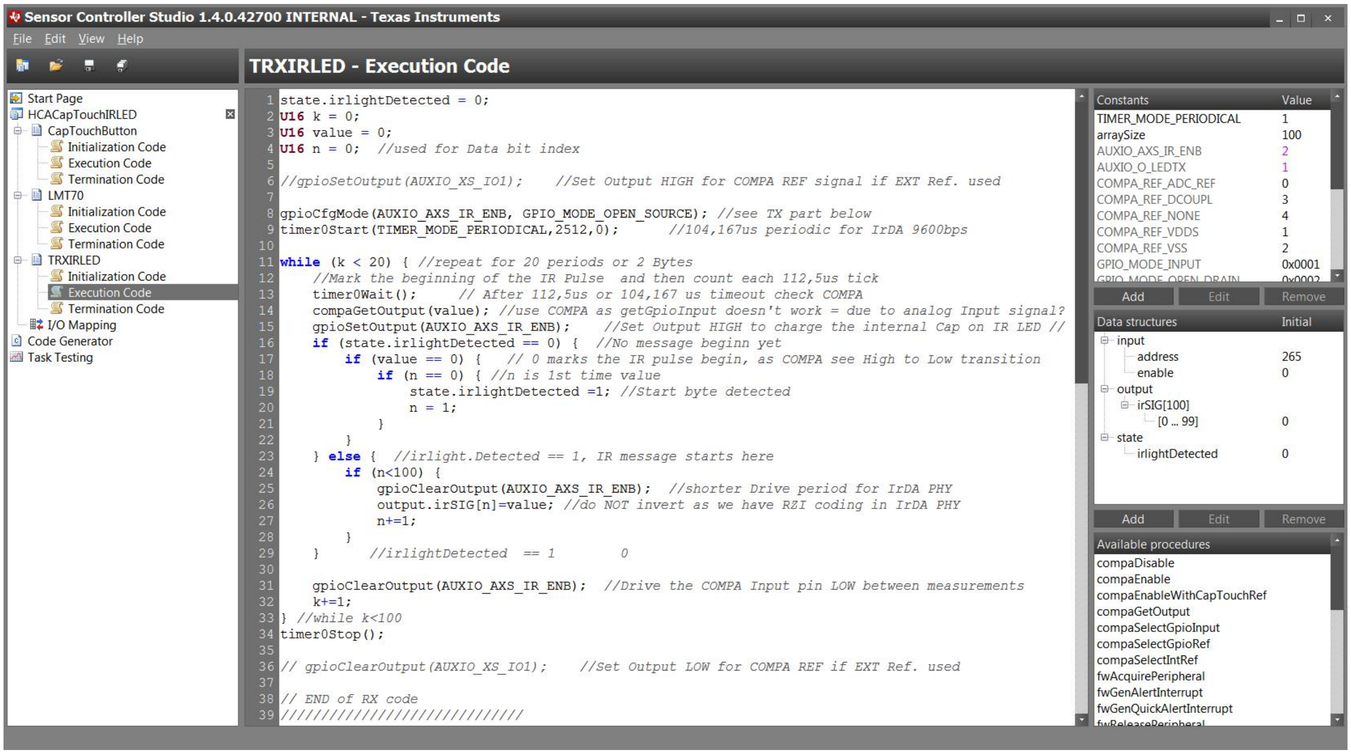

Figure 7. Execution Code for TRXIRLED Task (Receive Polling Example)

The *irlightDetected* flag can be used to send a notification to the HCA application, which can then handle the IR receive data readout; by setting the *input.enable* flag to "1", it can activate the transmit functionality as well. The transmit code shown in Figure 8 uses a predefined value for the 16-bit variable address, which is then split into two bytes and the corresponding Start and Stop bits are inserted.

