Eco Power Design

EWI
User manual

2.4 GHz IEEE Std. 802.15.4™

Transceiver Module

2.4 GHz IEEE Std. 802.15.4TM 5 dBm RF Transceiver Module

APPLICATIONS

- IEEE 802.15.4 systems
- ZigBee® systems
- Industrial monitoring and control
- Home and building automation
- Automatic Meter Reading
- Low-power wireless sensor networks
- Set-top boxes and remote controls
- Consumer electronics

KEY FEATURES

- State-of-the-art selectivity/co-existence
- Adjacent channel rejection: 49 dB
- Alternate channel rejection: 54 dB
- Excellent link budget (103dB)
- 400 m Line-of-sight range
- Extended temp range (-40 to +125°C)
- Wide supply range: 1.8 V – 3.8 V
- Extensive IEEE 802.15.4 MAC hardware support to offload the microcontroller
- AES-128 security module
- CC2420 interface compatibility mode

Low Power

- RX (receiving frame, -50 dBm) 18.5 mA
- TX 33.6 mA @ +5 dBm
- TX 25.8 mA @ 0 dBm
- <1µA in power down

Radio

- IEEE 802.15.4 compliant DSSS baseband modem with 250 kbps data rate
- Excellent receiver sensitivity (-98 dBm)
- Programmable output power up to +5 dBm
- RF frequency range 2394-2507 MHz
- Suitable for systems targeting compliance with US radio frequency regulations,
- FCC CFR47 Part 15

Microcontroller Support

- Digital RSSI/LQI support
- Automatic clear channel assessment for CSMA/CA
- Automatic CRC
- 768 bytes RAM for flexible buffering and security processing
- Fully supported MAC security
- 4 wire SPI
- Interrupt generator
- Frame filtering and processing engine
- Random number generator

