Remote Control of High-Brightness LEDs

Devices Supported
MC1321x

Document Number: DRM097

Rev. 0

04/2008

DRM097
Rev. 0
04/2008

Chapter 1
Introduction

Chapter 2
Control Theory for HBLED Lighting

Chapter 3
ZCOMM Board Description

Chapter 4
Demo System Description

Chapter 5
Software Implementation

Chapter 6
Demo Setup

Appendix A
Schematics

Appendix B
ZCOMM Board – Bill of Materials

Chapter 1
Introduction

1.1   Introduction

This document describes the design of a high-brightness LED demo system, which demonstrates wireless communication using Freescale's MC13213 (SiP) device, high-brightness LED dimming control using Freescale's MM908E625 (Quad Half H-Bridge with power supply + HC08), and the 3-axis acceleration sensor MMA7260QT from Freescale.

This demo system is a versatile remote control for different applications. For the application in this demo, the Freescale Luxeon Evaluation Kit by Future Electronics, with an HB LED board, was chosen.

Wireless communication is preferable because it provides flexibility in the positioning of application devices without a wire medium. Light emitting diodes (LEDs) are popular in general lighting areas. Advantages of using LED lighting are a long operating life, no fragile glass, no mercury, and low-voltage DC operation.

The HB LED demo system performs light dimming on the red, green, blue, and white high-brightness LEDs depending on the 3-axis acceleration sensor (MMA7260Q) readings on the ZSTAR remote control.

This design uses boards already available, such as the RD3152MMA7260Q (ZSTAR), Freescale Luxeon Evaluation Kit by Future Electronics, and the LIN evaluation kit. The wireless communication board, the ZCOMM (wireleZ-COMMunication) board, is a newly designed board.

The current device ZCOMM board introduces users to the MC13213 low-cost 8-bit microcontroller with 2.4 GHz wireless data transceiver. It includes a universal application connector used for direct connection to the application board, an RS232 port for communication with a control device, a background debug module BDM, for in-circuit hardware debugging and programming, switches, LEDs for monitoring purposes, and a host MCU, allowing the user flexibility in establishing wireless data networks between various electrical applications.

This reference design includes basic radio freqency theory, the system design concept, hardware implementation, and the software design, including the FreeMASTER software visualization tool.

Each wireless part communicates over the RF medium using the freely available software stack SMAC from Freescale.
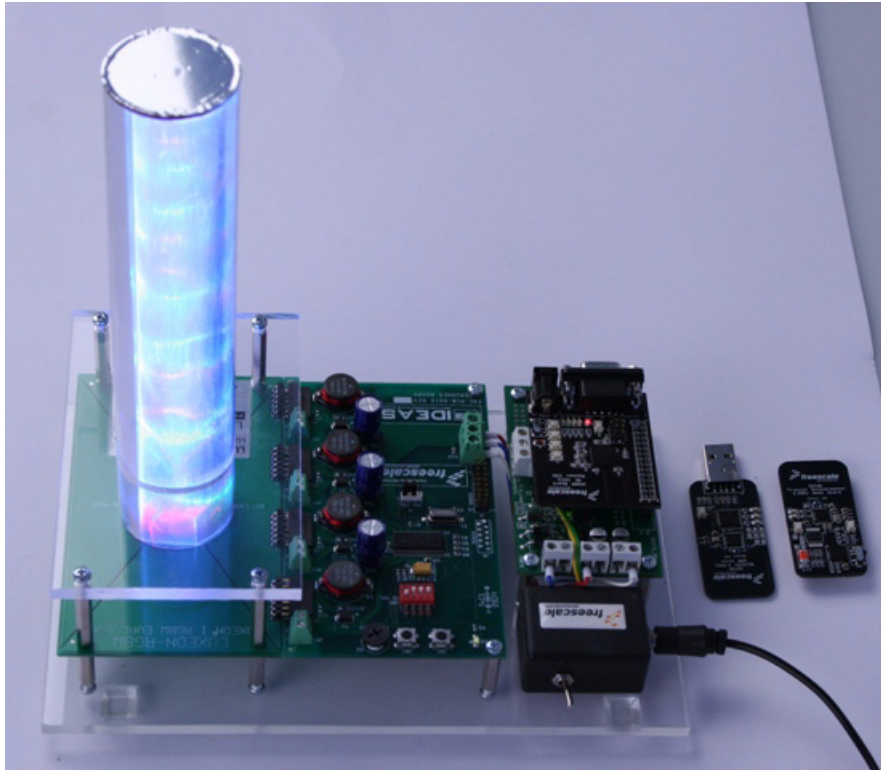
Figure 1-1. HB LED Demo System

1.2   Features

- Versitile wireless communication (2.4 GHz) between remote control, computer interface—ZSTAR (sensor, USB stick)—and application board—ZCOMM with MC13213 device
- Communication based on SMAC protocol layer
- Universal application connector and RS232 connector on ZCOMM board for different application boards to be connected
- Addressed networking (each end application is assigned a unique address)
- Visualization of the 3-axis accelerometer features
- SCI to LIN level shifting (LIN transceiver, KIT33661DEVB)
- High-brightness LEDs dimming control—Freescale Luxeon Evaluation Kit (MM908E625Quadrunner MCU) with a 370 mA current driving capability for each color
- Two lightning modes—RGB (red, green, blue) and white
- Input supply voltage from +3.5 V DC to +12 V DC
- FreeMASTER graphical user interface

1.3   System Overview

A block diagram of the system is shown in Figure 1-2.

A detailed description of the ZCOMM board is found in Chapter 3, "ZCOMM Board Description".
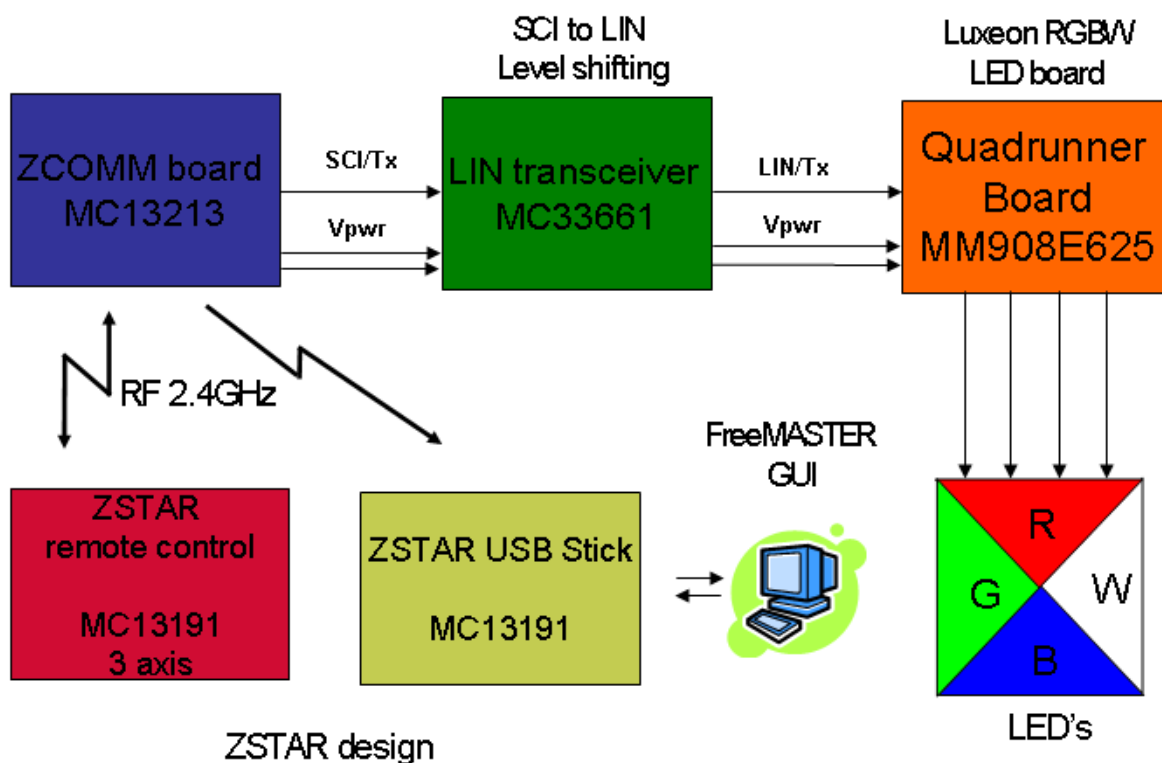
Figure 1-2. High-Brightness LED Demo System Block Diagram

1.4   Featured Products

This demo consists of several Freescale products. Their main features are listed below.

1.4.1   MC13213—2.4 GHz RF Transceiver and 8-Bit MCU

The MC1321x family is Freescale's second-generation ZigBee™ platform, which incorporates a low-power 2.4 GHz radio frequency transceiver and an 8-bit microcontroller on a single 9x9x1 mm 71-pin LGA package.

The MC1321x solution can be used for wireless applications from simple proprietary point-to-point connectivity to a complete ZigBee mesh network. The combination of the radio and a microcontroller in a small footprint package allows for a cost-effective solution. The MC1321x contains an RF transceiver that is an IEEE 802.15.4-compliant radio that operates in the 2.4 GHz ISM frequency band. The transceiver includes a low-noise amplifier, 1 mW nominal output power, PA with internal voltage controlled oscillator (VCO), integrated transmit/receive switch, on-board power supply regulation, and full spread-spectrum encoding and decoding.

The MC1321x also contains a microcontroller based on the HCS08 family of microcontrollers and can provide up to 60 KB of flash memory and 4 KB of RAM. The onboard MCU allows the communications stack and also the application to reside on the same system-in-package (SiP). Table 1-1 shows the MC1321x family organization.

Table 1-1. Memory Configuration

Microcontroller	Program Flash	Unified Data/Program RAM	Extended Features
MC13211	16 Kbyte	1 Kbyte	—
MC13212	32 Kbyte	2 Kbyte	—
MC13213	60 Kbyte	4 Kbyte	—
MC13214	60 Kbyte	4 Kbyte	ZigBee stack
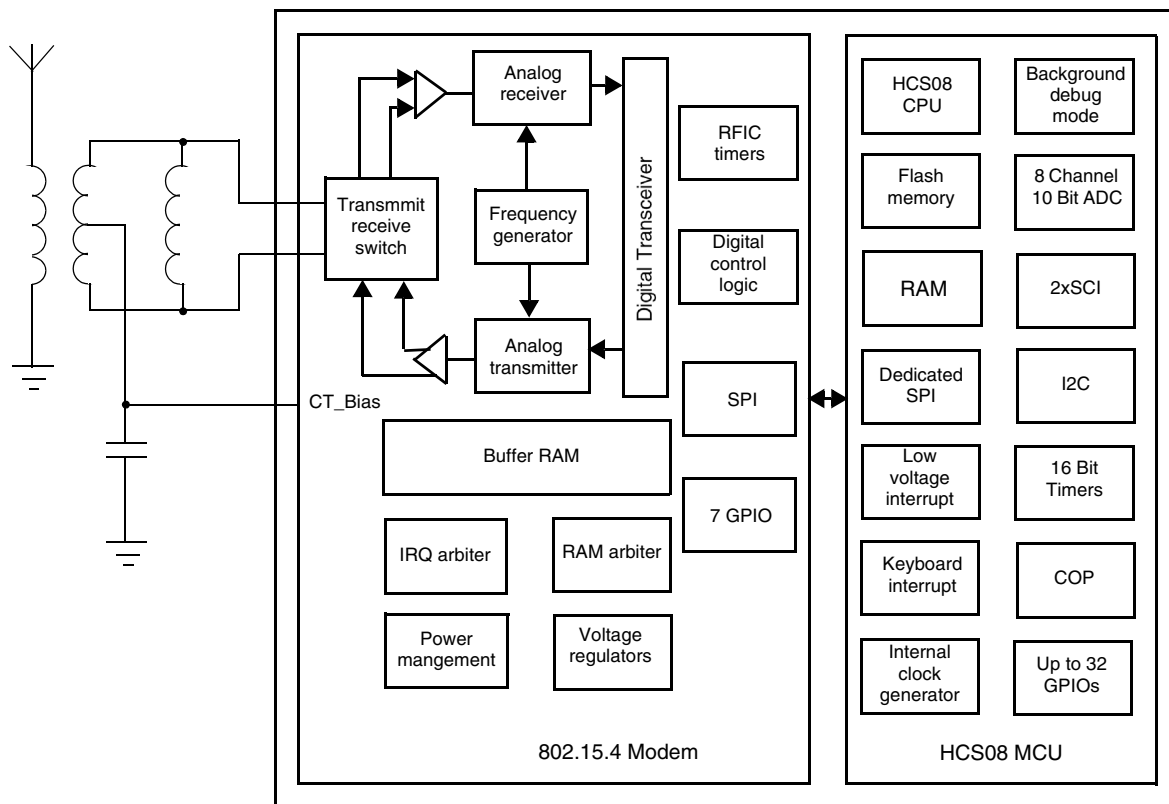
Figure 1-3. MC13213 Block Diagram

1.4.1.1   General Platform Features

- IEEE 802.15.4 standard compliant on-chip transceiver/modem
  - 2.4 GHz
  - 16 selectable channels
  - Programmable output power
- Multiple power saving modes
- 2 V to 3.4 V operating voltage with on-chip voltage regulators for modem
- –40°C to +85°C temperature range
- Low external component count
- Supports single 16 MHz crystal clock source operation or dual crystal operation

- Support for SMAC, IEEE 802.15.4, and ZigBee software
- 9 mm x 9 mm x 1 mm 71-pin LGA

1.4.1.2 Microcontroller Features

- Low-voltage MCU with a 40 MHz low-power HCS08 CPU core
- Up to 60K flash memory with block protection and security and 4K RAM
    — MC13211: 16 KB flash, 1 KB RAM
    — MC13212: 32 KB flash, 2 KB RAM
    — MC13213: 60 KB flash, 4 KB RAM
    — MC13214: 60 KB flash, 4 KB RAM with ZigBee Z-stack
- Low-power modes (Wait and three stop modes)
- Dedicated serial peripheral interface (SPI) connected internally to an 802.15.4 modem
- One 4-channel and one 1-channel 16-bit timer/pulse-width modulator (TPM) module with selectable input capture, output capture, and PWM capability
- 8-bit port keyboard interrupt (KBI)
- 8-channel 8-10-bit ADC
- Two independent serial communication interfaces (SCI)
- Multiple clock source options
    — Internal clock generator (ICG) with a 243 kHz oscillator that has ±0.2% trimming resolution and ±0.5% deviation across voltage.
    — Start-up oscillator of approximately 8 MHz
    — External crystal or resonator
    — External source from the modem clock for high accuracy source or a low-cost system option
- Inter-integrated circuit (IIC) interface with 100 kbps operation
- In-circuit debug and flash programming available via on-chip background debug module (BDM)
    — Two comparator and nine trigger modes
    — Eight deep FIFO for storing change-of-flow addresses and event-only data
    — Tag and force breakpoints
    — In-circuit debugging with single breakpoint
- System protection features
    — Programmable low voltage interrupt (LVI)
    — Optional watchdog timer (COP)
    — Illegal opcode detection
- Up to 32 MCU GPIOs with programmable pull-ups

1.4.1.3 RF Modem Features

- Fully compliant IEEE 802.15.4 transciever supports 250 kbps O-QPSK data in 5.0 MHz channels and full spread-spectrum encode and decode

- Operates on one of 16 selectable channels in the 2.4 GHz ISM band
- −1 to 0 dBm nominal output power, programmable from −27 dBm to +3 dBm typical
- Receive sensitivity of ≤92 dBm (typical) at 1% PER, 20-byte packet, much better than the IEEE 802.15.4 specification of −85 dBm
- Integrated transmit/receive switch
- Dual PA output pairs that can be programmed for full differential single port or dual port operation that supports an external LNA and/or PA
- Three low-power modes for increased battery life
- Programmable frequency clock output for use by the MCU
- Onboard trim capability for the 16 MHz crystal reference oscillator eliminates the need for external variable capacitors and allows for automated production frequency calibration
- Four internal timer comparators available to supplement the MCU timer resources
- Supports packet mode and streaming mode
- Seven GPIOs to supplement the MCU GPIO

1.4.2   MM908E625 – Integrated Quad Half H-Bridge with Power Supply

The 908E625 is an integrated single-package solution including a high-performance HC08 microcontroller with a *SMARTMOS*™ analog control IC. The HC08 includes flash memory, a timer, enhanced serial communications interface (ESCI), an analog-to-digital converter (ADC), serial peripheral interface (SPI) (only internal), and an internal clock generator (ICG) module. The analog control die provides fully protected H-Bridge/high-side outputs, voltage regulator, autonomous watchdog with cyclic wake-up, and a local interconnect network (LIN) physical layer. The single-package solution, together with the LIN, provides optimal application performance adjustments and space-saving PCB design. It is suited for the control of automotive mirror, doorlock, and light-leveling applications.

1.4.2.1   MM908E625 Features

- High-performance M68HC908EY16 core
- 16 KB of on-chip flash memory
- 512 bytes of RAM
- Internal clock generation module
- Two 16-bit, 2-Channel Timers
- 10-bit analog-to-digital converter
- LIN physical layer
- Autonomous watchdog with cyclic wakeup
- Three two-terminal hall-effect sensor input ports
- One analog input with switchable current source
- Four low RDS(ON) half-bridge outputs
- One low RDS(ON) high-side output
- 13 microcontroller I/Os

1.4.3   Triple Axis Accelerometer MMA7260QT

The MMA7260QT is a low-g accelerometer with a selectable 1.5 g to 6 g range. The MMA7260QT has many unique features that make it an ideal solution for many consumer applications, such as freefall protection for laptops and MP3 players, tilt detection for e-compass compensation and mobile phone scrolling, motion detection for handheld games and game controllers, position sensing for g-mice, shock detection for warranty monitors, and vibration for out of balance detection. Features such as low power, low current, and a sleep mode with a quick turn on time, allow the battery life to be extended in end applications. The 3-axis sensing in a small QFN package requires a 6mm x 6mm board space, with a profile of 1.45 mm, allowing easy integration into many small handheld electronics.

There are several other derivatives of the MMA7260QT:

- • MMA7261QT XYZ-axis 2.5g/3.3g/6.7g/10g
- • MMA6270QT XY-axis 1.5g/2g/4g/6g
- • MMA6271QT XY-axis 2.5g/3.3g/6.7g/10g
- • MMA6280QT XZ-axis 1.5g/2g/4g/6g
- • MMA6281QT XZ-axis 2.5g/3.3g/6.7g/10g

All members of this sensor family are footprint (QFN package) compatible, which simplifies evaluation and design of the target application.