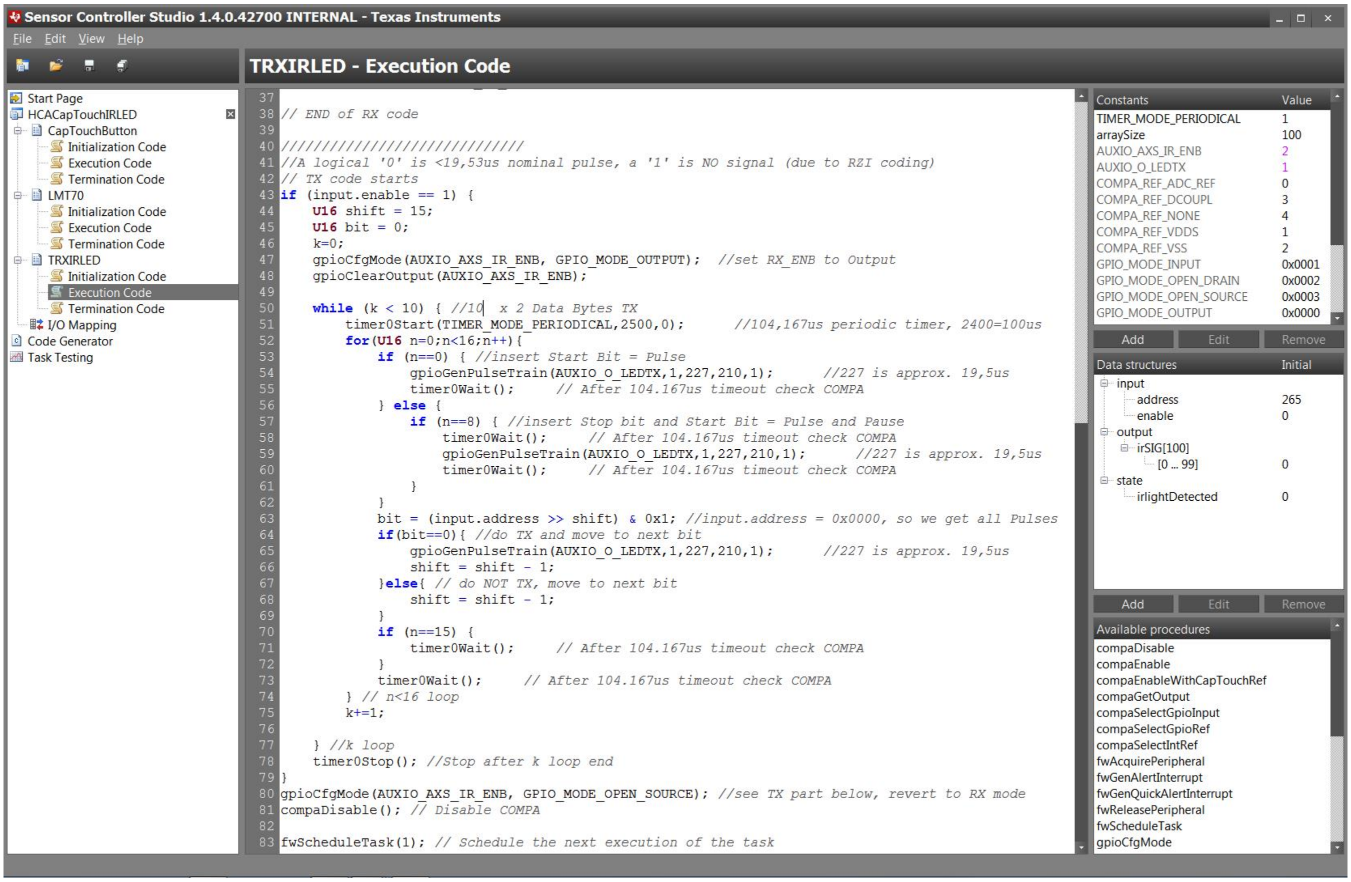

Figure 8. Execution Code for TRXIRLED Task (Transmit Example)

Finally, the IR_ENB pin is reverted to Open Source mode, which is needed for RX operation, and the COMPA module is disabled to save power. The TRXIRLED task itself is rescheduled for the next TI RTOS tick in 1 second.

2.6 Adapting TRXIRLED Task to Another IR LED

If a different IR LED is to be used (other than TSPF6200), adjusting the code to support the LED will be necessary.

Here are some considerations:

1. The LED specification drives the resistor value to adjust the maximum current through the LED.

NOTE: The CC1350 limits the maximum drive capability to 8 mA on pins DIO 5, 6, or 7; all other DIOs have a 4-mA or lower driving capability.

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2. Precise timing for the LED waveform must follow the IrDA PHY specification.

Timings for high and low pulses in transmit mode can be adjusted by modifying the SCS code project (TRXIRLED task) to implement another data rate. Using a faster data rate reduces the duration of the transmit IR pulse, which then reduces the sensitivity in the receive direction. Higher data rates may require a different COMPA reference level, which can be implemented using the external voltage divider with R3 and C2 (used as R).

NOTE: The source code example for the TIDA-01212 is based on the TI RTOS operating system and has been developed to show the IR LED transmit and receive functionality only at room temperature and a nominal 3.3-V supply. It is the user's responsibility to ensure that the IR LED communication in his or her application operates properly over the full temperature and voltage range.