FIGURE 1: Pin Diagram

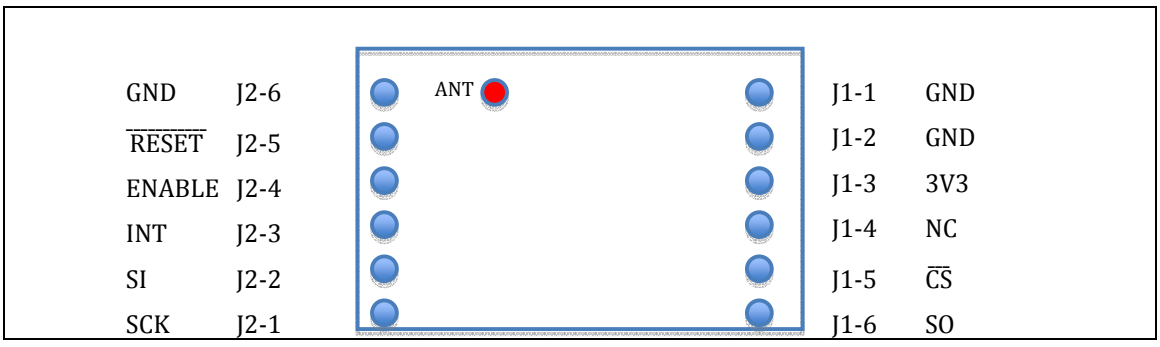


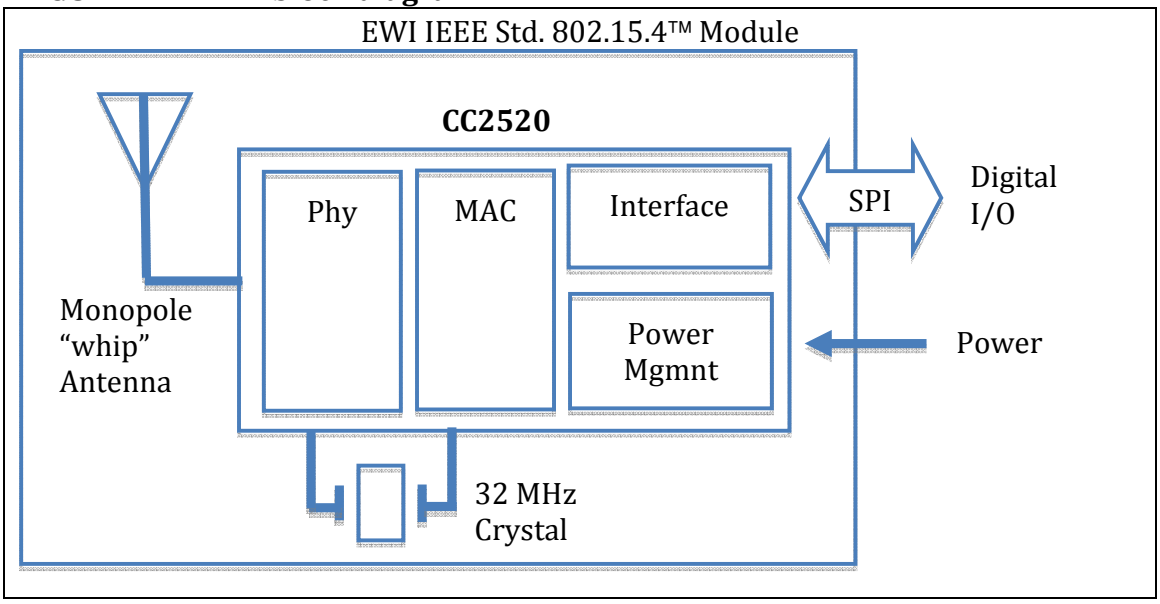
Table of Contents

1.0 Device Overview

The EWI module is a 2.4 GHz IEEE Std. 802.15.4™compliant, surface mount module with integrated crystal, internal voltage regulator, matching circuitry, and a monopole "whip" antenna. The EWI module operates in the non-licensed 2.4 GHz frequency band. The integrated module design frees the integrator from extensive RF and antenna design, and regulatory compliance testing, allowing quicker time to market.

The EWI module has received regulatory approvals for modular devices in the United States (FCC). Modular approval removes the need for expensive RF and antenna design, and allows the end user to place the EWI module inside a finished product and not require regulatory testing for an intentional radiator (RF transmitter).