Chapter 2
Control Theory for HBLED Lighting

2.1   Switching Regulator

A switching regulator regulates a current flow by dividing the input voltage and controlling the average current by means of the duty cycle. When a higher load current is required by the load, the percentage of on-time is increased to accommodate the change. There are two basic types of switching regulators: forward-mode regulators and flyback-mode regulators. The name of each type is derived from the way the magnetic elements are used within the regulator. In this design, forward-mode switching is used and you can find the theory below.

Forward-mode switching regulators have four functional components: a power switch, a rectifier, a series inductor, and a capacitor (see Figure 2-1). The power switch may be a power transistor or a metal oxide semiconductor field-effect transistor (MOSFET) placed directly between the input voltage and the LC filter section. The shunt diode, series inductor, and shunt capacitor form an energy storage tank whose purpose is to store enough energy to maintain the load voltage and current over the entire off-time of the power switch. The power switch serves only to fill up the energy lost to the load during its off-time. Flyback-mode switching regulators have the same four basic elements as the forward-mode regulators except that they have been rearranged in another configuration.
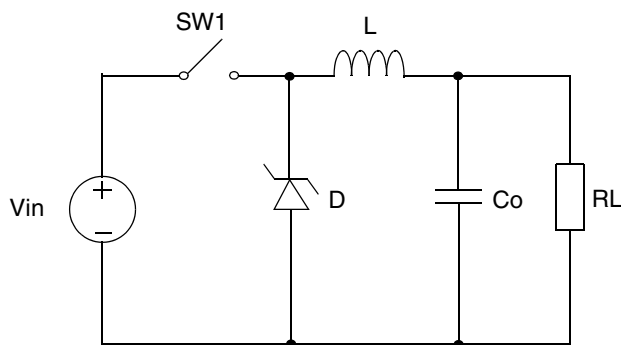
Figure 2-1. Forward Mode Switching Regulator

2.2   Buck Converter Basics

A buck, or step-down converter, is the most elementary forward-mode converter. Figure 2-1 shows its basic schematic.

The operation of this regulator topology has two distinct time periods. The first occurs when the series switch SW1 is on, the input voltage V_{in} is connected to the input of the inductor (L). The output of the inductor is the output voltage, and the rectifier (or catch diode) is reverse biased. During this period,

because there is a constant voltage source connected across the inductor, the inductor current begins to linearly ramp upwards, as described by the following equation:

$$IL(on) = [(Vin - Vout) \times ton] / L \qquad \textit{Eqn. 2-1}$$

During this on period, energy is stored within the core material in the form of magnetic flux. If the inductor is properly designed, there is sufficient energy stored to carry the requirements of the load during the off period.

The next period is the off period of the power switch. When the power switch turns off, the voltage across the inductor reverses its polarity and is clamped at one diode voltage drop below ground by the catch diode. The current flows through the catch diode, thus maintaining the load current loop. This removes the stored energy from the inductor. The inductor current during this time is:

$$IL(off) = [(Vout - VD) \times toff] / L \qquad \textit{Eqn. 2-2}$$

This period ends when the power switch is turned on again. Regulation of the converter is accomplished by varying the duty cycle of the power switch according to the loading conditions. To achieve this, the power switch requires electronic control for proper operation. It is possible to describe the duty cycle as:

$$d = ton / T \qquad \textit{Eqn. 2-3}$$

where T is the switching period.

For the buck converter with ideal components, the duty cycle can also be described as:

$$d = Vout / Vin \qquad \textit{Eqn. 2-4}$$

2.3   MM908E625 Driving High Brightness LED's Basics

This section contains a brief introduction to the basic circuit design used to drive the high-brightness LEDs using the MM908E625 integrated quad half H-bridge with power supply, embedded MCU, and LIN serial communication.

The main idea behind the circuit design to control the amount of current flowing through the high brightness LEDs is to implement a type of step-down buck regulator, controlling the current instead of the voltage output. Taking advantage of the low-side MOSFET current limit feature of the MM908E625 simplifies the overall design.

The circuit configuration in Figure 2-2 illustrates the basic operation of the current regulator.
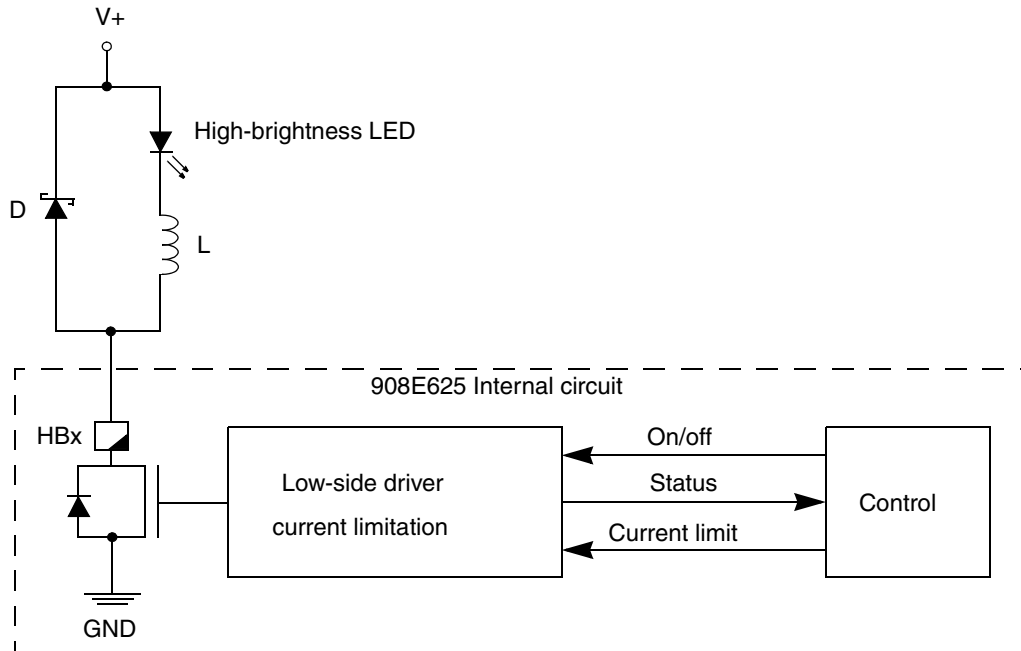
Figure 2-2. Basic Circuit Used to Drive the High Brightness LEDs

When switching on the low-side MOSFET (Figure 2-3), current flows through the high-brightness LED and inductor (L). When it reaches the current limit previously defined inside the MM908E625, the MOSFET is turned off automatically. At this point, the energy stored in the inductor (L) continues to flow through the LED because of the Schottky diode (D). The idea is to maintain a constant flow of current through the high-brightness LED. Before the current drops to zero, the low-side MOSFET is turned on again to start a new current cycle.

The switching frequency of the regulator was set up at 25 kHz. It is internally generated by the MM908E625 using the timer interface A (TIMA) module in a PWM configuration, feeding this signal in to the FGEN input.

Each low-side MOSFET switches off if a current above the selected current limit is detected. The MM908E625 offers five different current limits, the 370 mA was selected to comply with the LED's specification. The low-side MOSFET switches ON again if a rising edge on the FGEN input is detected.

HB low-side MOSFET is switched off
when it reaches the selected current limit

HB low-side MOSFET turns on
with each rising edge of the FGEN input

370 mA

DC component

ILS   Low-side MOSFET
       current

ILS   ID

ID   Diode current

OFF   OFF   OFF

ON   ON   ON

Half-bridge
Low-side output   Time

FGEN input
(MCU PWM signal)   Time

40us
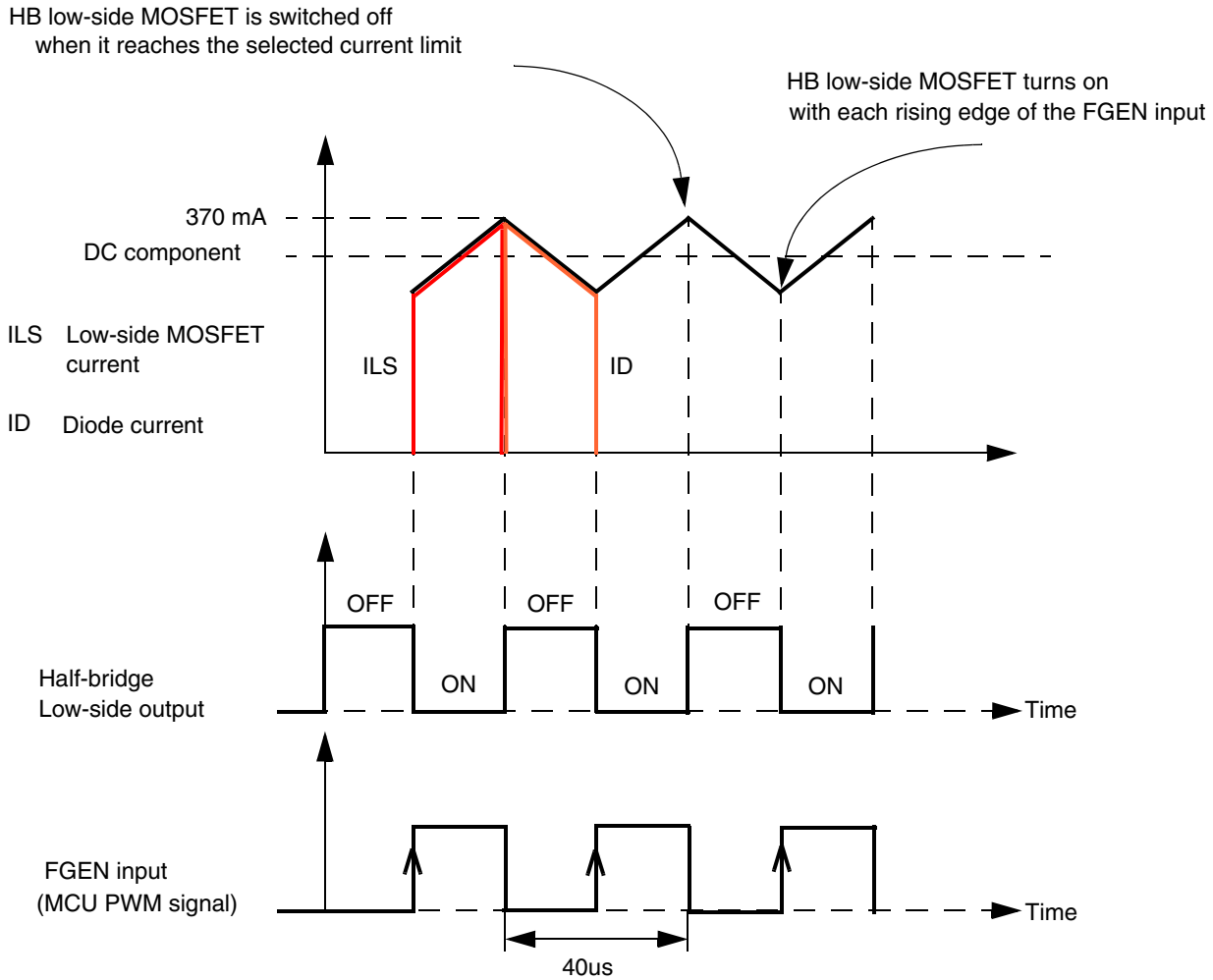
Figure 2-3. Low-Side MOSFET Switching on the MM908E625 to Drive the High-Brightness LEDs

2.4   Selection of Inductor L for Driving the High- Brightness LEDs

Looking closely at the specifications of the device, there is a feature essential to this application. Each of the four half-bridge outputs has a programmable current limit mode of operation when the low-side MOSFETs are used in PWM mode. This limit is implemented by turning off the MOSFET on a cycle-by-cycle basis after it reaches the preset current limit (Figure 2-3). In this application, the low side MOSFET conduction is activated on the rising edge of a base clock provided by the MCU. The MOSFET is on until the current limit is reached, at which time the limit circuit terminates the current cycle, turning off the MOSFET. Driving only the LED in this mode would not work properly because the current limit would be reached quickly and the MOSFET would turn off. An inductor is used to limit the speed of current change in the circuit (di/dt), effectively creating an efficient 4-channel buck switching current regulator.

The maximum low-side PWM clock frequency specification for the MM908E625 is 25 KHz. This rate is easily provided by the MCU timer output. TimerA CH1 (PTD1/TACH1) is used as a programmable 25 KHz clock source, driving the signal FGEN that controls the MOSFET conduction period (Figure 2-4).
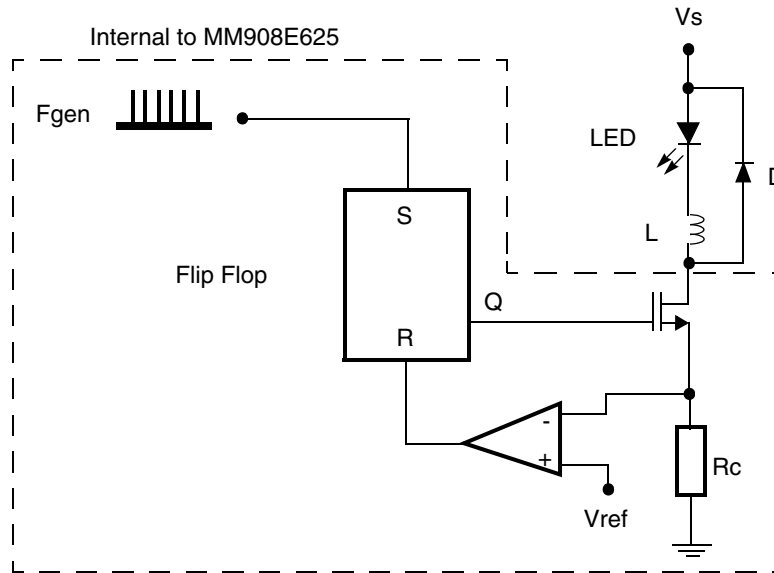
Figure 2-4. MM908E625 H-Bridge Output

The external inductor value determines the current ripple into the LED at the 25 KHz rate. The higher the PWM frequency is, the lower the value of the inductor can be. Selecting a value too low results in a high ripple current into the LED. Select a value that satisfies the average current that the LED requires, but do not exceed the peak current of the device. The only other external component required is a fast diode to catch the voltage spike that results when the MOSFET turns off. In this application, a 1 mH inductor was selected, providing roughly 150 mA of current ripple ΔIPP when driving a single LED with a V_f of 3.8 V and a supply voltage V_L of +12 V_{dc} by using the formula:

$$L = (V_L * \Delta t) / \Delta IPP$$ *Eqn. 2-5*

The Δt is the charging time, the time the low-side MOSFET switches stay ON. Considering a switching frequency of 25 kHz with a duty cycle of 50%, the time the MOSFET switches are on is 20 μs.

If we substitute the known values in the formula we get:

$$L = ((12\ V – 3.8\ V) * 20\ \mu s) / 150\ mA$$
$$L = 1.093\ mH$$ *Eqn. 2-6*

2.5 Advantages Using the MM908E625 to Drive High-Brightness LEDs

Advantages over other solutions to drive today's high brightness LEDs using the MM908E625 are:

- Low-cost solution to drive four high brightness LEDs with one chip
- Simple software and hardware design to control LED brightness
- Independent control over the four high-brightness LEDs
- High efficiency output control implementing a step-down buck switching regulator
- On-chip low-side MOSFET current limit feature used to control the amount of current flowing through the high brightness LEDs

- Low heat generation due to the use of the MM908E625 internal power MOSFETs with low $R_{DS(ON)}$
- RF communication can be established interfacing to a ZCOMM board by emulating SCI communication

2.6 Dimming the Four High-Brightness LEDs

A PWM mechanism was chosen for dimming the four LEDs. Having set the maximum current through the LEDs, by switching on and off the low-side MOSFETs using the FGEN signal and taking advantage of the current limit feature on the MM908E625 (Figure 2-4).

NOTE

If a 100% brightness is required, it is only necessary to turn on the low-side MOSFETs and have the automatic feature to take place. If a percentage different than full brightness is required, switch on and off the driving of the LEDs. This needs to be done at a low frequency with a certain duty cycle to generate a dimming sensation to the human eye, reducing the amount of current flowing through the LED over time.

The recommended refresh frequency for this PWM can be from 75 Hz to 100 Hz, to avoid any flickering sensation to the human eye. Also, it was decided to have a 20-step resolution for the duty cycle to keep the whole implementation as simple as possible.

Figure 2-5 shows a graphical representation of the PWM implementation used to dim the high brightness LEDs.

Each of the MM908E625's four half-bridge outputs has a programmable current limit mode of operation when the low-side MOSFETs are used in PWM mode. This limit is implemented by turning off the MOSFET on a cycle-by-cycle basis after it reaches the pre-set current limit (Figure 2-3). In this application, the low-side MOSFET conduction is activated on the rising edge of a base clock provided by the MCU. The MOSFET is on until the current limit is reached, at which time the limit circuit terminates the current cycle, turning off the MOSFET. Driving only the LED in this mode does not work properly because the current limit is reached quickly and the MOSFET turns off. An inductor is used to limit the speed of current change in the circuit (di/dt), effectively creating an efficient 4-channel buck switching current regulator.

The maximum low-side PWM clock frequency specification for the MM908E625 is 25 KHz. This rate is easily provided by the MCU timer output. TimerA CH1 (PTD1/TACH1) is used as a programmable 25 KHz clock source, driving the signal FGEN that controls the MOSFET conduction period.