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3 Testing and Results

The TI SCS 1.3.1.x or later version—a TI-provided tool chain—is needed to generate the binary code for the sensor controller; SCS can be downloaded at its product page[3]. The firmware code projects for SCS and CCS are provided as a single source code deliverable (TIDA-01212_firmware.zip). There is one CCS source code project provided, which includes a SCS sub-project, found in the install path /TIDA-01212_RTOS/sce and named "HCACapTouch_IRLED.scp", which handles the IrDA data rate of 9600 bps. A separate SCS and CCS project for the NEC IR protocol is also included, using the SRF06EB and TIDA-01212 combination. The firmware will set the CC1350 into receive mode and the IR LED will be polled periodically to detect IR light. If so, the duration of every signal level (high or low) is calculated and recorded in an array as a number of ticks. The duration of one such tick is 1/5 of 562.5 µs or 112.5 µs, as the shortest duration as per the NEC protocol is 562.5 µs of a high or low level. Five time oversampling in the IR NEC protocol delivers the required precision to detect these signal phases, even though there will be offset for the start of each bit time between the transmitting IR and the receive IR LED. The offset could result in one full tick more or less so that sometimes 4 or 6 ticks will be reported.

A full version of the TI CCS Version: 6.2.0.x (or later) together with the TI RTOS version 2.20.00.08 is required to compile and debug the TIDA-01212 firmware for both HCA and SRF06EB projects.

3.1 Sensor Controller Engine Code Test Procedure

For evaluating the IR LED task performance, a IR LED transmitter device is required and has been implemented using TIDA-01212 and a MSP430FR4133 LaunchPad evaluation board.

3.2 SCS Task TRXIRLED in IrDA 9600 bps

This SCE task uses the COMPA and either the internal 1.27-V reference (DCOUPL) or an external voltage level, provided through the R2 and C3 (used as R) components. A high level is output on IO1 line, on the TIDA-00848 HCA board or SRF06EB equals 3.3 V.Figure 9 shows the signal plot of a 1-second periodic receive code execution inside the TRXIRLED task:

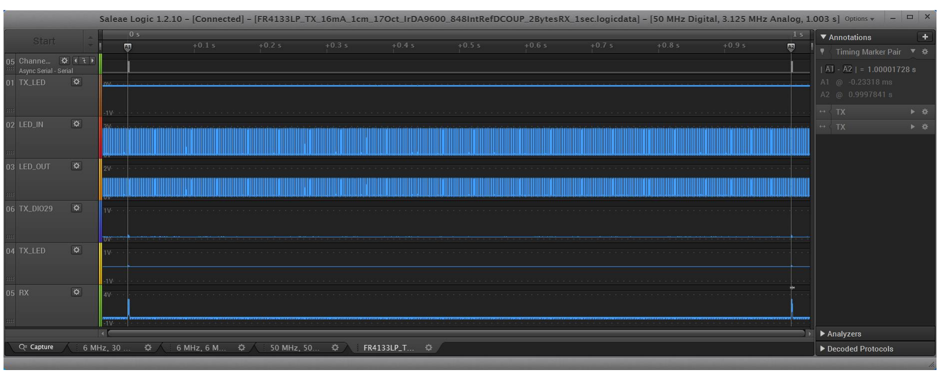

Figure 9. Transmit IR LED Pulses Train and RX Polling Period of 1 Second

Figure 10 shows the zoomed-in view of the IR pulses or bit time slots (20 in a row) is shown; the IR light in bit time slots 8 and 18 decreases the voltage level below 1.27 V. The exact voltage reduction depends on the intensity of IR light as well as the relative timing of the bit pulse versus the polling bit time slot.

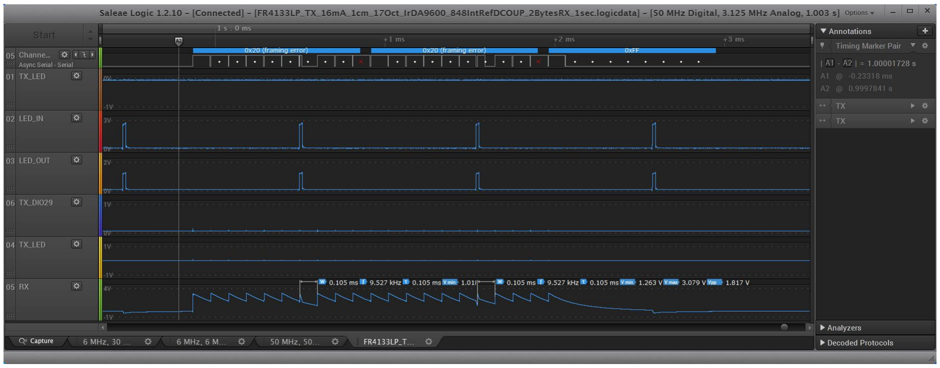

Figure 10. Zoom-in From Figure 9 (IR LED Pulses Make RX Voltage Level Drop Below 1.27 V)