FIGURE 1-1: EWI block diagram



1.1 Interface Description

Figure 1-1 shows a simplified block diagram of the EWI module. The module is based on the Texas Instrument CC2520 IEEE 802.15.4™ 2.4 GHz RF Transceiver IC. The module interfaces to many popular microcontrollers via a 4-wire serial SPI interface, interrupt, enable, Reset, power and ground, as shown in Figure 1-2. Table 1-1 provides the pin descriptions.

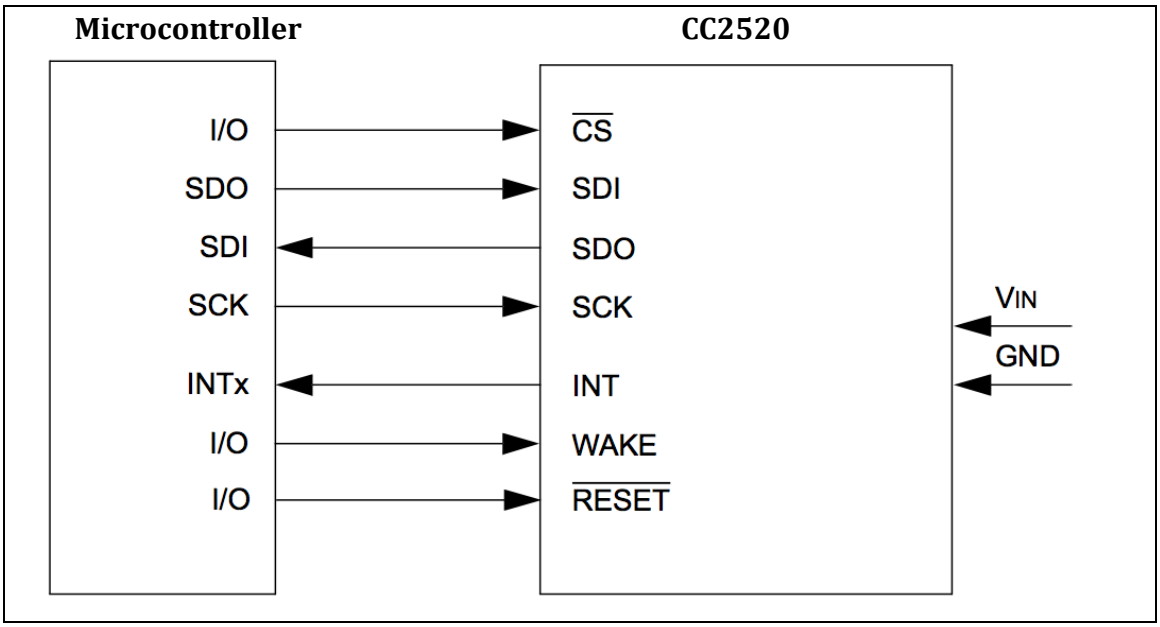
Data communications with the EWI module are documented in the "CC2520 DATASHEET 2.4 GHZ IEEE 802.15.4/ZIGBEE® RF TRANSCEIVER" (SWRS068 DECEMBER 2007). Refer to the CC2520 Data Sheet for specific serial interface protocol and register definitions.