LED current

Time

100%

Duty Cycle

100%

Time

LED current

Time

Results in 50%
duty cycle

Duty Cycle

100%

100%

Time

10ms
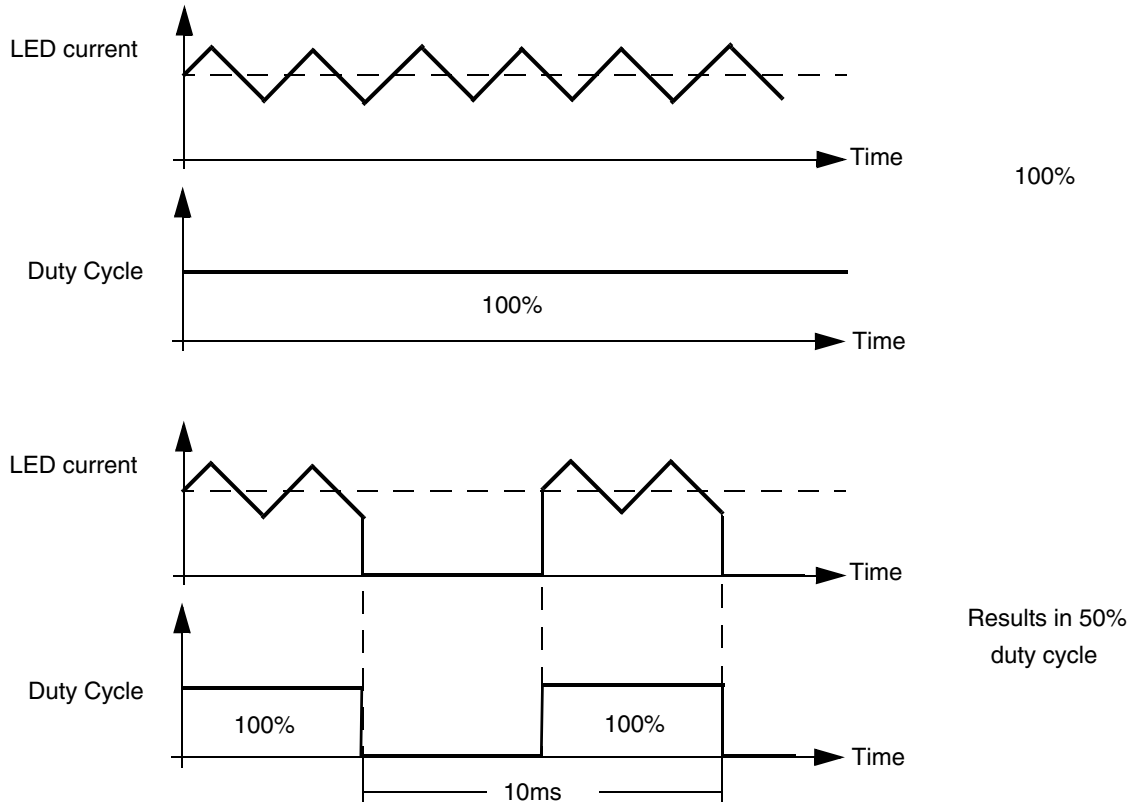
Figure 2-5. PWM Implementation for Dimming the High-Brightness LEDs

Chapter 3
ZCOMM Board Description

3.1 Board Overview

The main tasks of the ZCOMM board are to:

- Provide wireless communication (2.4 GHz) between the PC (ZSTAR USB stick) and application board using SMAC or IEEE 802.15.4 packet structure
- Make wireless communication as a master or slave device (transmit, receive, or duplex communication)
- Receive remote control for a different application board connected to the ZCOMM (via RS232, application connector)
- Control the application board wirelessly (with a compatible transceiver on the other side)
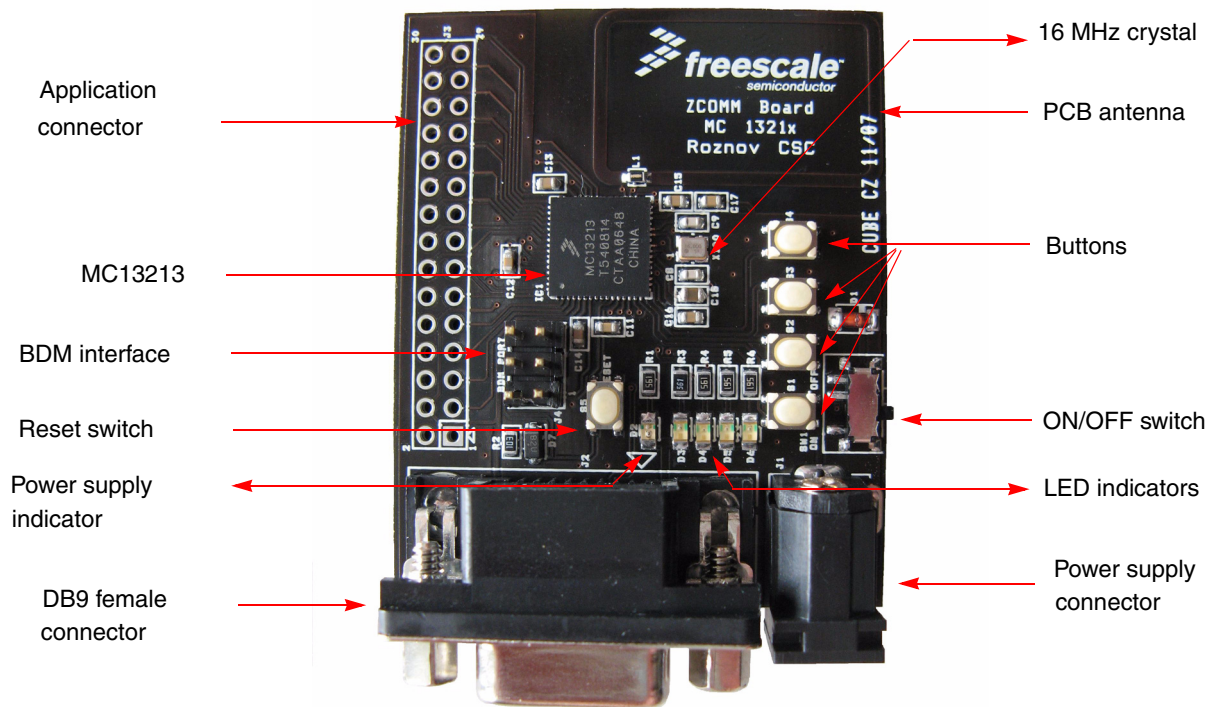
Figure 3-1. ZCOMM Board Overview (Top view)
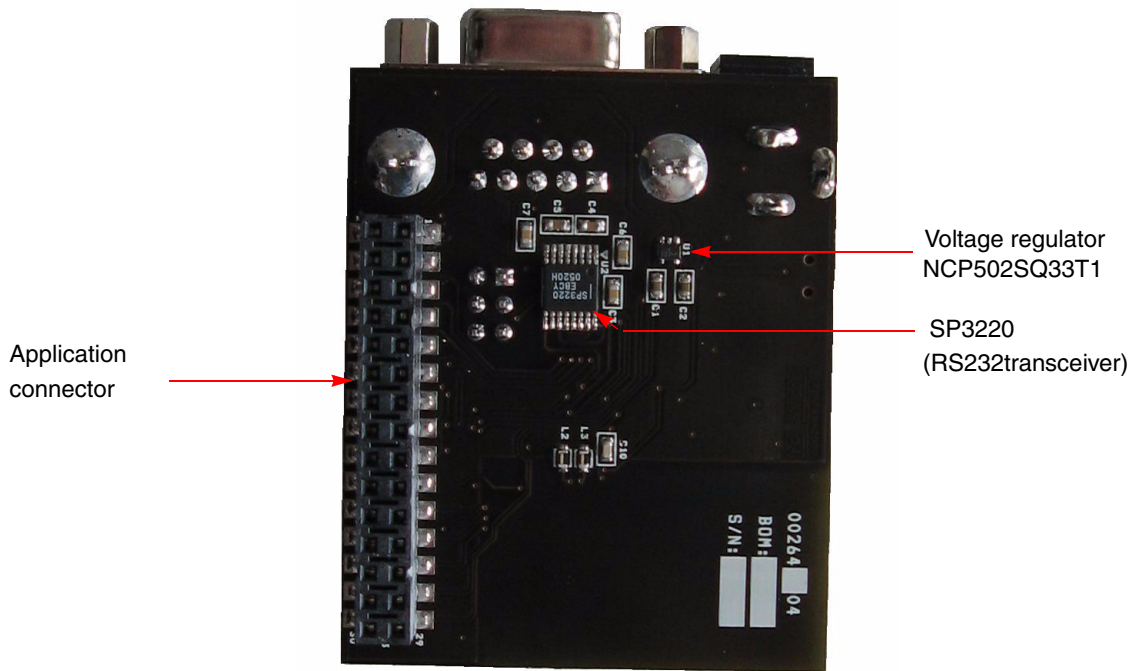
Figure 3-2. ZCOMM Board Overview (Bottom view)
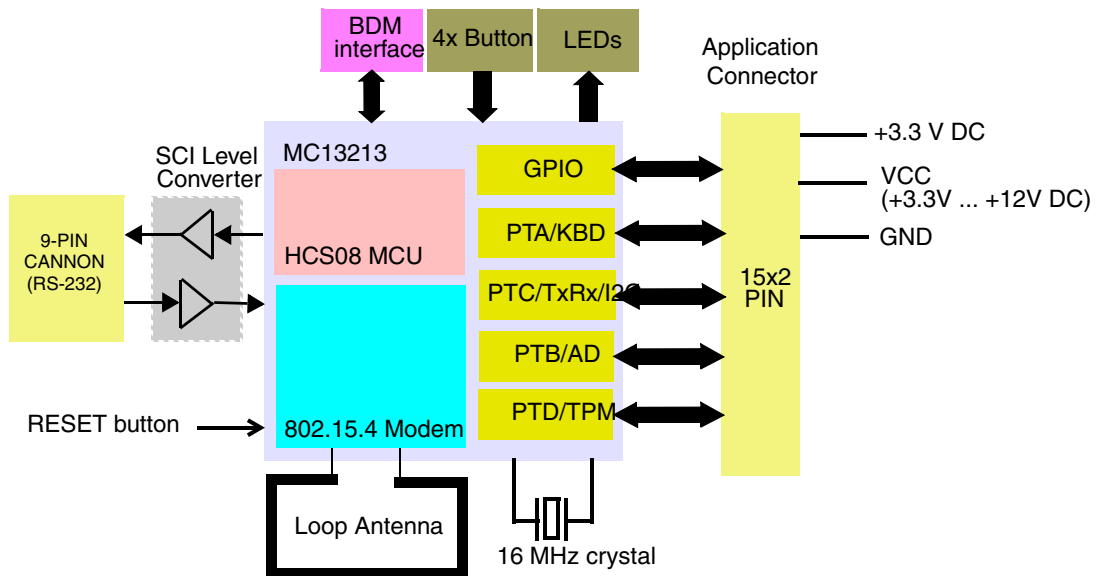
Figure 3-3. ZCOMM Board Block Diagram

The ZCOMM board uses a dual-layer printed circuit board (PCB) containing all the necessary circuitry for the MC13213 device, SCI communication, transferring data over a radio frequency (RF), and application connection (application connector).

The board can be powered from a DC voltage power supply of +3.3 V to +12 V. The application runs on Freescale's MC13213 device. Figure 3-3 shows the block diagram of the board.

3.2 ZCOMM Board Features

- Provides all hardware required for a complete 2.4 GHz wireless node using IEEE 802.15.4 packet structure
- One MC13213 low-power, low-voltage MCU with 3 2KB of on-chip flash and 2.4 GHz ZigBee™ transceiver RF reference design with printed circuit loop antenna (integrated transmit/receive switch)
- 16 MHz external crystal for 802.15.4 modem
- Background debug module (BDM) programming port for support of CodeWarrior™ Development Studio
- Provides an IEEE 802.15.4 modem
- Application connector provides the microcontroller ports for universal use in various applications
- SCI level converter (Sipex SP3220)
- RS-232 port (DB9 female connector) for interface with a personal computer or various applications
- On/Off switch
- Power supply jack (supply voltage of +3.3 V DC up to +12 V DC)
- Four switches and LEDs for control and monitoring
- Reset push button for program reset
- Scalable software support:
  - Proprietary point-to-point or star networking using Freescale's simple medium access control (SMAC) software
  - IEEE 802.15.4 Standard compliant networking using Freescale's MAC/PHY
  - ZigBee networking using Freescale's Z-stack software

3.3 ZCOMM Board Hardware Overview

3.3.1 ZCOMM Board MCU

The MC1321x contains a microcontroller based on the HCS08 family of MCUs and can provide up to 60 KB of flash memory and 4 KB of RAM. The onboard MCU allows the communications stack and also the application to reside on the same system-in-package (SiP). ZCOMM Board uses the MC13213 (see Section 1.4.1, "MC13213—2.4 GHz RF Transceiver and 8-Bit MCU") device.

3.3.2 Power Supply

The ZCOMM board can be powered from an external DC voltage power supply of +3.3 V up to +12 V through power jack J1. This external power supply voltage is switched to tthe dropout voltage regulator by on/off switch SW1. The 80 mA low-dropout voltage regulator NCP502SQ33T1 (+3.3 V) from ON Semiconductor provides voltage for all onboard devices.
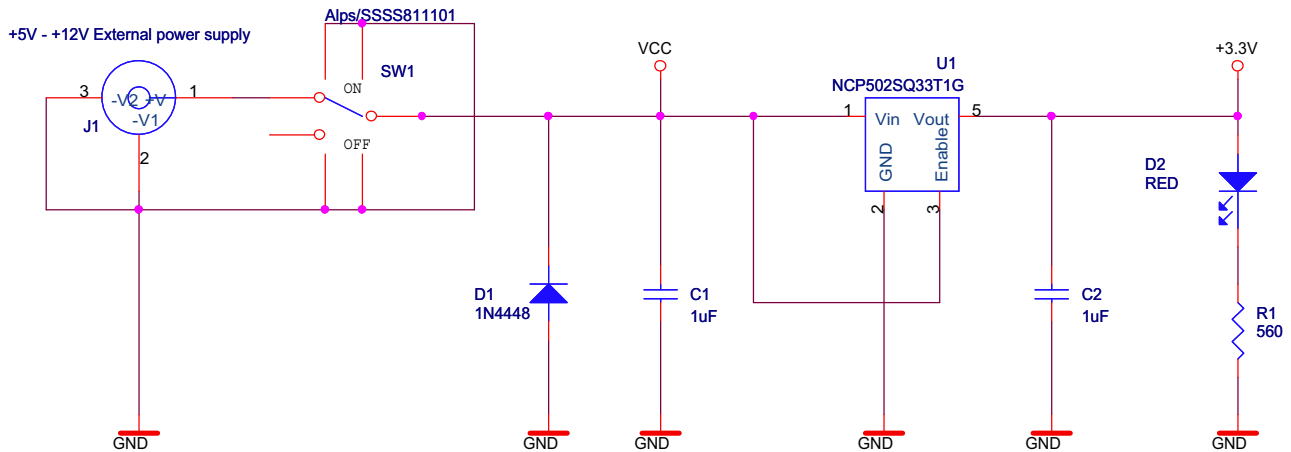
Figure 3-4. ZCOMM Board Power Supply Circuitry

The device is protected from power supply polarity changes by diode D1.

3.4 Background Debug Mode Interface

All MCUs in the HCS08 family contain a single-wire background debug interface that supports in-circuit programming of on-chip non-volatile memory and sophisticated non-intrusive debug capabilities. Typically, a simple interface pod is used to translate commands from a host computer into commands for the custom serial interface to the single-wire background debug system. The pod connects to the target system with ground (GND), the BKGD pin, RESET, and V_{DD}.

The J4 connector has a standard footprint intended for BDM purposes. The J4 connector carries all standard signals for background debug mode communication. J4 is a BDM port for use with a P&E BDM-Multilink cable. The BDM cable is used with CodeWarrior for the HCS08 to program the MCU flash memory as well as to perform in-circuit debugging.
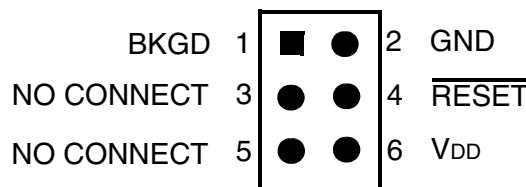
Figure 3-5. BDM Connector J4

3.4.1 Button Connections and LED Indicators

Four buttons (SW1, SW2, SW3, SW4) are connected directly to pins PTC4 – PTC7. These pins have internal pull-up resistors, but are not a part of the keyboard interrupt module. Therefore, do not allow a direct microcontroller wakeup from the stop modes.

The ZCOMM board contains also one RESET button (SW5), which is connected to the RESET pin.

PTB4–PTB7 pins are used for LED indicators. D3–D6 are LEDs connected to these pins. D2 is the LED (red) for power indication and D3–D6 are green LEDs used for optional purposes.

Connections to MCU ports are listed in Table 3-1.

Table 3-1.   LED and Button Connections to MC13213

LED/Switch	MC13213 Pin	I/O
D3 (LED)	PTB4	Output
D4 (LED)	PTB5	Output
D5 (LED)	PTB6	Output
D6 (LED)	PTB7	Output
S1	PTC4	Input
S2	PTC5	Input
S3	PTC6	Input
S4	PTC7	Input
RESET(S5)	RESET	—

3.4.2   Serial Communication (RS232 Interface)

Serial communication uses the SCI1 module of the GB60 microcontroller in the MC1321x, a SP3220 from Sipex, and a DB9 female connector.

The RS232 port is J2, a DB9 connector. A standard straight-through DB9 serial cable can be used with a PC or other application that uses an RS232 communication port. The port follows the non-standard RS232 DCE DB9 convention, but only a three-wire modification with RxD,TxD and GND pins, as shown in Figure 3-7. This modification doesn't need any control communication channels. Conversion from TTL levels from the microcontroller into RS232 levels is provided by the SP3220 device.
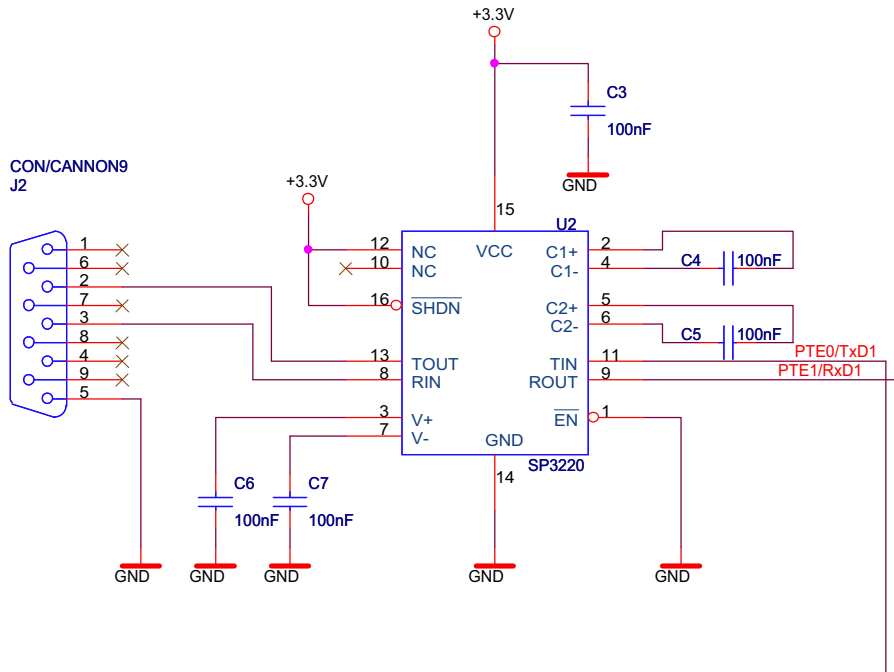
Figure 3-6. Serial Communication Circuitry

The transmit-receive pin of the SP3220 is connected with the PTE0/TxD1-PTE1/RxD1 pin of the MC13213. The SP3220 is powered by a +3.3 V DC derived from the voltage regulator. The enable pin of the SP3220 (pin1) is fixed to GND. Therefore, the SP3220 remains in working mode. This RS232 interface is inteded to enable control, to communicate or receive data from, an external application.