3.2.1 SCS Task LMT70

The task LMT70 is reused from the TIDA-00646 without any change. The provided SCE project includes the LMT70 task such that the total code size includes the temperature sensing functionality. Note that due to reusing the J9 pins in the TIDA-00848 (originally planned for two LMT70A matched precision temperature sensors) to wire the IR LED, the LMT70 task is *not* started. In real applications, this task will add some minor average current on top, depending on the period of reading out the LMT70A sensors, which is often in the range of once in 30 to 60 seconds.

3.2.1.1 CapTouchButton Task

This task is reused from the TIDA-00848 without any change; it is used as a trigger to "switch on" the LCD display for a configurable time period; otherwise, the LCD is "switched off" or fully disabled and no LCD segments are visible. The detection is scheduled every second, just as the TRXIRLED task.

3.3 CCS Code Project

The sensor controller code has been integrated inside the /sce folder within the TIDA-01212 firmware. The /wmbus folder contains the functionality to generate valid wM-Bus data packets for the S-, T-, and C-modes in transmit direction and has been functionally tested. The transmit operation of wM-Bus packets has been reused from the TIDA-00848 code example without any further testing.

The TIDA-01212 hardware is tested in transmit and receive modes:

- Transmitting IR data at 9600 bps
- Transmitting IR NEC protocol data
- Receiving IrDA protocol at 9600 bps (TX unit is another TIDA-01212 connected to a MSP430FR4133LP)
- Receiving IR NEC protocol

3.4 Sensor Controller Task for NEC IR Protocol Detection

The *state.irlightDetected* variable at the bottom graph is representing the IR LED incoming event.

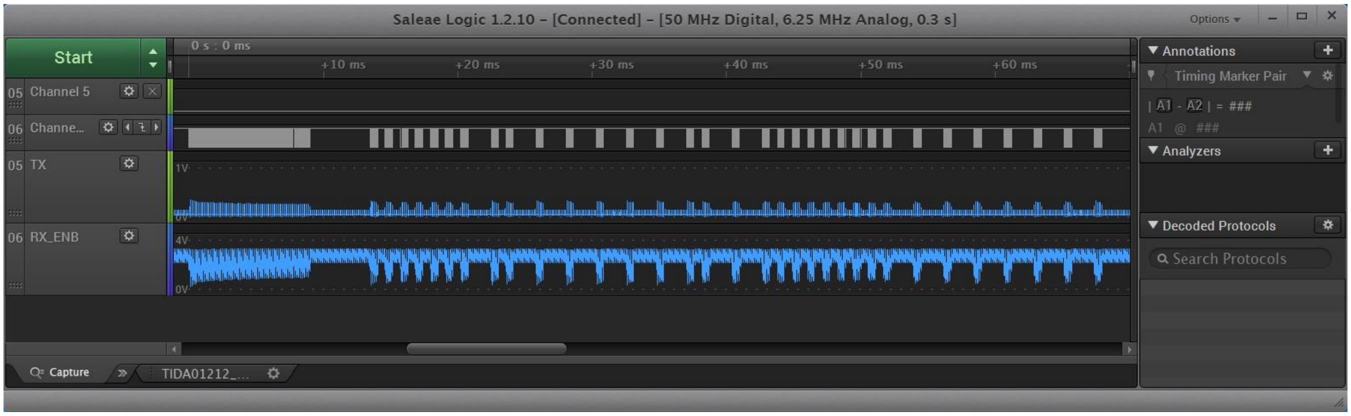

Figure 11. IR Input Signal From TV RC Using NEC IR Protocol

The IR transmitted signal from an off the shelf Tevion remote control (RC) has been captured in Figure 11, where the Key "1" of the Tevion RC gets detected and decoded as 32 bits in irSIG[2-33]. The initial two irSIG[0:1] array elements hold the 79 timer ticks of 112.5 µs for the HIGH period (preamble of 9 ms) and the 41 ticks each for the LOW period of 4.5 ms following the preamble. Note that due to phase difference between the RC (transmitter) and the receiver (device under test), the number of ticks for the preamble and LOW phase afterwards will vary around 79 and 40 with ±1 tick mostly. The RC Key "1" is coded in the third byte irSIG[18-25] as "1000 0000", and the same value is transmitted inverted, as seen in irSIG[26-33] as "0111 1111". Here a plot of Key 1 with two I/Os (TX and RX_ENB) is shown; note also that the last pulse to the right is the "end of message" burst.