TABLE 1-1: Pin Description

Pin	Symbol	Type	Description
J2-6	GND	Power	Ground
J2-5	$\overline{\text{RESET}}$	DI	Global hardware Reset pin
J2-4	ENABLE	DI	External wake-up trigger
J2-3	INT	DO	Interrupt pin to microcontroller
J2-2	SI	DI	Serial interface data input
J2-1	SCK	DI	Serial interface clock
J1-6	SO	DO	Serial interface data output from CC2520
J1-5	$\overline{\text{CS}}$	DI	Serial interface enable
J1-4	NC	--	No connection
J1-3	3V3	Power	Power supply
J1-2	GND	Ground	Ground
J1-1	GND	Ground	Ground

Legend: Pin type abbreviation: D = Digital, I = Input, O = Output

FIGURE 1-2: Microcontroller to EWI Module Interface



1.2 Mounting Details

The EWI is a surface mountable module. Module dimensions are shown in Figure1-3. The module Printed Circuit Board (PCB) is 0.032" thick with 0.1in connection pins as shown in fig 1-3. Figure 1-4 is a recommended host PCB footprint for the EWI.

The EWI has a monopole “whip” antenna. For the best performance, follow the mounting details shown in Figure1-5. It is recommended that the module be mounted with no metallic structures in the area marked in fig 1-5