If RS232 is not needed, the SP3220 can be shut down by low level voltage on the GPIO7 pin of the microcontroller MC13213 for lower power consumption. For normal function, a high level on GPIO7 is needed.
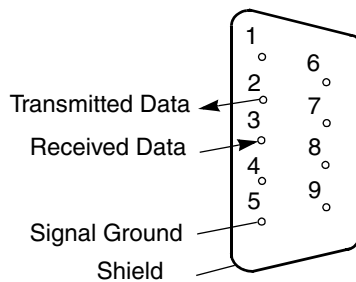
Figure 3-7. DB9 Female Connector (Looking into the Connector)

3.4.3   MC13213 RF Interface

The RF interfaces (antennas) were designed with the cost and board size in mind. Among several designs, the PCB layout antennas were the main consideration (cost). Of several PCB antenna designs available for the 2.4 GHz band (F-antenna, dipole, loop), the loop antenna has been selected mainly because of the size required on the PCB.

The MC1321x transceiver includes an integrated transmit/receive switch. The RFIN_P and RFIN_M pins can be used for receive and transmit paths with the same loop antenna.

The loop antenna is placed on the top side of the ZCOMM Board (see <st-blue>Figure 3-1). The antenna is designed as a rectangle, 26.4 x 16.8 mm (1040 x 660 mils), and made of 1.25 mm (50 mils) wide trace copper. The corners are rounded with a 1.85 mm (73 mils) radius.

The matching is provided by the L1 (transmit/receive antenna) coils. L2 and L3 coils bias the transmitter output transistors to the V_{DDA} level.

The inductors used in this design are manufactured by TDK:

 • L1 (4.7 nH) MLG1608B4N7ST
 • L2, L3 (22 nH) MLG1608B22NJT

3.4.4   Clock Configuration

The MC1321x device allows for an array of system clock configurations. The ZCOMM board uses a single crystal system clock solution. The modem provides a CLKO programmable frequency clock output used as an external source to the CPU (Figure 3-8).
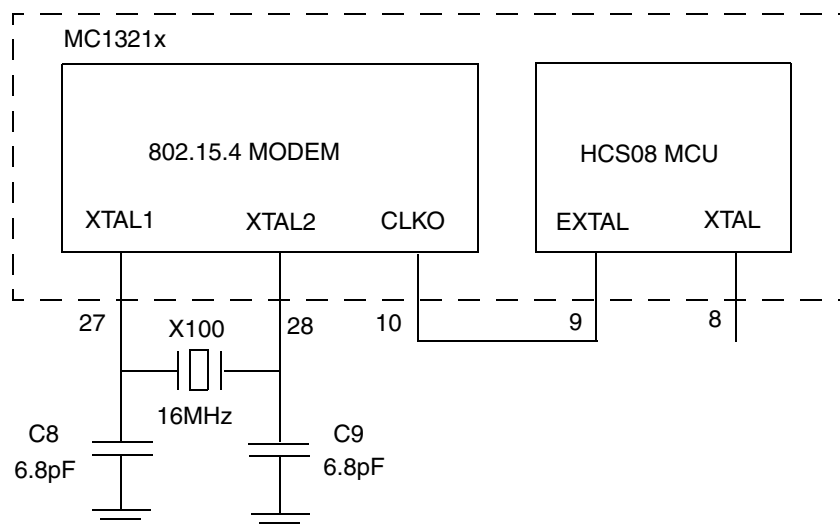
Figure 3-8. ZCOMM Board Single Crystal System Clock Structure

3.4.5   ZCOMM Board Power Connections

When designing the power connection for the MC1321x SiP, these points must be considered:

 • The LNA SiP package has a single common ground flag (VSS)
 • The MCU has a single common power pin VDD except for the VDDAD power supply to the ATD module
 • For the modem, there are two primary power inputs, including VBATT for modem power and VDDINT for digital interface power
 • For logic level compatibility between the chips, VDD, VBATT, and VDDINT must be connected to a common source supply of +2.0 to +3.4 Vdc

Remote Control of High-Brightness LEDs, Rev. 0

- VDDAD analog supply to the MCU ATD is also normally wired to the common source supply

- Modem input VBATT feeds the common supply to the analog and digital circuitry regulators; the analog regulator output VDDA is provided for bypassing and supplying VDDLO1 and VDDLO2, which are the power rails for the local oscillators

- Modem output VDDVCO is provided to allow a separate bypass of the modem radio VCO regulated supply
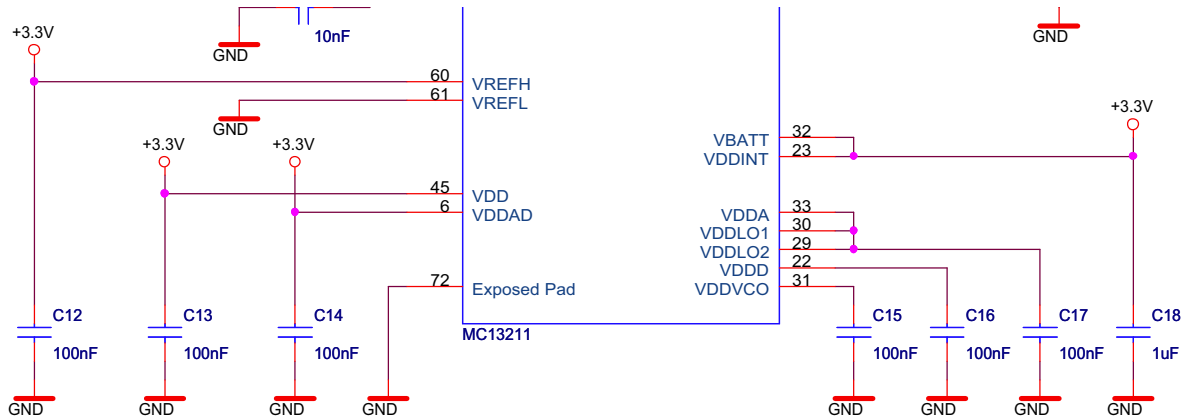
Figure 3-9. ZCOMM Board Power Supply Connections

3.4.6   Application Connector

The application connector is J3, a 15x2 female header (SSM series from Samtec), placed at the bottom of the board (see Figure 3-2). The connector makes it possible to plug the male header not only the from bottom, but also from the top of the board through holes, the special attribute of this connector. It provides I/O ports for the MCU, ADC, timers, SCI2 port, I2C bus, GPIO and KBD pins, which can be used for various purposes. Application connector pin connections to the MC13213 are shown in Figure 3-2. The function of every pin can be defined during the programming algorithm for the ZCOMM board. The connector also offers the useful voltage VCC, which is directly connected from the DC connector, stabilised +3.3 Vdc and GND.

Table 3-1. Application Connector Pin Cnnections to MC13213

PIN	MC13213 Port	PIN	MC13213 Port
1	GND	2	VCC
3	PTA7/KBD7	4	+3.3 V
5	PTA6/KBD6	6	PTC0/TxD2
7	PTA5/KBD5	8	PTC1/RxD2
9	PTA4/KBD4	10	PTC2/SDA
11	PTA3/KBD3	12	PTC3/SCL
13	PTA2/KBD2	14	PTB3/AD3
15	PTA1/KBD1	16	PTB2/AD2

PIN	MC13213 Port	PIN	MC13213 Port
17	PTA0/KBD0	18	PTB1/AD1
19	GPIO1	20	PTB0/AD0
21	GPIO2	22	PTD7/TPM2CH4
23	GPIO3	24	PTD6/TPM2CH3
25	GPIO4	26	PTD5/TPM2CH2
27	GPIO5	28	PTD4/TPM2CH1
29	GPIO6	30	PTD2/TPM1CH2

3.4.7   Schematic

The ZCOMM board schematic can be seen in Figure C-2. It is a simple system from the hardware point of view, designed to demonstrate the performance of Freescale's ZigBee and MCU with external crystal used in the application.

3.4.8   PCB Layout

The PCB is designed to a smaller design, so can also use relatively small SMD 0603 parts. The dimensions of the board are 55 x 45 mm and are mainly limited by dimensions of the connectors. The PCB layout can be seen in Figure 3-10, Figure 3-11, and parts placement in Figure 3-12 and Figure 3-13.

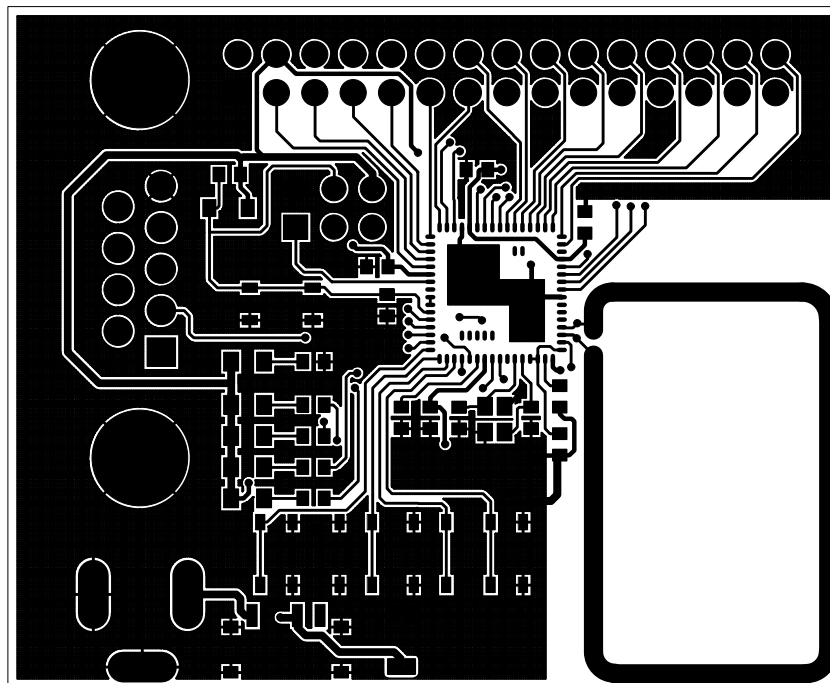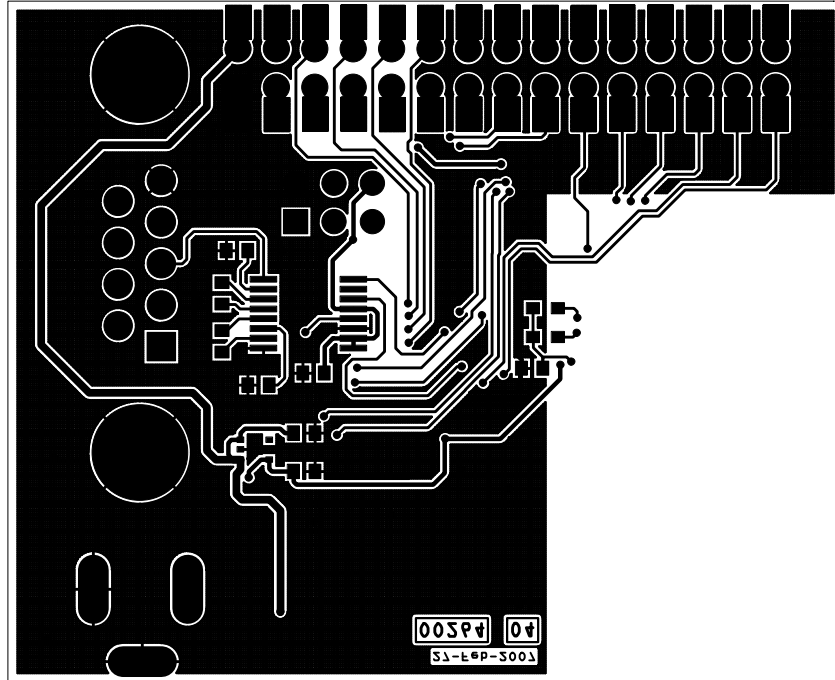**Figure 3-10. ZCOMM PCB Layout—Top**

Figure 3-11. ZCOMM PCB Layout—Bottom
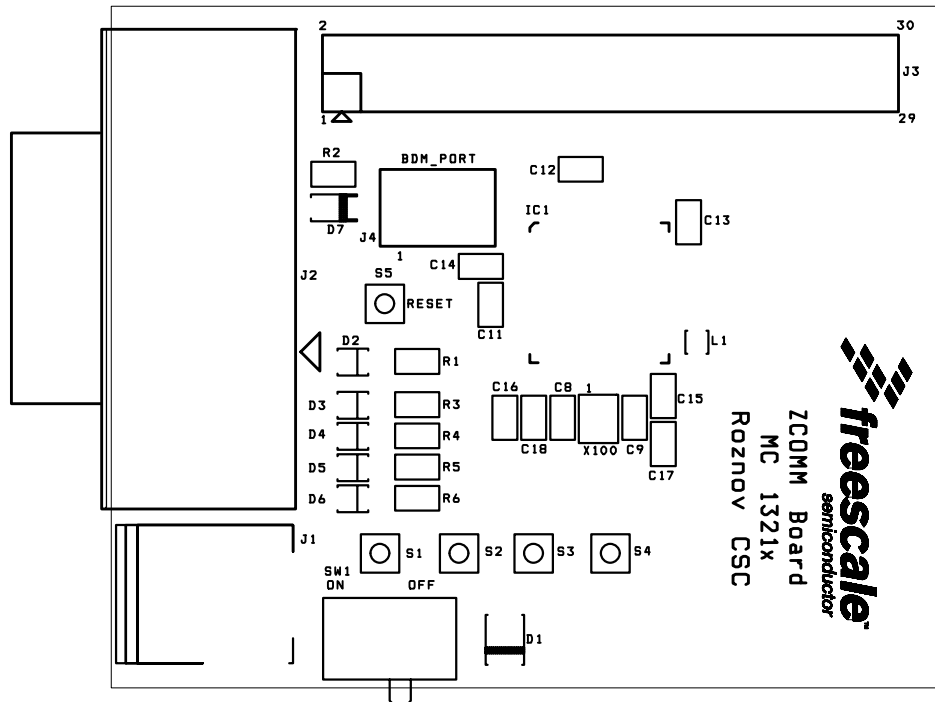
Figure 3-12. ZCOMM Component Layout—Top

Remote Control of High-Brightness LEDs, Rev. 0
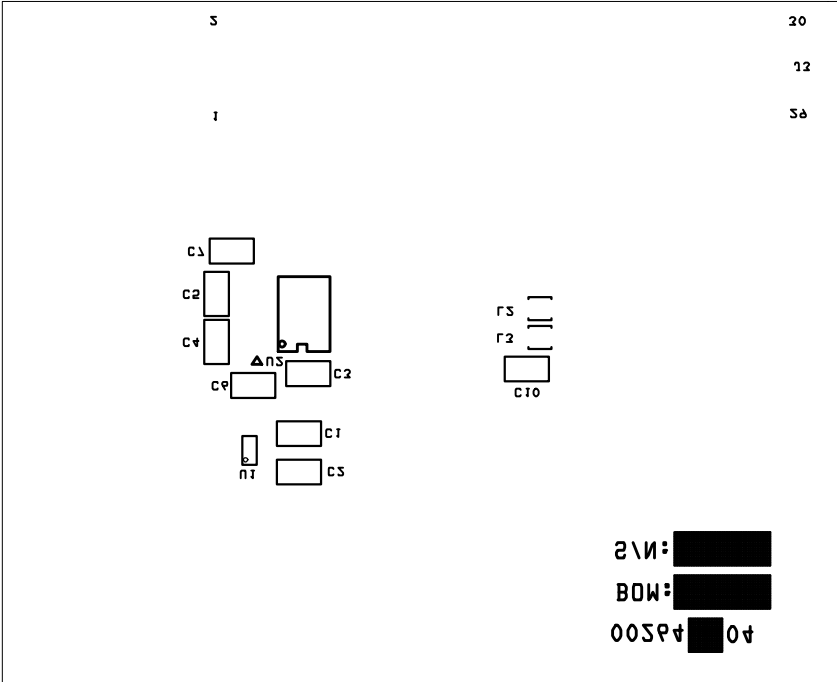
Figure 3-13. ZCOMM Component Layout—Bottom

Chapter 4
Demo System Description

4.1   General System Concept

A standard system control concept includes these hardware boards:

- Remote control board (i.e. the ZSTAR accelerometer control board)
- ZCOMM board
- Application board (i.e. the HB LED demo system board)

The remote control board runs the main control algorithm and generates a control signal converted to data (i.e. the ZSTAR generates data from the accelerometer sensor), which is transmitted by the 2.4 GHz RF wireless signal. The ZCOMM board receives, evaluates, and converts this data signal for further required communication via the application connector or RS-232 port to any application board. The application board uses this data for its own purpose (i.e. the HB LED demo control light intensity in RGB LEDs). This communication is bidirectional.

Remote Control Board

Figure 4-1. System Concept

4.2   High-Brightness LED Demo System Concept

The High-Brightness LED demo system consists of:

- ZCOMM board (<st-blue>Chapter 3)
- LIN transceiver board
- Quadrunner board + LED board

- ZSTAR boards (remote control, USB stick)

This chapter describes the remaining boards of the HB LED demo system and operation of the system.

4.2.1   Communication

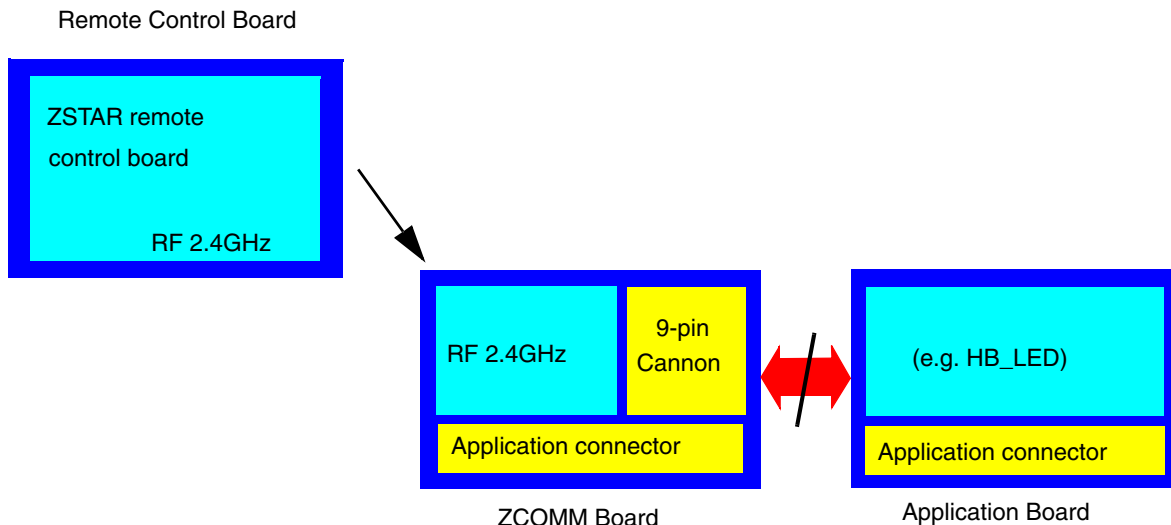The scope concept of the HB LED demo is to control an RGB LED board (from Quadrunner kit) with a remote control board from ZSTAR. To display data on a PC using the USB stick from ZSTAR design. Figure 1-2 shows the main system block diagram. Communication between the ZCOMM and remote control is bidirectional. The ZCOMM sends a broadcast to find any transmitting remote control with an address matching the ZCOMM board. If there is a transmitting device with the requested match, communication is set up. The ZCOMM then receives data from the sensor and the remote control buttons. The USB stick behaves as a sniffer only, receiving data from the ZCOMM board, moving it forward to the PC for the FreeMASTER GUI. The ZCOMM controls the brightness levels of the RGBW LEDs on the Quadrunner LED board. The LIN transceiver board with an MC33661 is used, due to the MM908E625 used on the Quadrunner board. The MM908E625 performs serial communication through the LIN physical layer. A SCI to LIN level shifter was used to make the SCI levels from the ZCOMM signal compatible with LIN levels on the MM908E625.