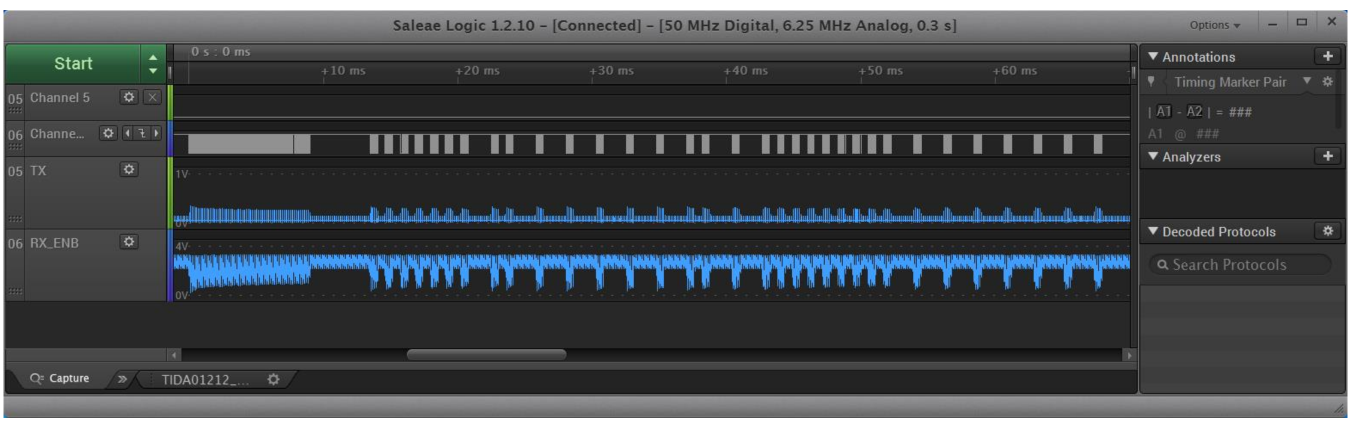

Figure 12. RX_ENB is the Analog Signal Input to COMPA (Using an Internal Reference of DCOUPL = 1.27 V)

The preamble and the following low level phase can be easily recognized within the RX_ENB (blue line in Figure 13) with the time measured at approximately 4.5 ms.

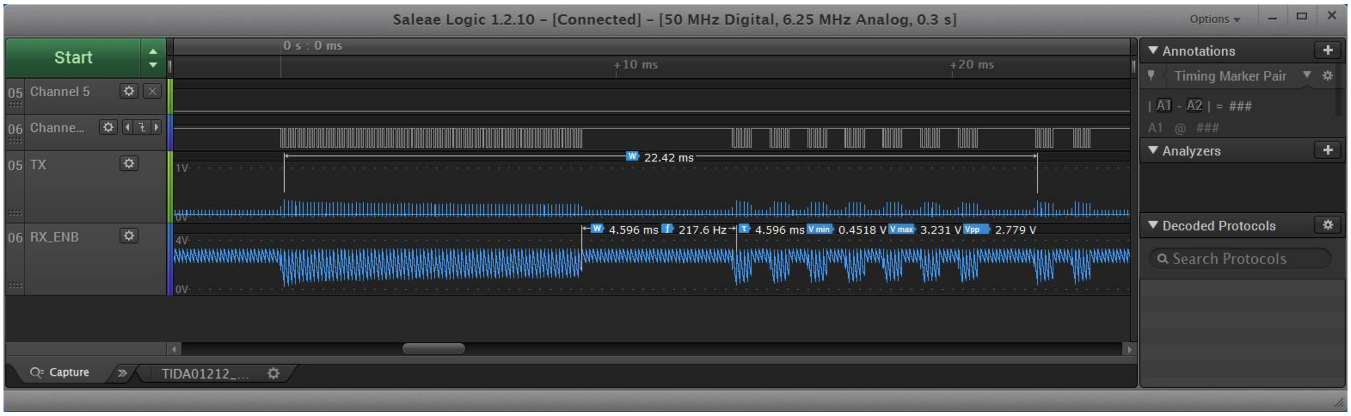

Figure 13. Timings for IR From TVR Using NEC IR Protocol, Preamble, Low Phase, and First Bits

In Figure 14, the timing of the logical "0" as per the NEC IR protocol has been captured and measured.