FIGURE 1-4: Recommended PCB Footprint

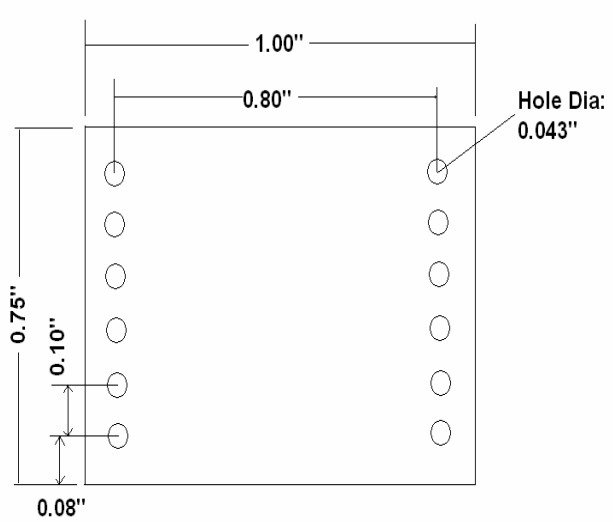


FIGURE 1-3: Module Details

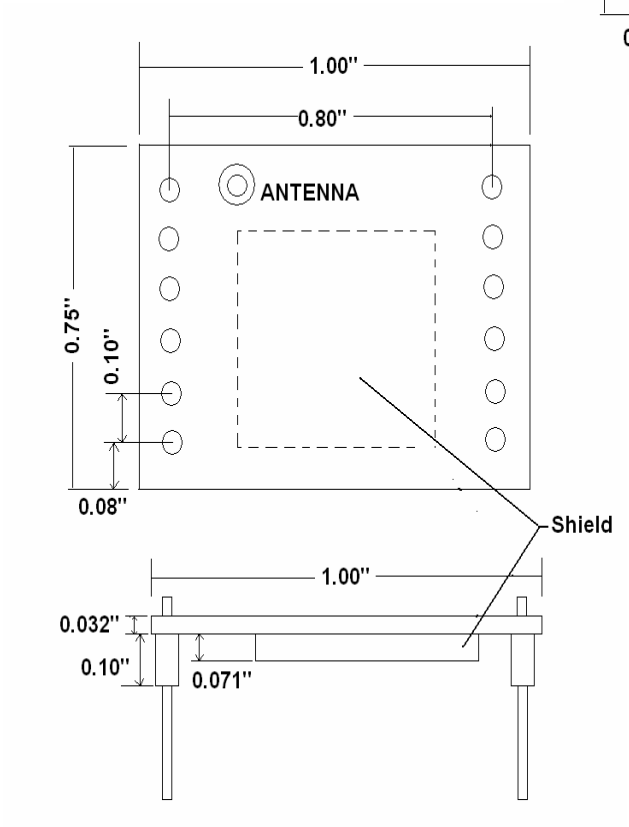
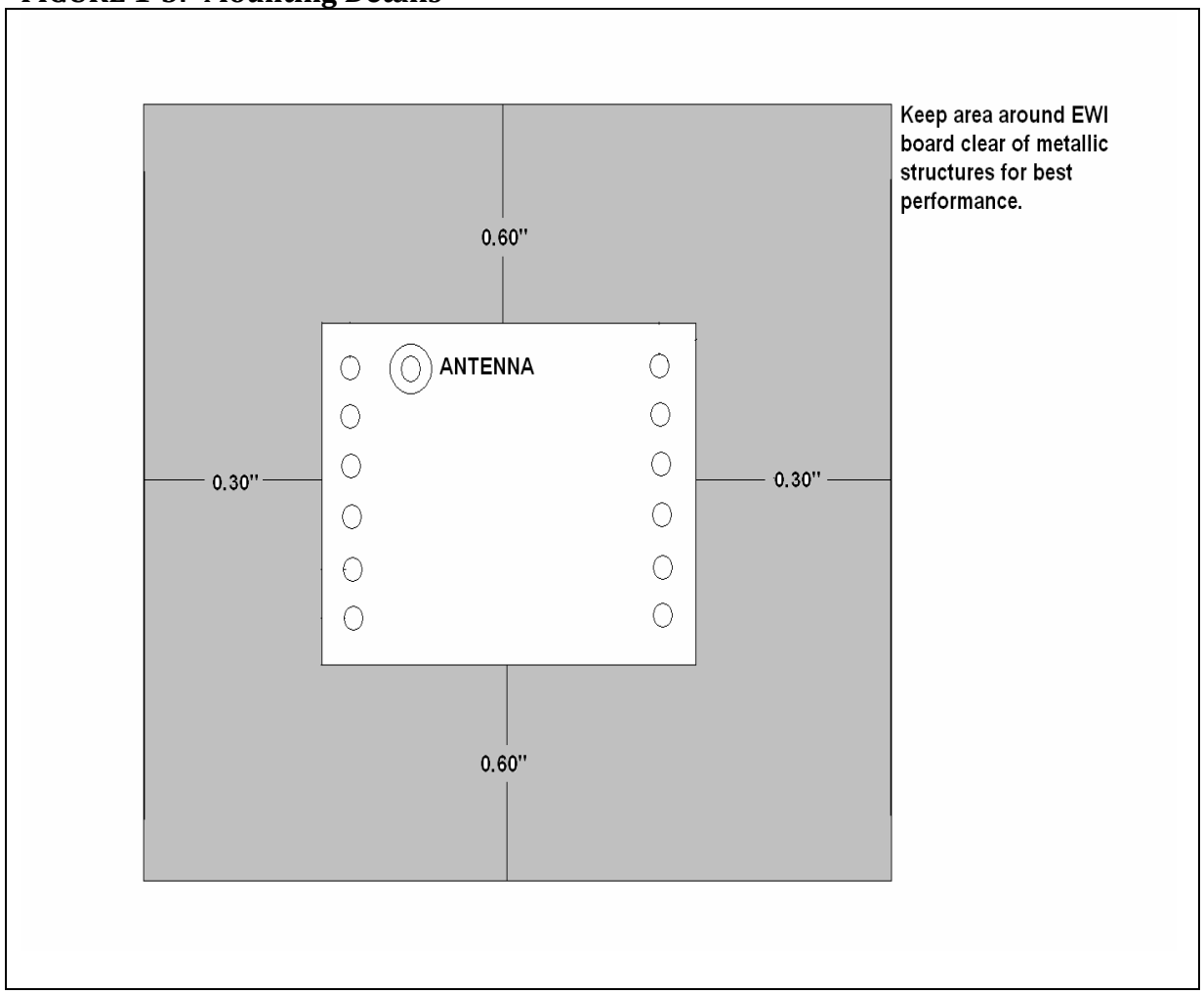


FIGURE 1-5: Mounting Details



2.0 Circuit Description

The EWI is a complete 2.4 GHz IEEE Std. 802.15.4™ compliant surface mount module with integrated crystal, internal voltage regulator, matching circuitry, and a monopole "whip" antenna. The EWI module interfaces to many popular microcontrollers via a 4-wire serial SPI interface, interrupt, wake, Reset, power and ground. Data communications with the EWI module are documented in the "CC2520 DATASHEET 2.4 GHZ IEEE 802.15.4/ZIGBEE® RF TRANSCEIVER" (SWRS068 DECEMBER 2007). Refer to the CC2520 Data Sheet for specific serial interface protocol and register definitions.