The HB LED demo system performs light dimming of the red, green, blue, and white high-brightness LEDs depending on the 3-axis acceleration sensor (MMA7260Q) positioned on the ZSTAR remote control. The red, green, blue colors correspond to the X, Y, Z axis. White color corresponds to the X axis in separate mode. Moving the remote control in different directions with different acceleration, you can mix each partial color to get a final color on the light pipe. Z-data packets with position data are sent from the remote control wirelessly (2.4 GHz) to the ZCOMM board. Based on these values, the HB LEDs are PWM controlled. XYZ information is then sent from the ZCOMM board to the ZSTAR USB stick on the PC, where the FreeMASTER GUI provides a better visualization for colour management.

4.2.2   LIN Transceiver Board

This evaluation kit (KIT33661DEVB – Evaluation Kit – LIN enhanced Physical Interface), featuring the MC33661 local interconnect network (LIN), is a serial communication protocol designed to support automotive networks in conjunction with a controller area network (CAN). As the lowest level of a hierarchical network, LIN enables cost-effective communication with sensors and actuators when all the features of CAN are not required.

The MC33661 is a physical layer component dedicated to automotive LIN subbus applications. It offers slew rate selection for optimized operation at 10 kbps and 20 kbps, fast baud rates (above 100 kbps) for test and programming modes, excellent radiated emission performance, and a safe behavior in the event of LIN bus short-to-ground or LIN bus leakage during low-power modes.

4.3   Features

- Operational from VSUP 6.0 V to 18 V DC, functional up to 27 V DC, and handles 40 V during load dump
- Active bus waveshaping offering excellent radiated emission performance
- 5.0 kV ESD on LIN bus terminal

- 30 kΩ internal pull-up resistor
- LIN bus short-to-ground or high leakage in sleep mode
- –18 V to +40 V DC voltage at LIN terminal
- 8.0 µA standby current in sleep mode
- Local and remote wake-up capability reported by the INH and RXD terminals
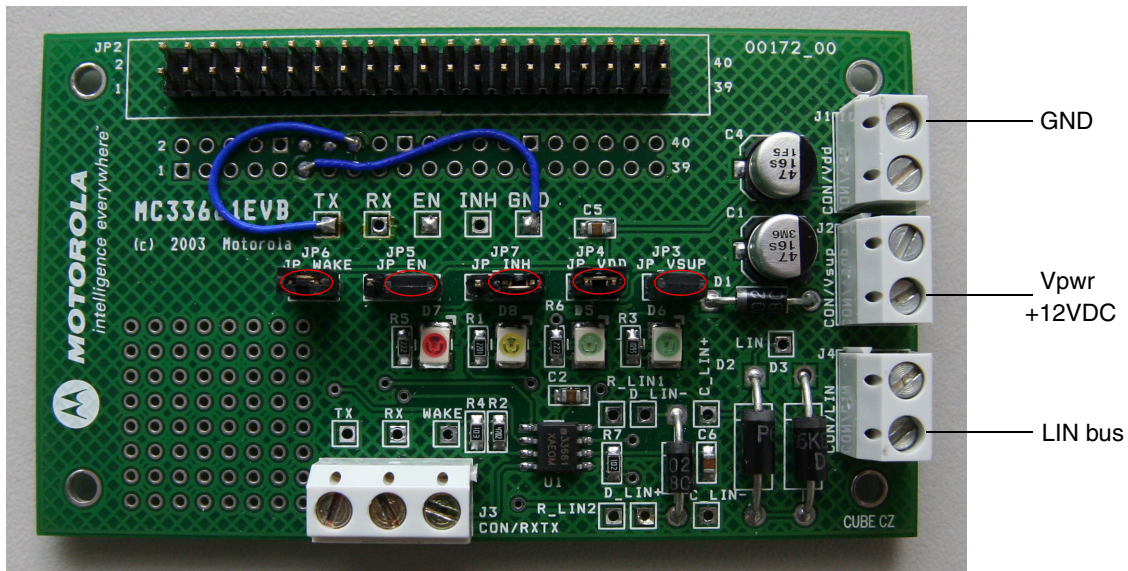- 5.0 V and 3.3 V compatible digital inputs without any external components required

Figure 4-2. Jumpers Configuration

The LIN transceiver board in the HB LED demo system is a functional reuse of the KIT33661DEVB with several changes and connections to achieve the requested function. The main goal of using a LIN transceiver is to convert an SCI level ZCOMM (0 to +3.3 Vdc) into a LIN level signal (0 to +12 Vdc), compatible to the Quadrunner board. This is done by the MC33661 device. The SCI signal from the ZCOMM is attached to pin4 (Tx) of the MC33661. The translated LIN signal required is available at pin6 (LIN). The application connector (J3) on the ZCOMM board is connected to the JP2 connector on the LIN transceiver board. The system of interconnections between the ZCOMM and the LIN board for +3.3Vdc, GND and an SCI—TxD2 signal, can be seen in Figure 4-3. To match the ZCOMM board with the LIN board, pin1 of the ZCOMM must connect with pin11 of the LIN board. A +12 Vdc Vpwr is connected to the LIN Board J2 power supply connector externally from a power supply black box. For proper functioning of the LIN board, 2x1 header connectors (JP3, JP4, JP6) must be connected by jumper, and pins 2-3 of the 3x1 header connectors (JP5, JP7) must be connected together. Jumper configurations are shown in Figure 4-2.
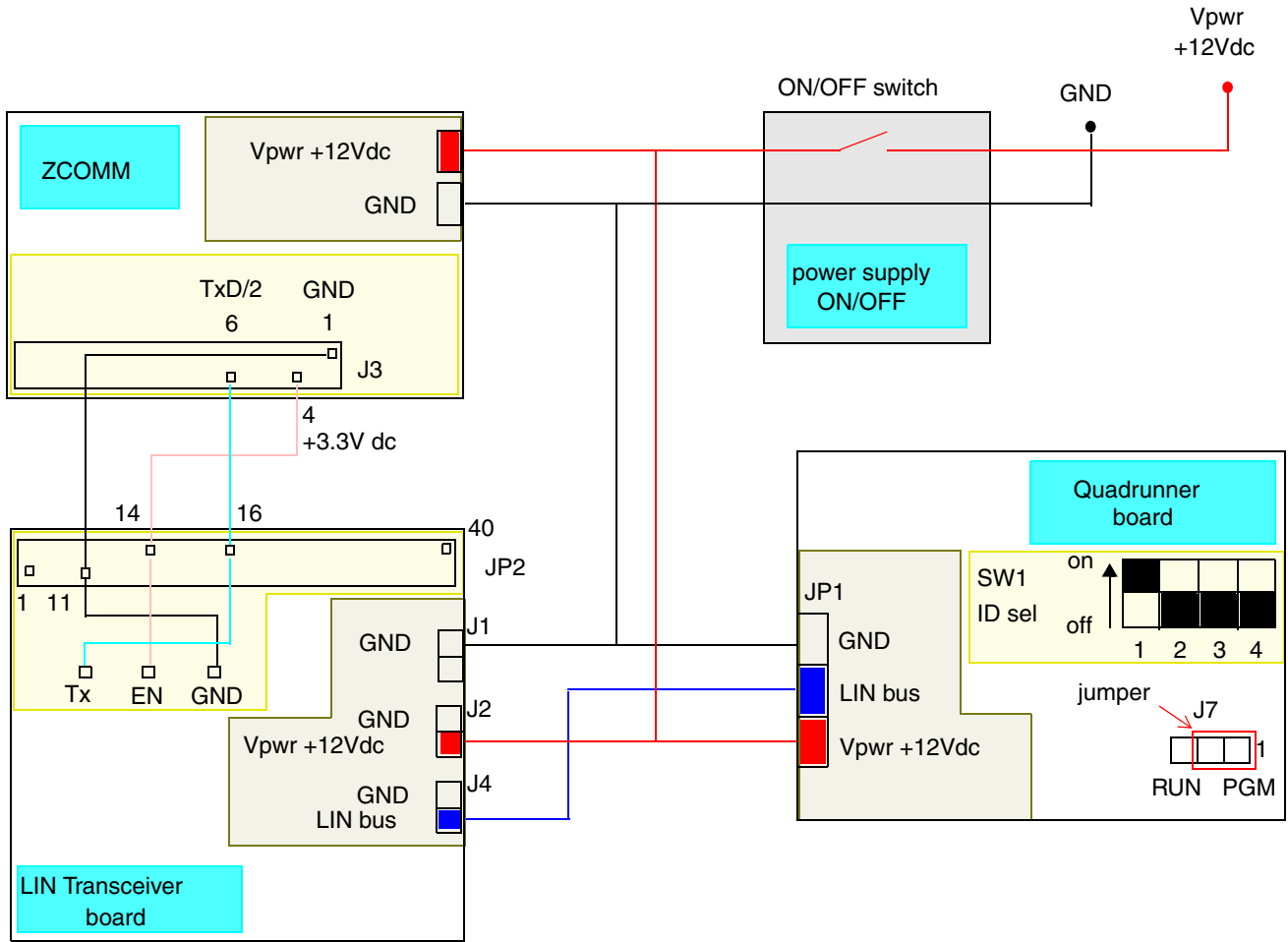
Figure 4-3. HB LED Demo System Boards Interconnection

4.3.1 Quadrunner Lumiled Demo Board

This chapter introduces a fully integrated 4-channel Luxeon LED driver solution controlled by a single device that includes an 8-bit microcontroller and power drive circuitry (Figure 4-4). One to four Luxeon LEDs, driven at 350 mA or 700 mA and connected in series, can be controlled per channel. Up to 16 LEDs can be driven from a single device. The on-chip LIN PHY interface supports single-wire, half-duplex networking communication, making this solution efficient for remote control of generated light, which is what is actually used for the HB LED demo system. Applications such as automotive, consumer indoor and outdoor lighting, emergency vehicles, and entertainment can see significant cost benefits from this level of integration.

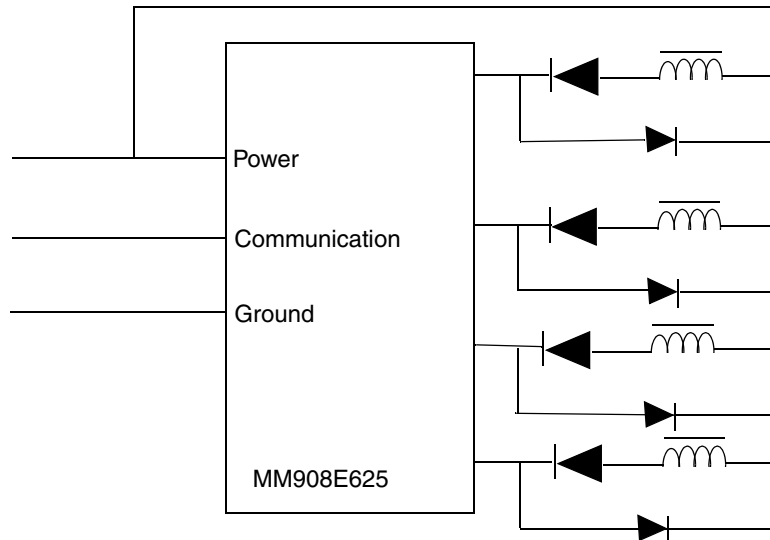**Figure 4-4. Networked Four Channel LED Driver**

Luxeon I, 1-watt LEDs from Lumileds, require a regulated constant-current source of 350 mA at a forward voltage of ~3.7 V for the blue, green, and white colors, due to their InGaN process technology. Red and amber devices are of AlInGaP process technology and require a lower forward voltage of ~2.85 V. Luxeon III, 3-watt devices can be driven at their rated 700 mA, or overdriven at up to 1 amp. The high-power 5-watt LEDs are constructed internally with a series die on a substrate. Therefore, they have twice the forward voltage drop, but require 700 mA of constant-current.

To get detailed information on driving a high-brightness LED, please see Control Theory for HBLED Lighting.

4.3.1.1   Dimming and Intensity

Dimming, the variation of the LEDs intensity, is accomplished by varying the ratio of the on-time versus off-time (duty cycle; see Figure 4-5) of the clock signal driving the FGEN pin (see Figure 2-4). When the LEDs are quickly turned on and off at the rated current, the eye does not notice the blanking of the emitted light. It is not recommended to vary the current into the LED. This does not yield a linear response and is difficult to manage at low intensities. The software pulse-width modulation (PWM) technique is widely used in the industry. It easily provides the minimum required refresh rate of between 60 and 100 Hz to minimize any visible flicker in the LEDs light output. The higher the refresh rate, the better the visible results are. The algorithm described in Section 2.6, "Dimming the Four High-Brightness LEDs", provides 250 levels of intensity on each independent channel at a refresh rate of 100 Hz.

$$\text{Duty Factor (\%)} = t_{on}/(t_{on}+t_{off})*100 \qquad \textit{Eqn. 4-1}$$

If

DF . . . . DUTY FACTOR

DF = 10%

0 1   10   20   time (ms)

If

DF = 50%

ton   toff

0   5   10   20   time (ms)

DF = 100%

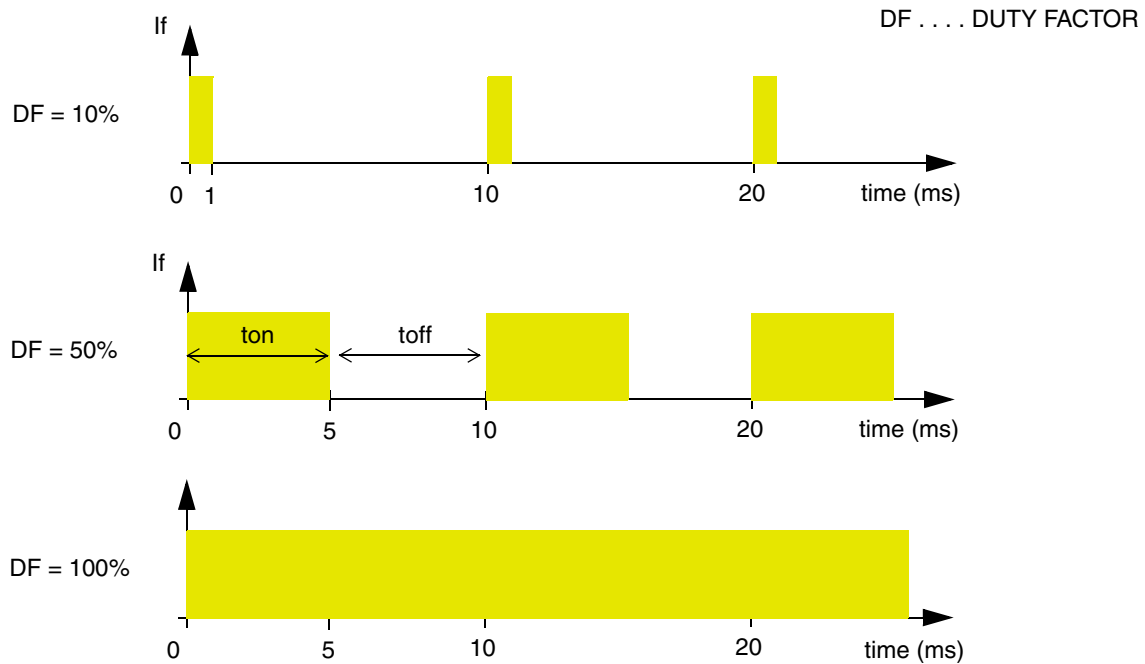0   5   10   20   time (ms)

Figure 4-5. Intensity Modulation

The Quadrunner Lumiled demo board is powered by +12 Vdc from an external power supply (see Figure 4-3). The white wire to the Quadrunner board (in Figure 4-6) is the GND connection, the red wire is the +12 Vdc connection. The blue color in the middle of connector JP1 is the LIN connection. The Quadrunner Lumiled demo board can work in more functions associated with the dip switch positions on the demo board. One of the functions is to work in a master slave mode. To set the Quadrunner Lumiled demo board in this mode, place switches 2-4 on dip switch SW1 in positions closest to U1, and switch 1 away from U1 on the demo board (see Default Jumper/Switch Configuration). In this mode, the Quadrunner board acts like a slave device, controlled from ZCOMM instructions translated into LIN level signals.
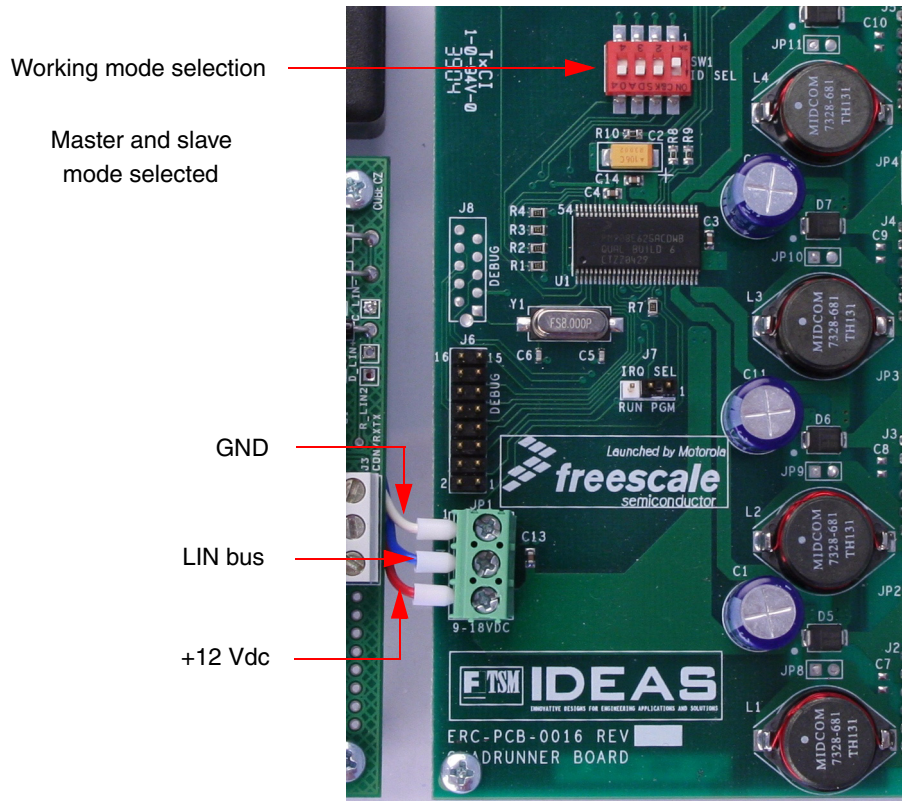
Figure 4-6. Quadrunner Lumiled Demo Board Control Settings

Chapter 5
Software Implementation

5.1   Introduction

The software implementation of the HB LED demo system has four parts:

- The first is in charge of the ZSTAR software
    — Accelerometer
    — RF protocol
- The second is in charge of the ZCOMM Board software
    — RF protocol
    — SCI
- The third is in charge of the LIN Transceiver software
    — SCI
    — LIN
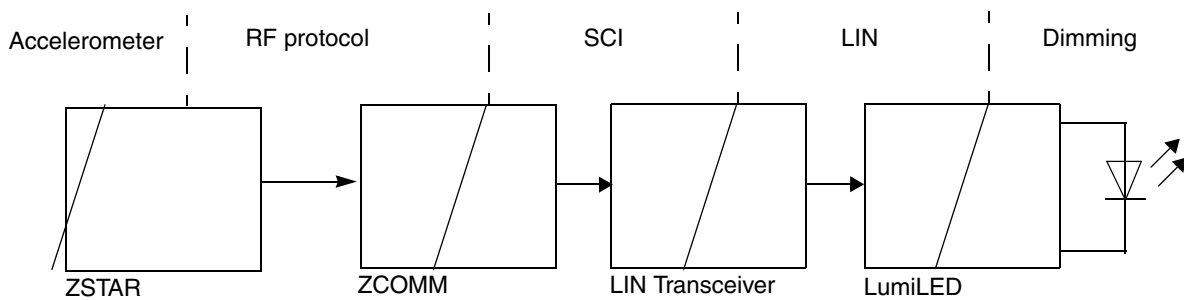- The fourth part is in charge of the LumiLED Board software
    — LIN
    — Dimming

Figure 5-1. Software String

The ZSTAR, LIN Transceiver, and LumiLED are standard boards and their software was not changed.