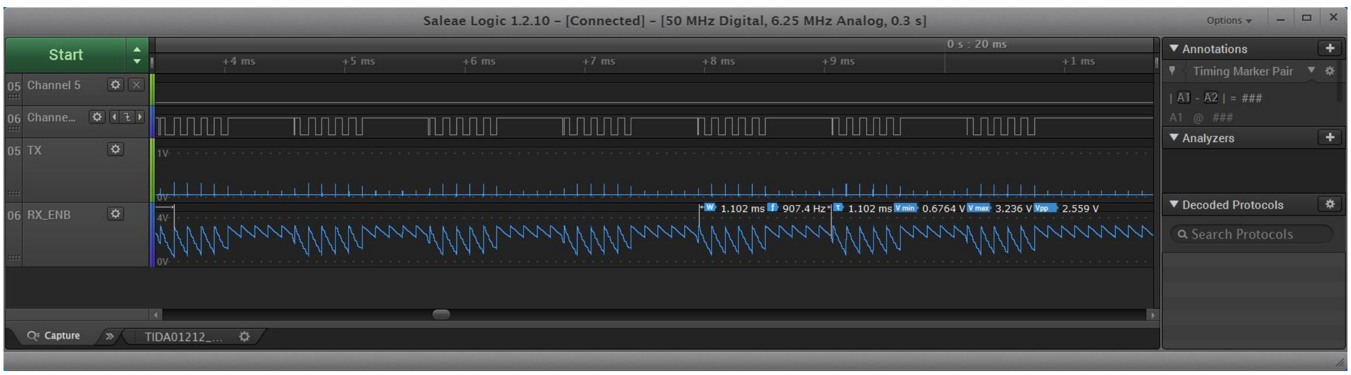

Figure 14. Timing of Logical "0" as per NEC IR Protocol

Finally, the logical "1" of the protocol is shown in Figure 15, consisting of a HIGH phase and three times longer LOW phase with a total duration of 2.25 ms.

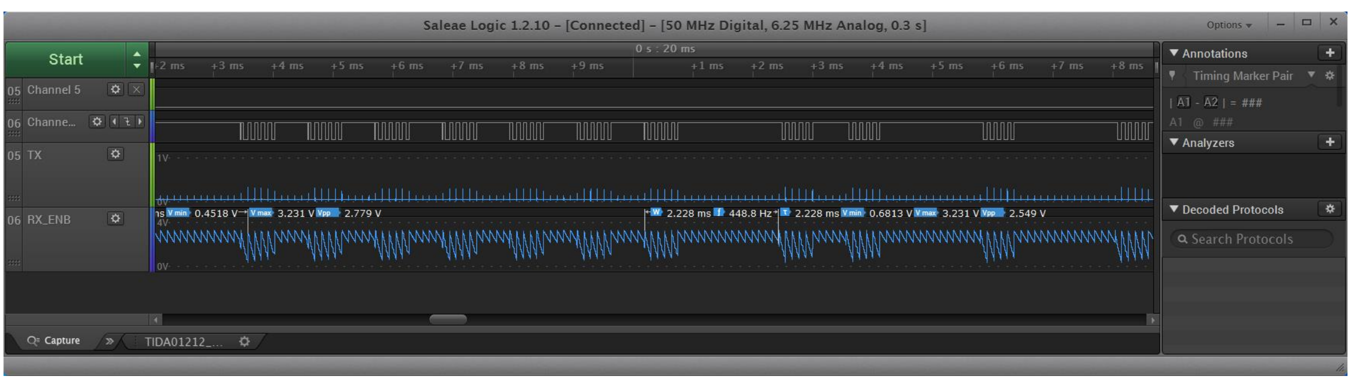

Figure 15. Logical "1" Timing as per NEC IR Protocol

3.5 IR LED Transmission in NEC IR Protocol

The transmit operation of the TIDA-01212 has been tested using the CCS project. Only DIO5, DIO6, and DIO7 have the high driving strength of 8 mA, which must be set in the application code immediately after the scifInit() function call with this CC13xx DriverLib function:

- IOCIODrvStrengthSet(IOID_6, IOC_CURRENT_8MA, PIN_DRVSTR_MAX);

The effect of this driverLib function call was successfully verified on one TIDA-01212, where almost 0.5 V of higher output voltage at the DIO5 pin during IR LED transmission was measured.