2.1 Schematic

A schematic diagram of the module is shown in Figure 2-1 and the Bill of Materials (BOM) is shown in Table 2-1. The EWI module is based on the Texas Instruments CC2520 IEEE 802.15.4™ 2.4 GHz RF Transceiver IC (U1). The serial I/O (SCK, SI, SO and CS), RESET, ENABLE and INT pins are brought out to the module pins.
Crystal, X1, is a 32 MHz resonator with a frequency tolerance of ±10 ppm @ 25°C to meet the IEEE Std. 802.15.4 symbol rate tolerance of ±40 ppm.

FIGURE 2-1: EWI Schematic

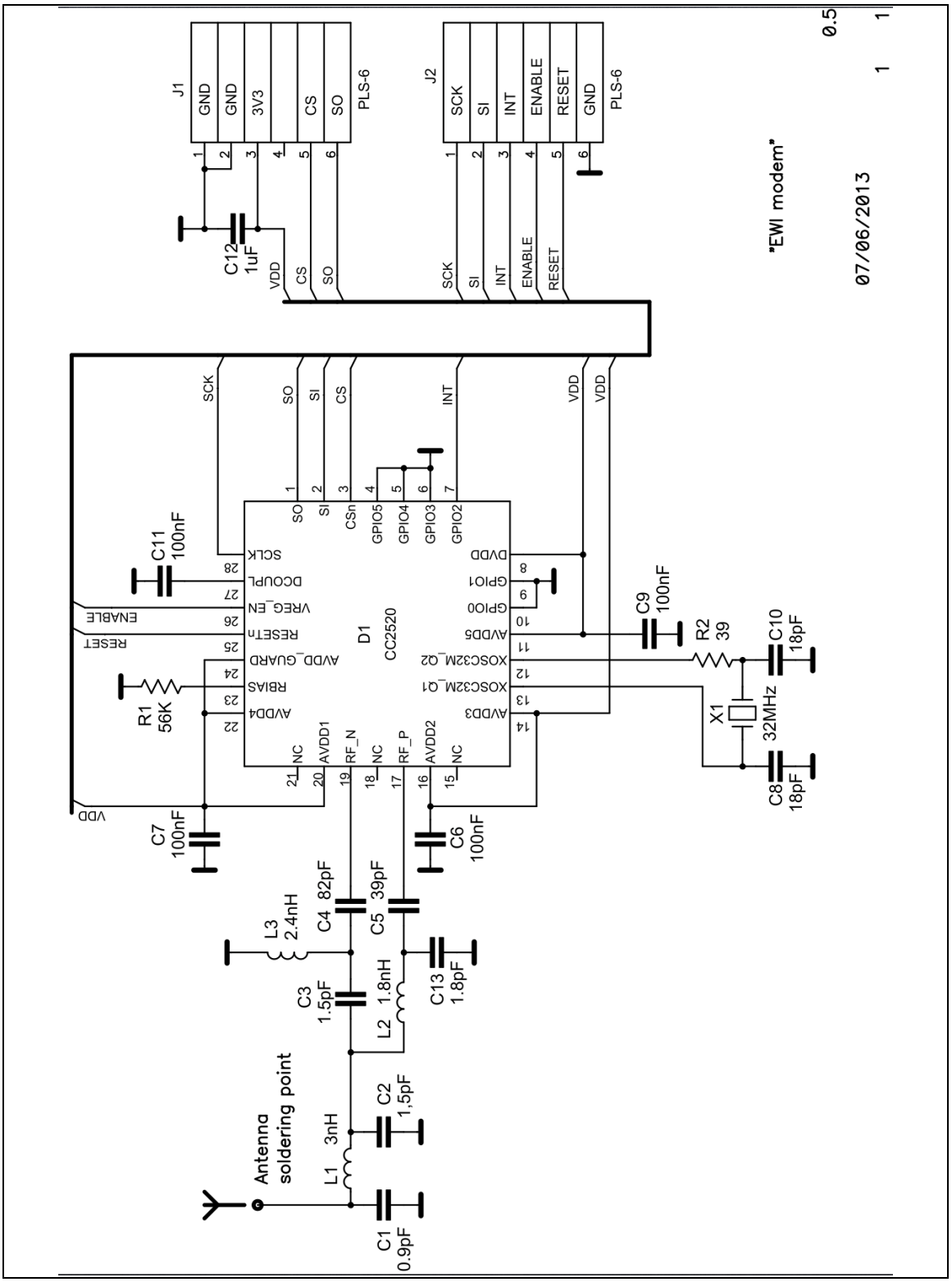


TABLE 2-1: EWI Bill Of Material

Ref	Description	Manufacturer (alt. Manuf.)	Part Number (alt. Part. No.)
C1	Capacitor 0402 0.9pF NP0	Johanson Technology (Murata)	500R07S0R9BV4S (GJM1555C1HR90BB01D)
C2	Capacitor 0402 1.5pF NP0	Johanson Technology (Murata)	500R07S1R5BV4S (GJM1555C1H1R5CB01D)
C12	Capacitor 0402 1uF X5R	Murata	GRM155R60J105KE19
C3	Capacitor 0402 1.5pF NP0	Murata	GRM1555C1H1R5CZ01
C13	Capacitor 0402 1.8pF NP0	Murata	GRM1555C1H1R8CZ01
C8	Capacitor 0402 15pF NP0	Murata	GRM1555C1H150JZ01
C10	Capacitor 0402 15pF NP0	Murata	GRM1555C1H150JZ01
C5	Capacitor 0402 39pF NP0	Murata	GRM1555C1H390JZ01
C4	Capacitor 0402 82pF NP0	Murata	GRM1555C1H820JZ01
C6	Capacitor 0402 100nF X5R	Murata	GRM155R61A104KA01
C7	Capacitor 0402 100nF X5R	Murata	GRM155R61A104KA01
C9	Capacitor 0402 100nF X5R	Murata	GRM155R61A104KA01
C11	Capacitor 0402 100nF X5R	Murata	GRM155R61A104KA01
J1	Connector PLS-6, 6pin 2.54mm pitch		
J2	Connector PLS-6, 6pin 2.54mm pitch		
D1	Transceiver IEEE 802.15.4	TI	CC2520RHDT
L1	Inductor 0402 3nH	Johanson Technology (Murata)	L-07C3N0SV6S (LQG15HN3N0S02D)
L2	Inductor 0402 1.8nH	Johanson Technology (Murata)	L-07C1N8SV6S (LQG15HN1N8S02D)
L3	Inductor 0402 2.4nH	Johanson Technology (Murata)	L-07C2N4SV6S (LQG15HN2N4S02D)
R2	Resistor 0402 39 5%	any	
R1	Resistor 0402 56k 1%	any	
X1	32MHz resonator, 8pF, 80 Ohm, 10ppm (25C), 15ppm (temperature range), -40...+85C, 3.2x2.5mm	SJK	SJK-7U-32.000-08-10-60-C-15
	8pF, 10ppm (25C), -40...+85C, 3.2x2.5mm	PDI	C332000XFAD08XX
	8pF, 50ppm (25C), -40...+125C, 3.2x2.5mm	PDI	C332000XFCS08RX

2.2 Printed Circuit Board

The MRF24J40MB module printed circuit board is constructed with FR4 material, four layers and 0.032 inches thick. The layers are shown in Figure 2-2 through Figure 2-6. The stack up of the PCB is shown in Figure 2-7.