5.2 ZCOMM Board S/W Description
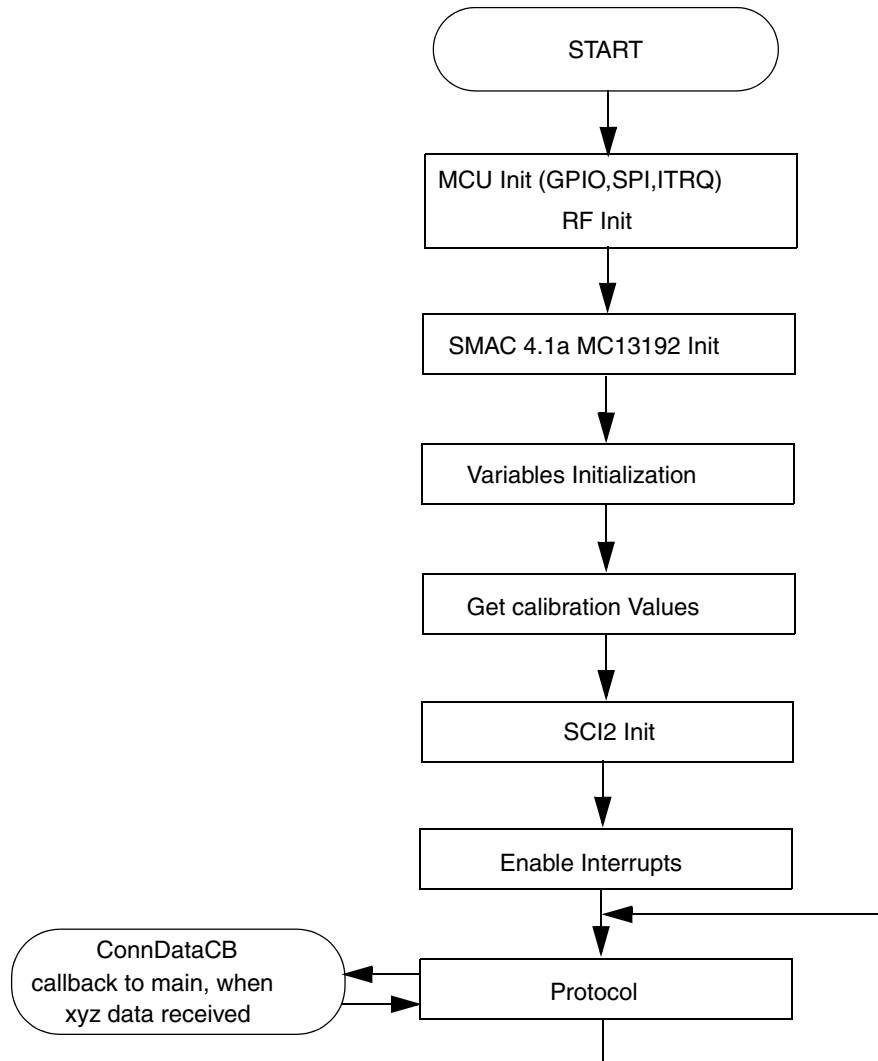
5.2.1 ZCOMM Flow Diagram

Figure 5-2. ZCOMM Software Main Flow Diagram

The main routine initializes the MCU, RF modem, SMAC protocol, variables, gets calibrated values of the X, Y, Z axes from the accelerometer, initializes the SCI2 communication, enables interrupts, and then enters an endless loop.

The endless loop contains specific execution modules (RF protocol). ConnDataCB (callback function) from Protocol() is called in every cycle when xyz data is received. After xyz data has been received, these variables are converted and filtered into 8-bit resolution values. If switch_mode is white, the white LED brightness is controlled by the converted x-axis variable. The red, green, and blue colors stay off. If switch_mode is not white, the white LED stays off and the red, green, and blue colors are controlled by the converted x,y,z-axis variables.
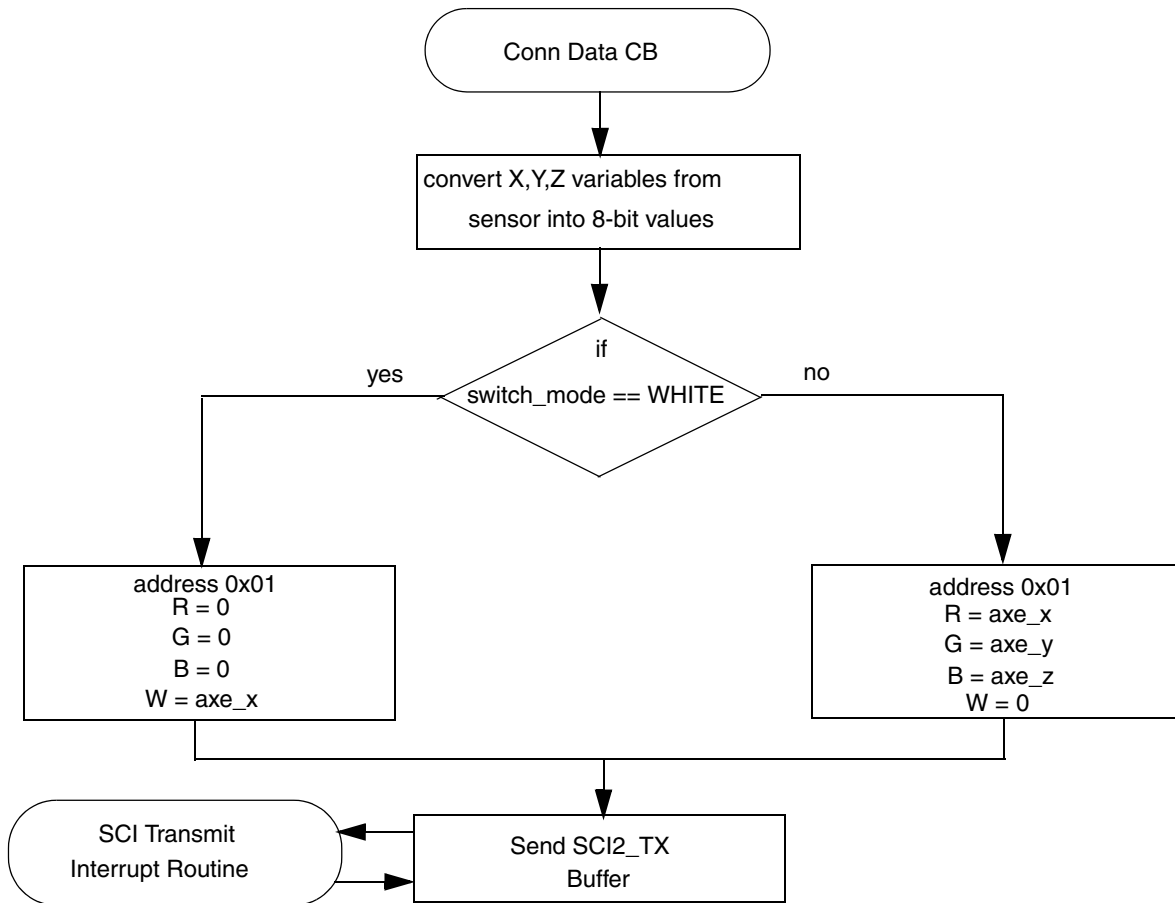
Figure 5-3. ConnData CB (CallBack) Flow Diagram

The address 0x01 with four values (R,G,B,W) is saved to the SCI transmit buffer and then via SCI2 channel into SCI ZCOMM data format and sent to the LIN Transceiver board.

5.2.2 ZCOMM SCI Data Format

To control the Quadrunner board remotely from the ZCOMM board, the DIP switch SW1 on the Quadrunner board must be configured according to the master-slave mode (ZCOMM—master; Quadrunner—slave).

DIP switch positions for master-slave mode:

> 4 - 3 - 2 - 1
>
> ON - X - X - X

For the HB LED demo system, this configuration was chosen:

> 4 - 3 - 2 - 1
>
> ON - ON - ON - OFF

This configuration represents the address of the slave device (address 0x01). When the DIP switch configuration does not match the address in the source code, the system does not communicate properly. The ZCOMM data packet format to the Quadrunner board is based on this rule.

ZCOMM uses a simple packet format for light dimming management of the Lumiled board high-brightness LEDs. The packet becomes the address (0x01) of the slave (Quadrunner), the payload data (X, Y and Z axis) for the RGB, and white color LEDs. X, Y and Z are variables converted into 8-bit values. These data packets are sent to the Quadrunner board in 30 Hz intervals in the RF protocol loop.
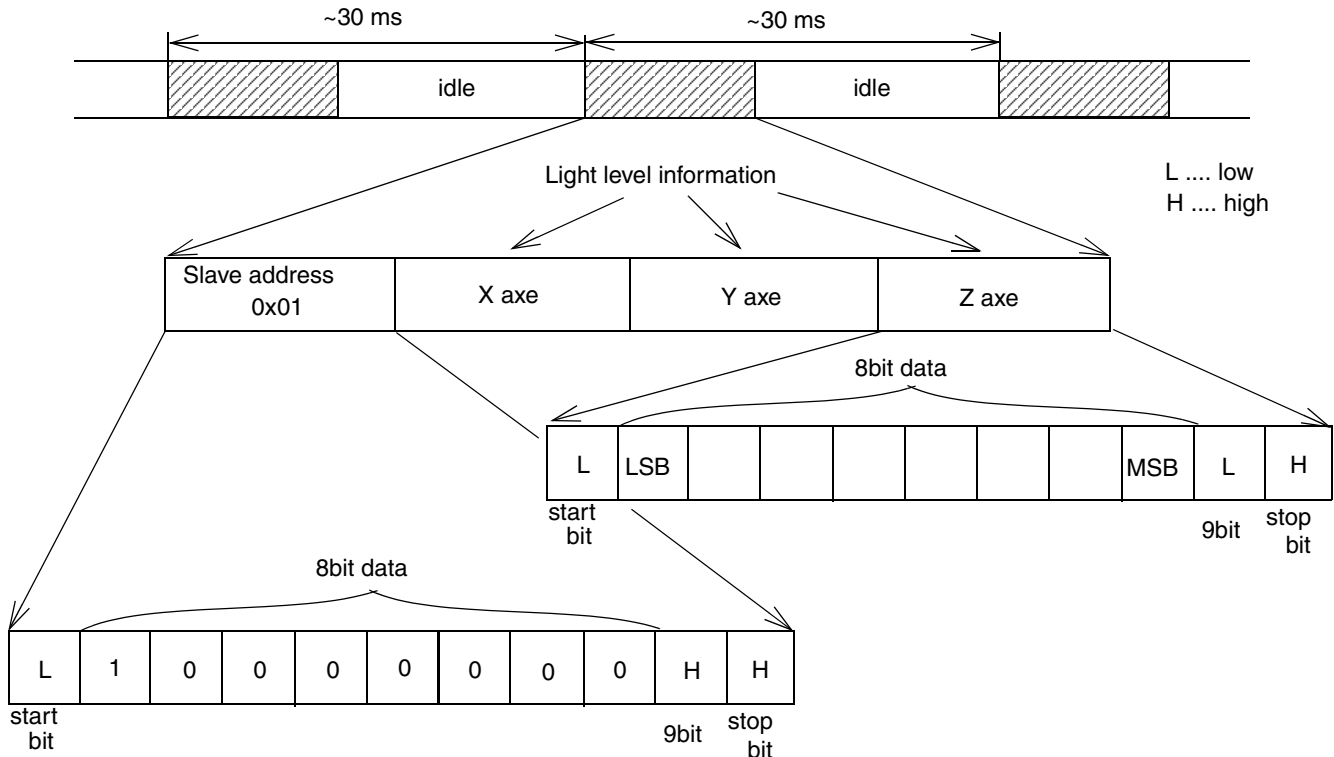
Figure 5-4. ZCOMM SCI Data Packet Structure

The light level information goes from 0, to indicate the lowest level (channel OFF), to a value of 255 to indicate the maximum light level (fully ON).

5.2.3   ZCOMM RF Protocol

This section describes the design of the ZCOMM software blocks. The software description is composed of these topics:

- Simple Media Access Controller (SMAC) modifications description
- Air ZCOMM RF protocol description
- Serial STAR Protocol and ZCOMM Extensions (Over USB) protocol description

5.2.3.1   Simple Media Access Controller (SMAC)

The SMAC is a simple ANSI C-based code stack available as sample source code that can be used to develop proprietary RF transceiver applications using the MC13192.

SMAC features include:

- Compact footprint:
  — 2-KB flash
  — 10 bytes (+ maximum packet length) RAM
  — As low as 16 kHz bus clock
- Can be used to demonstrate coin cell operation for a remote control
- MC13192 compatible
- Low-power, proprietary, bidirectional RF communication link
- ANSI C source code targeted at the HCS08 core and portable to almost any CPU core (including 4-bit)
- Low-priority IRQ
- Sample application included, extremely easy to use
- Liberally commented
- CodeWarrior™ experimental edition for support

The development of the ZCOMM software is based on the free SMAC stack available from Freescale. The SMAC version used was 4.1a. All changes are based on reusing ZSTAR RF protocol definitions and SMAC modifications. One modification was made because the original version did not support the MC13213 device. All changes are made using conditional compile options, using the MC13213 definition.

A fully detailed description of the SMAC is in the SMAC Reference Manual (SMACRM.pdf), available together with SMAC source code, and a description of the ZSTAR design available in the ZSTAR Reference Manual (ZSTARRM.pdf).

5.2.3.2   SMAC Modification

The modification of the SMAC is minimal, because the core, peripherals, and naming conventions are the same as in the MC9S08GB/GT code (originally in the SMAC 4.1a code) and the ZSTAR code.

```
MC13192_hw_config.c
#if defined(ZSTARJW32) || defined(ZSTARQG8)
                                  SPIDrvWrite(0x07,0x0800);   /* Disable CLKo in Doze */
#else
SPIDrvWrite(0x07,0x5C00);   /* RF_switch mode, CT_bias EN */
#endif
```

5.2.3.3   ZCOMM RF protocol

ZCOMM uses a simple protocol for an RF transfer of information between ZCOMM and ZSTAR (Sensor Board and USB Sniffer). Acceleration (X, Y, and Z axis), temperature, bandgap voltage, button, and calibration data can be accessed. The protocol is built on top of Simple Media Access Controller (SMAC)

drivers available for the MC13191/2 transceiver family. The protocol is bidirectional, allowing the set up of address dependent connections amongst ZCOMM and ZSTAR sensor board also known as PAIRING protocol. All data is transferred in Zpackets. This protocol is primarily targeted at simple demo purposes, allowing a fast transfer of the accelerometer data in short packets with minimum overheads and with minimum battery loads.

The ZCOMM board acts as a master of the communication connection. After power on, ZCOMM transmits a broadcast call every 40 ms, trying to get a connection and waiting for an answer from any device for pairing. If 255 broadcast calls go without answer, the GetConnected() function returns 0 and ZCOMM goes to idle mode. Each ZCOMM board has a specific network number and connects only with the sensor board matching its network number. This network number is stored in flash memory on the ZCOMM and ZSTAR boards (sensor, USB). This network number is 16 bit long.

The ZSTAR sensor board network number can be rewritten for any other ZCOMM board. After the sensor board is turned off, press both buttons and turn the sensor board on. The first received network number from the air is then stored to flash memory as a new network number.

The ZSTAR USB board acts as a sniffer, only receiving data packets from a ZCOMM board after a connection is started, containing ZSTAR_ACK, axis X, axis Y, axis Z, and switch_mode data. This data is displayed on a PC FreeMASTER GUI.