3.6 TIDA-01212 Current Consumption

The power consumption of the TIDA-01212 was measured with an Agilent N6781A 2 quadrant source or measure unit for battery drain analysis. The average current drawn is 1.731 µA, as reported in the field "Avg" in Figure 16.

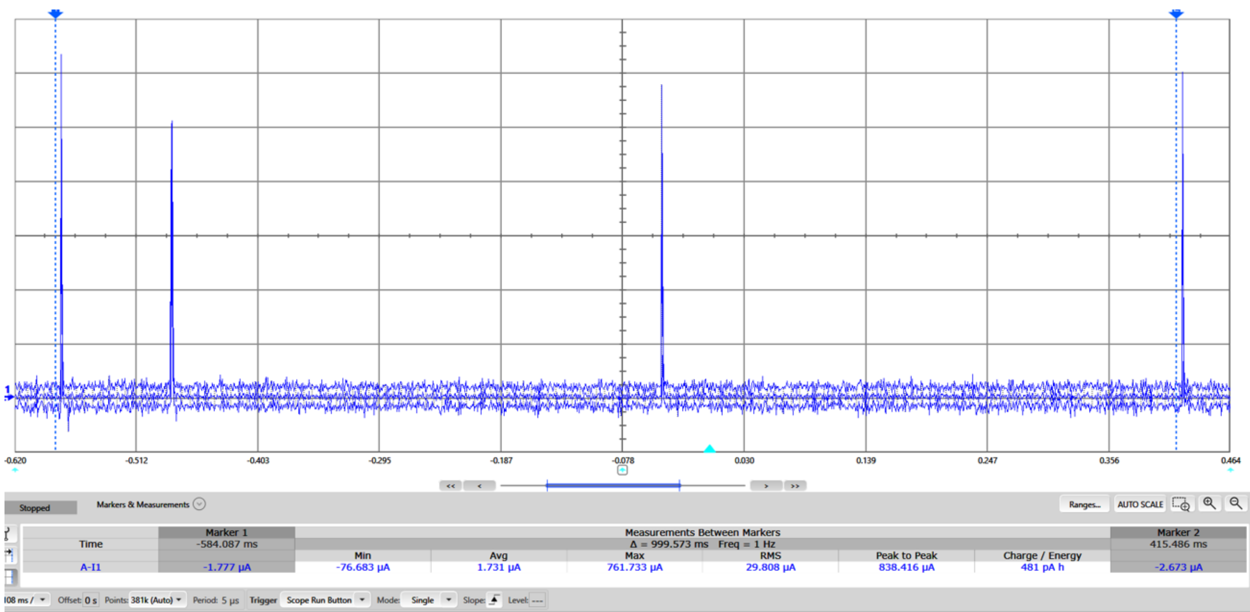

Figure 16. Current Consumption Measurement

For reference, the full current consumption profile of the example code is provided, which includes the RF current pulse, the standby or sleep mode with the periodic recharge pulses, and then the LCD activity of 2 seconds, where the timing markers "1" and "2" are placed (see the two vertical dashed lines in Figure 17). The field "Avg" reports a value of 976,181 µA for the current drawn when the LCD is visible.