FIGURE 2-2: Top Silk Screen

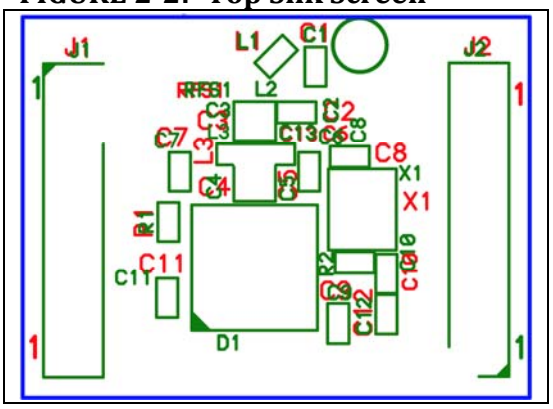


FIGURE 2-3: Top Copper

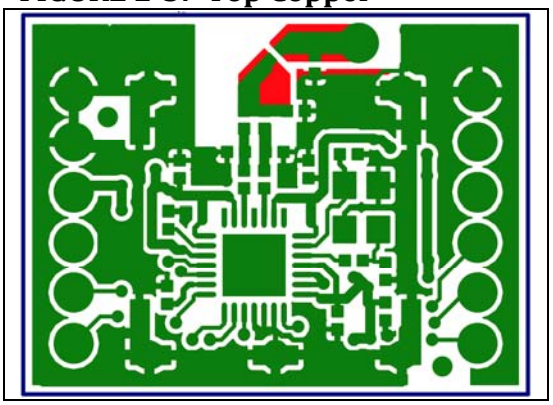
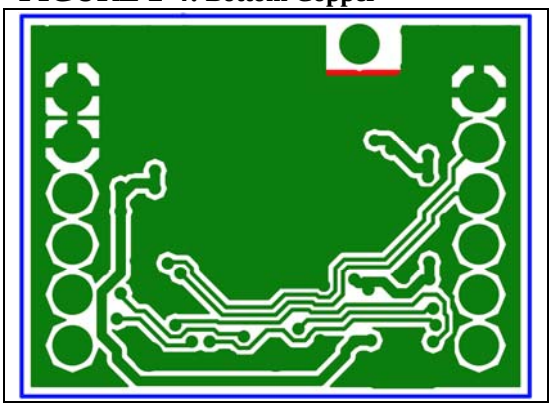


FIGURE 2-4: Bottom Copper



2.3 Monopole "whip" Antenna

The EWI has a monopole "whip" antenna. The ground and power planes under the components serve as a counterpoise to the "whip" antenna. Additional ground plane on the host PCB will substantially enhance the performance of the module. For best performance, place the module on the host PCB following the recommendations in Section 1.2 "Mounting Details".

The design goal was to create a compact, low-cost antenna with the best radiation pattern. Figure 2-9 shows the simulation drawing and Figure2-10 and Figure2-11 show the 2D and 3D radiation patterns, respectively. As shown by the radiation patterns, the performance of the antenna is dependant upon the orientation of the module. Figure 2-12 shows the impedance simulation and Figure 2-13 shows the SWR simulation. The discrete matching circuitry matches the impedance of the antenna with the CC2520 transceiver IC.

3.0 Regulatory Approval

The EWI module has received regulatory approvals for modular devices in the United States. Modular approval allows the end user to place the EWI module inside a finished product and not require regulatory testing for an intentional radiator (RF transmitter), provided no changes or modifications are made to the module circuitry. Changes or modifications could void the user's authority to operate the equipment. The end user must comply with all of the instructions provided by the Grantee, which indicate installation and/or operating conditions necessary for compliance.
The integrator may still be responsible for testing the end product for any additional compliance requirements required with this module, installed (for example: digital device emission, PC peripheral requirements, etc.) in the specific country that the end device will be marketed.
Annex F of the IEEE Std. 802.15.4 document has a good summary of regulatory requirements in various countries concerning IEEE Std. 802.15.4 devices. The standard can be downloaded from the IEEE Standards web page:
http://standards.ieee.org/getieee802/802.15.html.
Refer to the specific country radio regulations for details on regulatory compliance.

3.1 United States

The EWI module has received Federaö Communications Commission (FCC) CFR47 Telecommunications, Part 15 Subpart C "Intentional Radiators" 15.247 and modular approval in accordance with FCC Public Notice DA 00-1407 Released: June 26, 2000, Part 15 Unlicensed Modular Transmitter Approval. The EWI module can be integrated into a finished product without obtaining subsequent and separate FCC approvals.
The EWI module has been labeled with its own FCC ID number, and if the FCC ID is not visible when the module is installed inside another device, then the outside of the finished product into which the module is installed must also display a label referring to the enclosed module. This exterior label can use wording such as the following:

Contains Transmitter Module FCC ID: OA3EWI
-or-
Contains FCC ID: OA3EWI
This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.
This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy, and if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that

interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:
- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment in to an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

3.1.1 EWI Settings

To meet the FCC requirements, the following settings must be observed by the integrator:
• The EWI transmit power setting (RFCON3 0x203) cannot exceed -1.9 dB.
• Only channels 11 through 25 may be selected (RFCON0 0x200).