There is the main RF protocol loop (RF Protocol Data Flow Chart) from zstar_rf.c:

```
void Protocol(void)
{ for(;;)
        {
                MLMESetChannelRequest(SiteSurvey());
                if (GetConnected() == 1)
                DoProtocol();
        }
}
```

SiteSurvey() finds a quiet channel for communication. GetConnected() returns 1 when the sensor board answers a broadcast with the proper network number and, after starting communication, starts to transmit zstar data packets. After that, ZCOMM sends a ZSTAR_ACK (acknowledge) to the sensor and the USB board after every data packet is received from the sensor board.
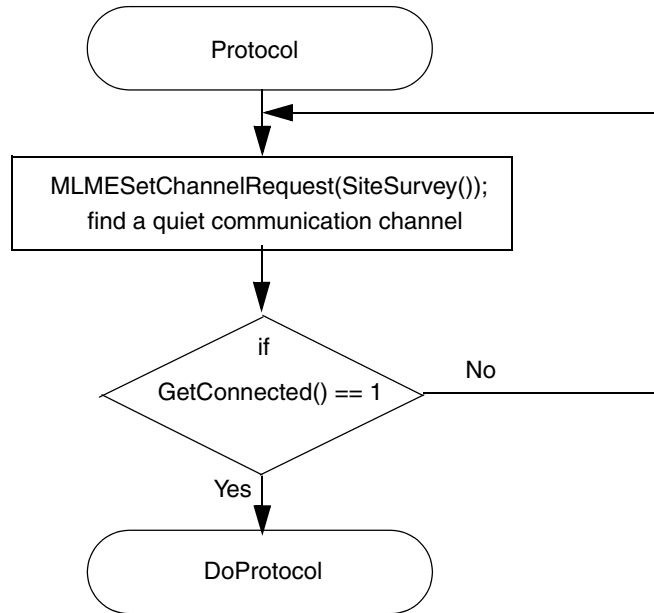
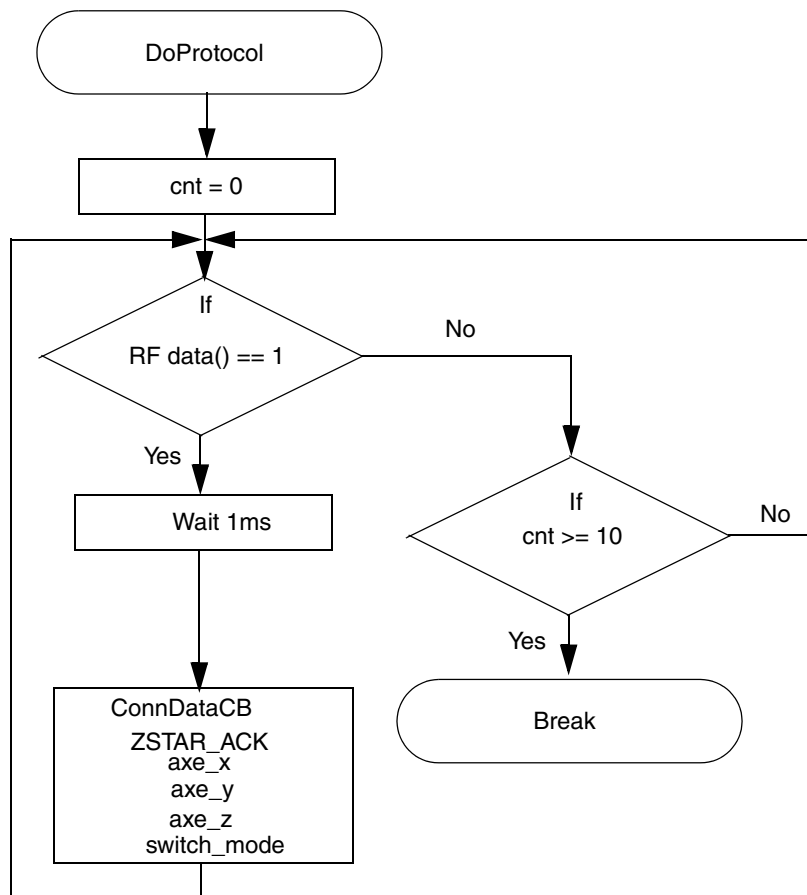**Figure 5-5. RF Protocol Data Flow Chart**

Figure 5-6. DoProtocol Data Flow Chart

If RF data is received, a 1ms delay is performed and then ConnDataCB is called.

ZSTAR_ACK is sent as the data acknowledgement so the ZCOMM board board knows that the connection is alive. If the receive window is opened by the ZCOMM board and the ZSTAR_ACK has not been received, the operation (periodic transmission of a data packet) continues, but the ZCOMM board tries to receive an acknowledgement more frequently. If the acknowledgement is not received several times, the connection is dropped and the ZCOMM board tries to re-establish the connection.

Chapter 6
Demo Setup

6.1 Introduction

This section shows how to setup the high-brightness LED demo system and run the included FreeMASTER GUI. You can use the on board open source BDM module to program the MCU flash memory and debug new applications.

6.2 Setup Instructions and User Guide for Controlling the HB LED Demo System

The required elements for running and controlling the HB LED demo system with FreeMASTER GUI are:

- Quadrunner Lumiled demo board + Lightpipe
- ZCOMM board
- ZSTAR; sensor board + USB stick (sniffer)
- LIN transceiver board
- +12 Vdc external power supply
- FreeMASTER GUI running on a PC

6.2.1 Configuration Jumpers

Configuration jumpers of the HB LED demo system are:

- JP3, JP4, JP5, JP6, JP7 on the LIN transceiver board
- ID selection switch SW1 and J7 on the Quadrunner board

Table 6-1. Default Jumper/Switch Configuration

Jumper/Switch	Configuration	Board
JP3	Closed	LIN board
JP4	Closed	LIN board
JP5	Position 2-3 closed	LIN board
JP6	Closed	LIN board
JP7	Position 2-3 closed	LIN board
SW1	1-2-3-4; Off-On-On-On	Quadrunner
J7	Postion 1-2 closed	Quadrunner

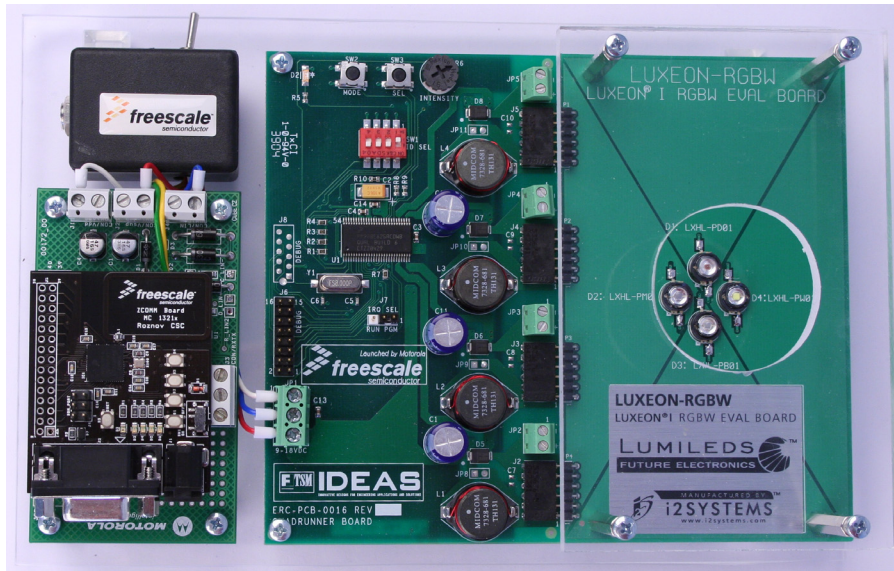The default jumper configuration is shown in Default Jumper/Switch Configuration.
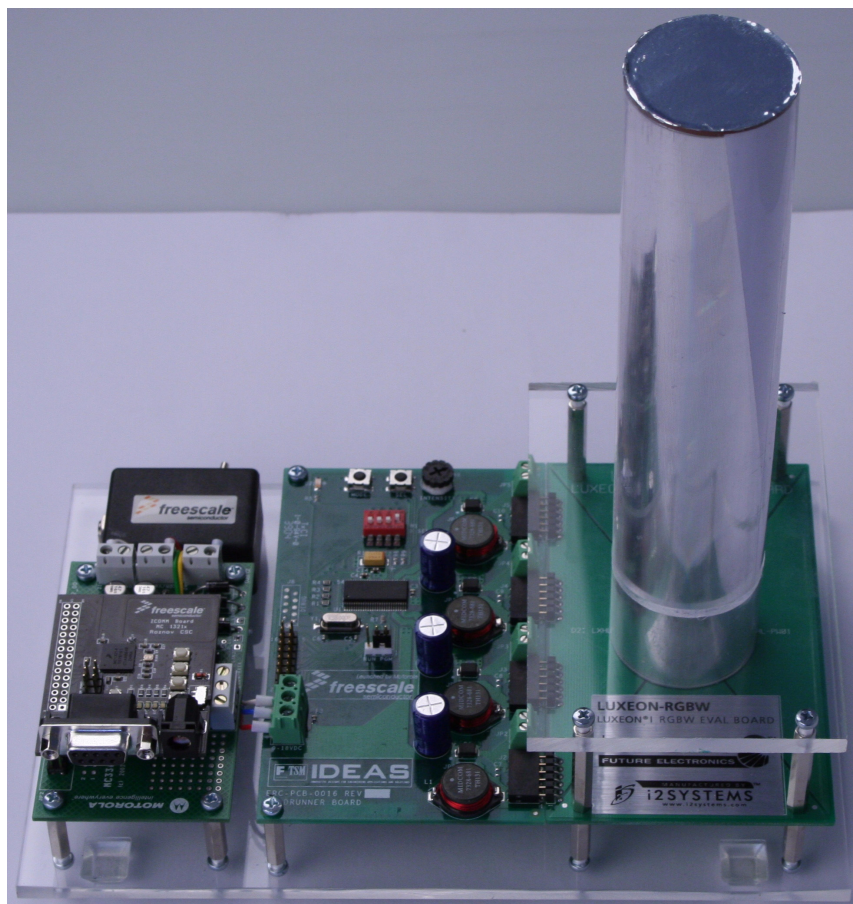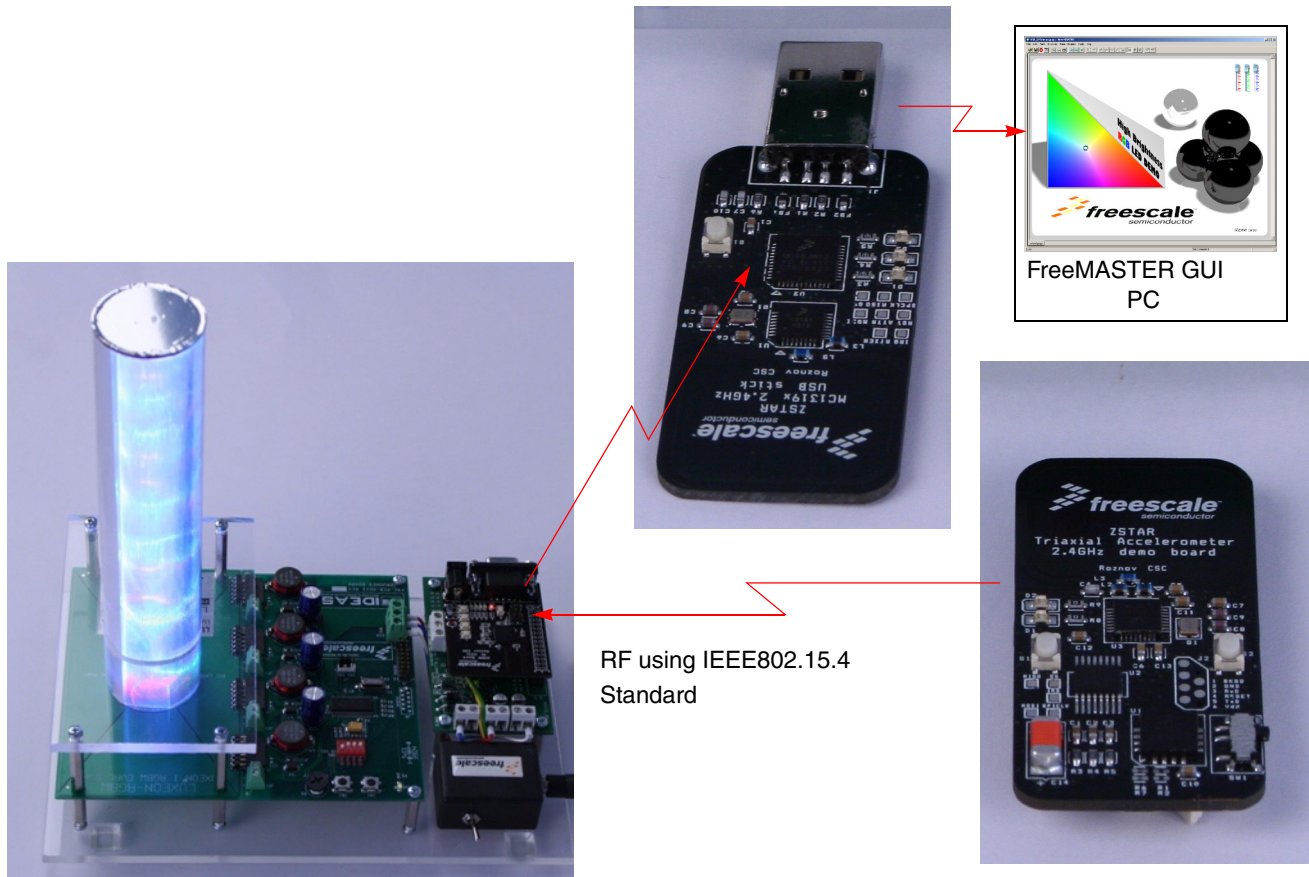

Figure 6-1. HB LED Demo System (Without Lightpipe)

Figure 6-2. HB LED Demo System (Lightpipe Mounted)

Figure 6-3. System Communication Overview

6.3   Starting Up the HB LED demo system

This sequence gets the HB LED demo system up and running and gets the FreeMASTER graphical user interface ready to display RGBW color elements.

- Verify that the ZCOMM, LIN, and Quadrunner boards are connected together properly.
- Put the Lightpipe into the gap in the plastic cover over the LEDs (see <st-blue>Figure 6-2.) .
- Plug the +12 Vdc wall-mount power supply into the power supply black box.
- Turn on the ZCOMM board with on/off switch SW1.
- Turn on the main ON/OFF switch on the power supply box. ZCOMM LED D2 (red-power on) should turn on and LED D3 (green) should blink.
- Power the ZSTAR remote control with a +3 Vdc battery (CR2032) and turn switch SW1 to the on position. LED D2 should blink.
- When communication starts, ZCOMM LED D4 and ZSTAR LED D1 should blink and ZSTAR LED D2 flashes, turning off and on again when acknowledging RF messages coming in from the ZCOMM board.
- The HB LED demo system works in two modes. First mode (after start, power on) controls the white LED separately from the RGB LEDs. Brightness level is given by the X axis of the sensor in the remote control.

- Second mode controls the red, green, and blue LED according to the X, Y, Z axes.
- To switch between these two modes, push the button S2 on the remote control.
- It is now time to run the graphical user interface program, RGB_LEDdemo.pmp, on the PC. On startup, the interface should look like <st-blue>Figure 6-4.. To run the GUI properly, see section FreeMASTER GUI.
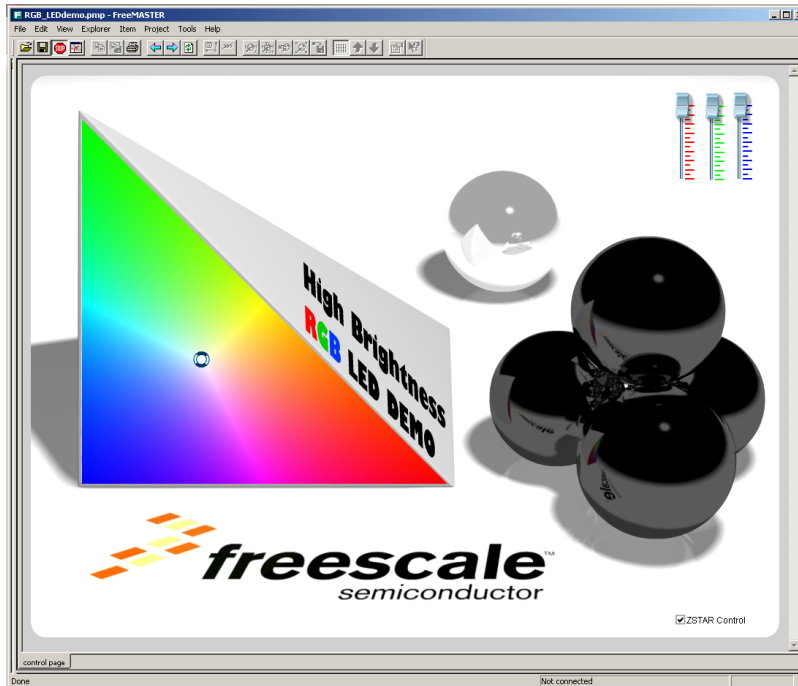

Figure 6-4. FreeMASTER Graphical User Interface Startup Window

6.3.1 Troubleshooting

Communication is not running

- Verify that the boards are powered properly
- Verify that the ZCOMM and ZSTAR remote control boards are turned on

Remote control can not control the Quadrunner Lumiled board even when communication is running

- Check the ID selection switch on the Quadrunner board
- Check the default jumper configuration (Default Jumper/Switch Configuration)

6.4 FreeMASTER GUI

To run FreeMASTER on your computer, run the installation file fmaster13-2.exe from the *FreeMASTER/freemaster_install* directory on the enclosed CD.

After you have installed the FreeMASTER software, finish setting up the system and connect the power supply. Turn the demo on with switch SW1. You can then start the FreeMASTER program.

- Plug the ZSTAR USB stick (sniffer) into the USB com port of the PC.

- Run the graphical user interface program, RGB_LEDdemo.pmp, on the PC.
- Setup the communication. Open the Options window by selecting the menu sequence *Project /Options*. Choose an appropriate COM port (usually COM7). Change the port if necessary. The baud rate should be at 57600 baud.
- Click on the start/stop button on the FreeMASTER toolbar. When proper communication options are chosen, the white bowl should change the intensity of its color. Switch to the RGB mode (remote control S2 button) and the RGB bowls change their level of brightness.