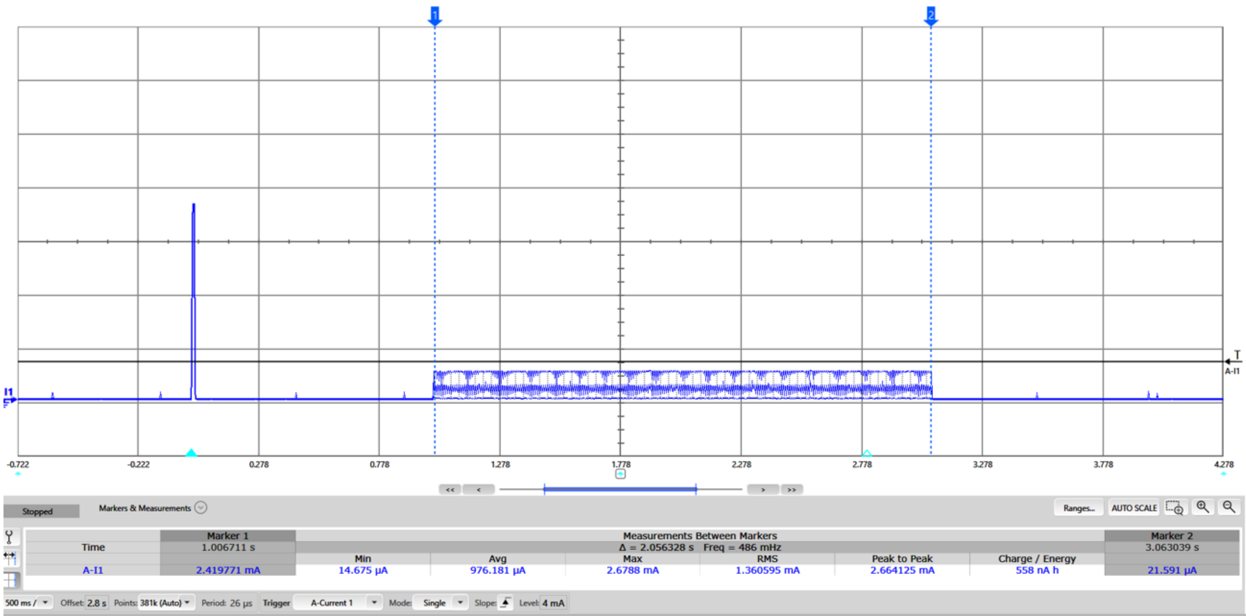

Figure 17. RF Transmission Pulse, Sleep Mode, and LCD Activity With TIDA-00848+TIDA-01212

4 Design Files

4.1 Schematics

To download the schematics, see the design files at TIDA-01212.

4.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDA-01212.

4.3 PCB Layout Recommendations

4.3.1 Layout Prints

To download the layer plots, see the design files at TIDA-01212.

4.4 Altium Project

To download the Altium project files, see the design files at TIDA-01212.

4.5 Gerber Files

To download the Gerber files, see the design files at TIDA-01212.

4.6 Assembly Drawings

To download the assembly drawings, see the design files at TIDA-01212.

5 Software Files

To download the software files, see the design files at TIDA-01212.

6 Related Documentation

1. Infrared Data Association Serial Infrared Physical Layer Specification version 1.4 (May 30th, 2001)
2. Texas Instruments, *Reference Design for Segment LCD Control Using GPIO Pins to Increase System Flexibility*, TIDA-00848 Design Guide (TIDUBQ7)
3. Texas Instruments, Sensor Controller Studio (http://www.ti.com/tool/sensor-controller-studio)
4. Vishay Semiconductors, *Infrared Data Communication According to IrDA® Standard Part 1: Physical Layer*, Doc.#: 82513, Rev 1.4, 20-Sep-06
5. Vishay Semiconductors, *High Power Infrared Emitting Diode, 890 nm, GaAlAs / Double Hetero*, TSPF6200 Datasheet, Doc.#: 82425, Rev. 1.2
6. Mitsubishi Electric Research Laboratories, TR2003-35, July 2003 (http://www.merl.com)
7. Altium, *NEC Infrared Transmission Protocol*, NEC IR protocol
8. IEC 62056-21 Specification, *Electricity metering – Data exchange for meter reading, tariff and load control – Part 21: Direct local data exchange*
9. Texas Instruments, MSP430FR4133LP Product Page (http://www.ti.com/tool/msp-exp430fr4133)
10. Vishay Semiconductors, TFBS4650 IRDA Module SIR Transceiver Product Page (http://www.vishay.com/product?docid=84672)

6.1 Trademarks

All trademarks are the property of their respective owners.

7 Terminology

HCA— Heat cost allocators

Battery-powered electronic devices, used to capture the proportionate thermal output of radiators in consumer units, popular or mandatory in many European countries

IrDA PHY— Infrared Data Association Serial Infrared Physical Layer Specification

8 About the Author

MILEN STEFANOV (M.Sc.E.E) is a system engineer at TI, working in the Grid Infrastructure field and an expert in RF communication technologies and metering applications. After graduating, he spent 5 years as a research assistant at the University of Chemnitz (TUC) and 3.5 years in the semiconductor industry in high-speed optical and wired communications as a system engineer. He joined TI in 2003 to become a Wi-Fi expert and support TI's Wi-Fi products at major OEMs; since 2010, he has focused on metering and sub-1GHz RF solutions for the European Grid Infrastructure market. Mr. Stefanov has published multiple articles on wM-Bus technology in Europe and presented technical papers at the Wireless Congress and Smart Home & Metering summits in Munich.

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