6.4.1   Troubleshooting

FreeMASTER GUI—not connected

- Verify communication options are correct (COMx port, Baud Rate- 57600)
- Click on the Start/Stop communication button on the toolbar menu
- Remove and plug in the USB sniffer again

FreeMASTER GUI—Connected (receiving strange network values)

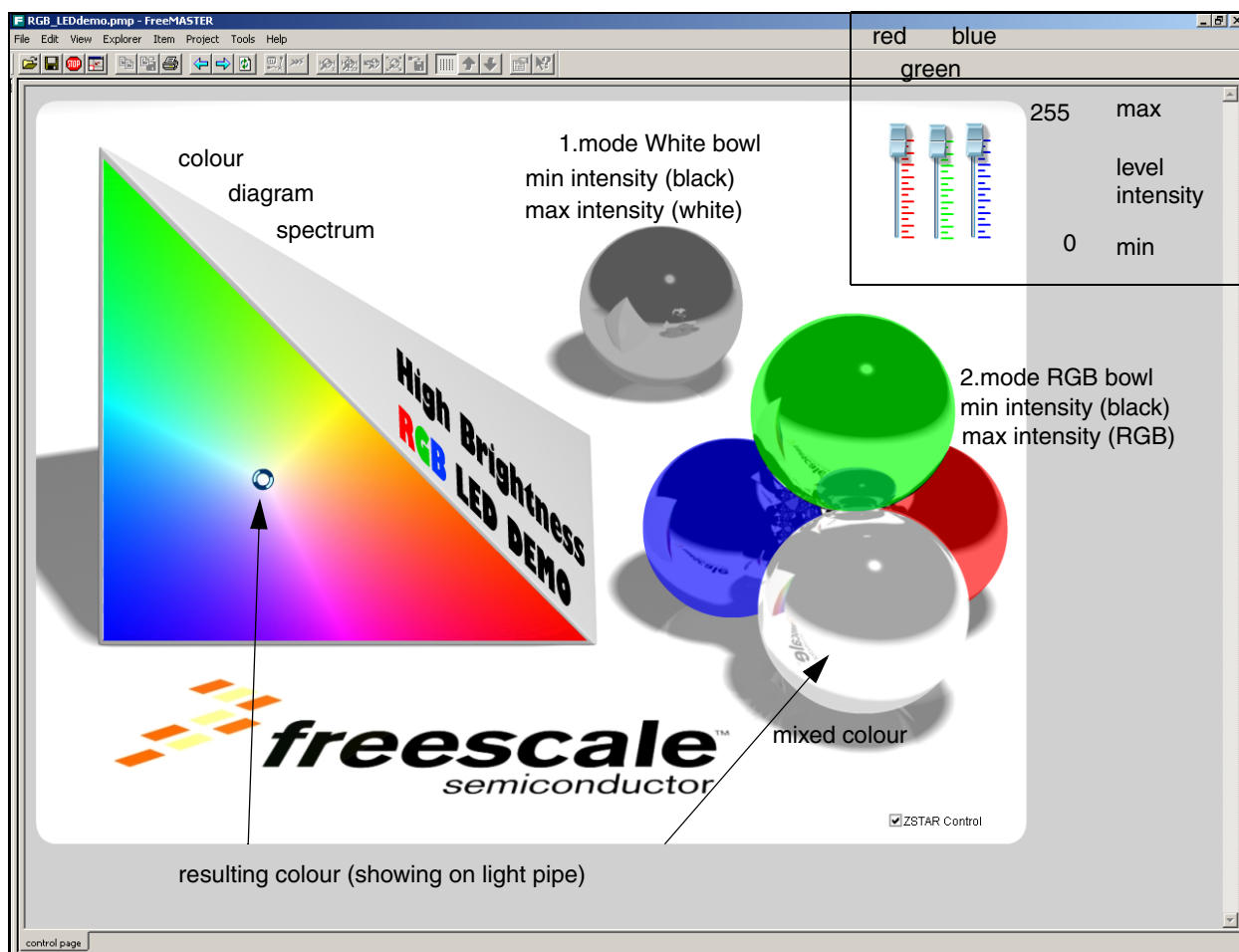- Push button S1 on the USB sniffer (proper network channel selection)

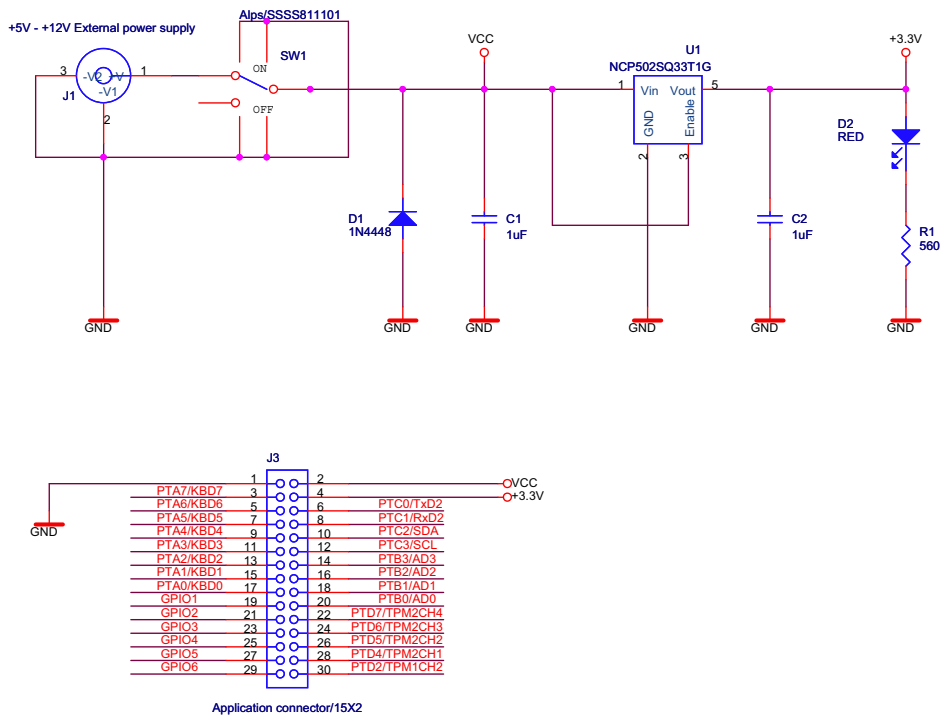**Figure 6-5. FreeMASTER Software Control Page**

Appendix A
Schematics

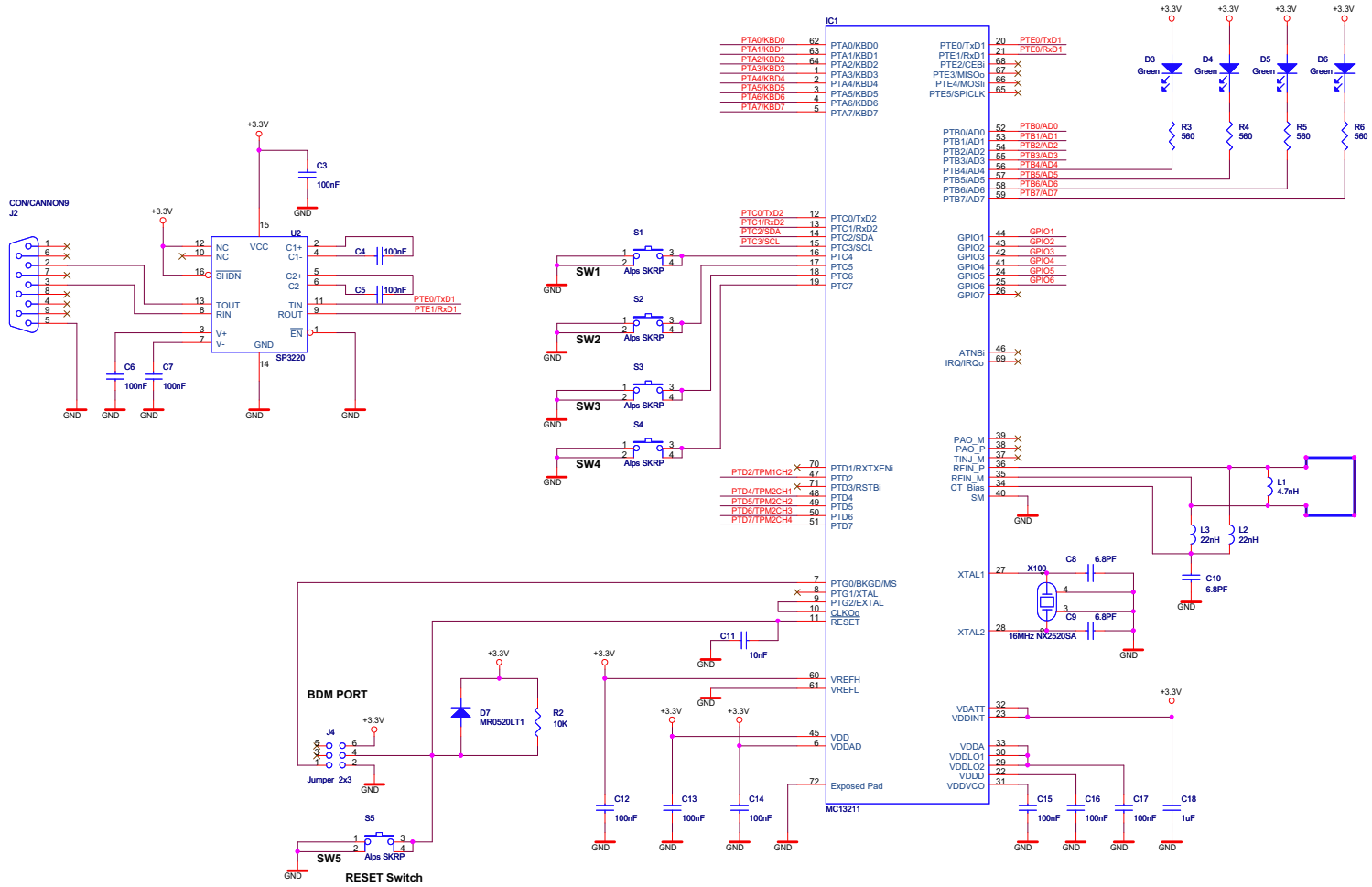**Figure A-1. ZCOMM Board (Power Supply, Application Connector)**

Remote Control of High-Brightness LEDs, Rev. 0

Figure A-2. ZCOMM Board (MC13213, RS232)

Figure A-3. LIN Transceiver

9-18 VDC

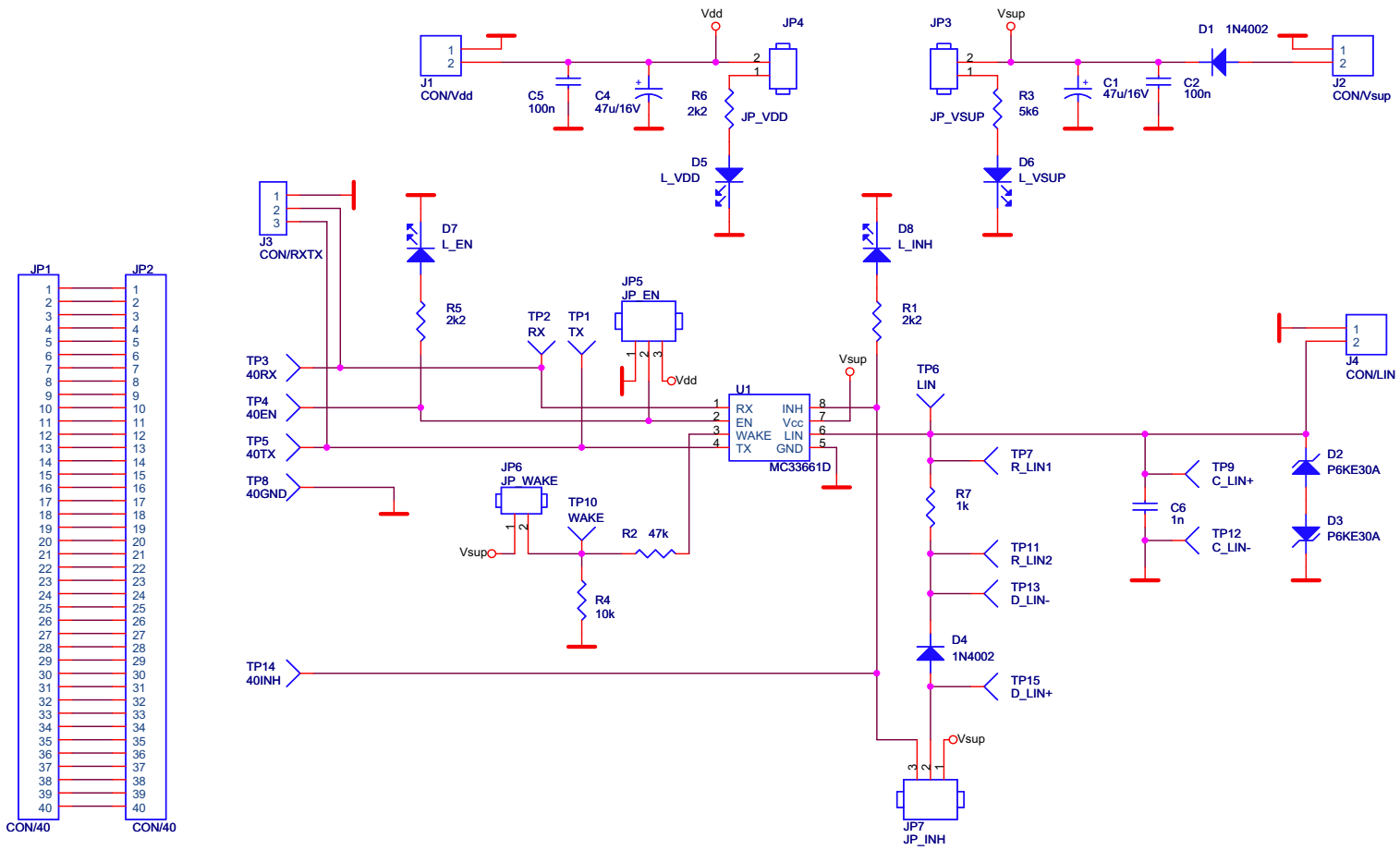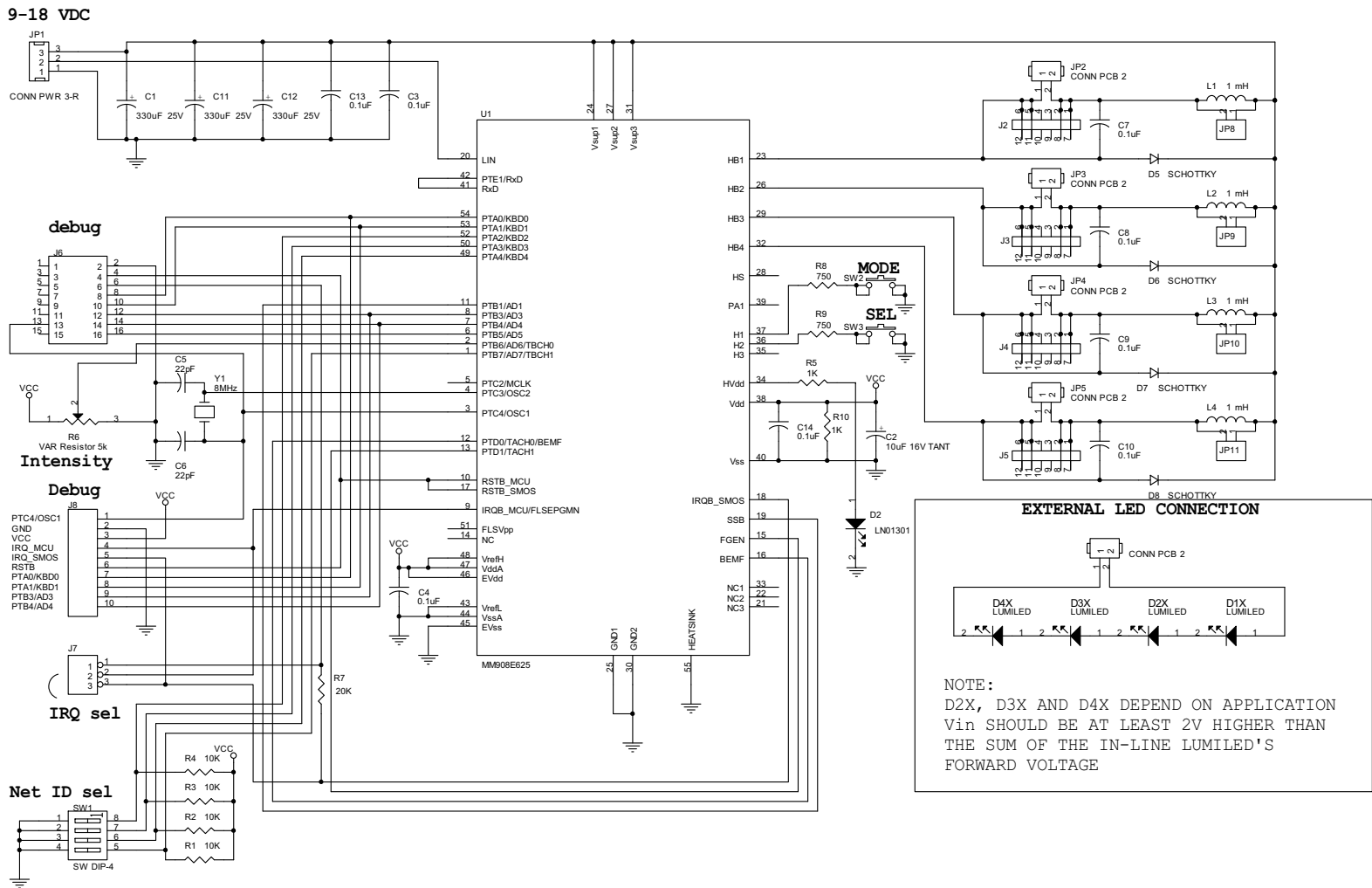## Figure A-4. Quadrunner Lumiled Board

Appendix B
ZCOMM Board – Bill of Materials

Table B-1. ZCOMM Board BOM

Reference	Part Value	Description	Mfg.	Mfg. Part No.
C8-10	6.8pF	ceramic SMD 0603	any acceptable	
C11	10nF	ceramic SMD 0603	TDK	C1608X7R1H103K
C3-7, C12-17	100nF	ceramic SMD 0603	TDK	C1608X7R1H104K
C1-2, C18	1uF	ceramic SMD 0603	TDK	C1608X7R1H105K
D1	1N4148/1N4448	SMD Switching Diode SOD80C (minimelf)	any acceptable	
D2		Red SMD 0603 LED	any acceptable	
D3-6		Green SMD 0603 LED	any acceptable	
D7	MBR0520	Schotky Rectifier	OnSemi	MBR0520LT1
R1, R3-6	560	SMD Resistor 0603	any acceptable	
R2	10K	SMD Resistor 0603	any acceptable	
L1	4.7nH	SMD Inductor 0603	TDK	MLG1608B4N7ST
L2-3	22nH	SMD Inductor 0603	TDK	MLG1608B22NJT
X100	NX2520SA	crystal, 16MHz	NDK	NX2520SA 16MHz EXS00A-02940
U1	NCP502SQ33T1G	voltage regulator	ONSEMI	NCP502SQ33T1G
U2	SP3220	RS232 transceiver	Sipex	SP3220EBCA
IC1	MC13213	Freescale ZigBee Platform + MCU	Freescale	MC13213
S1-5	Alps SKRP	button	Alps	SKRPADE010
SW1	Alps/SSSS811101	On/Off switch	Alps	SSSS811101
J1		Power Jack type connector 2.1mm	Elekon	K375A
J2	DB9/female	Cannon 9-pin(RS232) female 90°	any acceptable	
J3		Application Connector 15x2	Samtec	SSM-115-S-DV