3.1.2 RF Exposure

All transmitters regulated by FCC must comply with RF exposure requirements. OET Bulletin 65 "Evaluating Compliance with FCC Guidelines for Human Exposure to Radio Frequency Electromagnetic Fields" provides assistance in determining whether proposed or existing transmitting facilities, operations or devices comply with limits for human exposure to Radio Frequency (RF) fields adopted by the Federal Communications Commission (FCC). The bulletin offers guidelines and suggestions for evaluating compliance.
If appropriate, compliance with exposure guidelines for mobile and unlicensed devices can be accomplished by the use of warning labels and by providing users with information concerning minimum separation distances from transmitting structures and proper installation of antennas.

The following statement must be included as a CAUTION statement in manuals and OEM products to alert users of FCC RF exposure compliance:

To satisfy FCC RF exposure requirements for mobile and base station transmission devices, a separation distance of 20 cm or more should be maintained between the antenna of this device and persons during operation. To ensure compliance, operation at closer than this distance is not recommended. The antenna(s) used for this transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.

If the EWI module is used in a portable application (antenna is less than 20 cm from persons during operation), the integrator is responsible for performing Specific Absorption Rate (SAR) testing in accordance with FCCrules 2.1091.

3.1.3 Helpful Web Sites

Federal Communications Commission (FCC): http://www.fcc.gov

4.0 Electrical Characteristics

TABLE 4-1: Recommended Operating Conditions

Parameters	Min	Typ	Max	Units
Ambient Operating Temperature	-40		125	°C
Supply Voltage for RF, Analog and Digital Circuits	1.8		3.8	V
Supply Voltage for Digital I/O				
Input High Voltage			80%	of VDD
Input Low Voltage	30%			of VDD

TABLE 4-2: Current Consumption

T_A =25°C, VDD=3.0 V, f_c =2440 MHz if nothing else stated. All parameters measured on Texas Instruments' CC2520 EM 2.1 reference design with 50 Ω load

Parameter	Condition	Min	Typ	Max	Units
Receive current	Wait for sync		22.3	24.8	mA
	T_A=-40 to 125°C, VDD=1.8 to 3.8 V, f_c =2394 to 2507 MHz			26.3	mA
	Wait for sync, Low-current RX setting		18.8		mA
	Receving frame, -50 dBm input level		18.8		mA
Transmit current	0 dBm setting		25.8	28.8	mA
	+5 dBm setting		33.6	37.2	mA
	T_A=-40 to 125°C, VDD=1.8 to 3.8 V, f_c =2394 to 2507 MHz			37.5	mA
Active Mode current	XOSC on, digital regulator on.		1.6	1.9	mA
	T_A=-40 to 125°C, VDD=1.8 to 3.8 V, f_c =2394 to 2507 MHz			2.6	mA
LPM1 current	XOSC off, digital regulator on. State retention.		175	250	µA
	T_A=-40 to 125°C, VDD=1.8 to 3.8 V, f_c =2394 to 2507 MHz			1000	µA
LPM2 current	XOSC off, digital regulator off. No state retention.				
	T_A=-40 to 125°C, VDD=1.8 to 3.8 V, f_c =2394 to 2507 MHz		30	120	nA
				4.5	µA

TABLE 4-3: Receiver AC Characteristics

TA =25°C, VDD=3.0 V, fc =2440 MHz if nothing else stated. All parameters measured on Texas Instruments' CC2520 EM 2.1 reference design with 50 Ω load.

Parameter	Condition	Min	Typ	Max	Units
Receiver sensitivity	[2] requires -85 dBm T_A=-40 to 125°C, VDD=1.8 to 3.8V, fc =2394 to 2507 MHz	-99	-98 -88	-95	dBm
Saturation	[2] requires -20 dBm 6 dBm				
Interferer Rejection	Wanted signal 3 dB above the sensitivity level, 802.15.4 modulated interferer at 802.15.4 channels: ±5 MHz from wanted signal. [2] requires 0 dB ±10 MHz from wanted signal. [2] requires 30 dB ±20MHz or above. Wanted signal at -82dBm.		49 54 55		dB dB dB
Maximum Spurious Emission Conducted measurement in a 50Ω single ended load. Complies with EN 300 328, EN 300 440 class 2, FCC CFR47, Part 15 and ARIB STD-T-66	30 – 1000 MHz 1 – 12.75 GHz		< -80 -56		dBm dBm
Frequency error tolerance	Input level is 3 dB above sensitivity level.		+/-400		kHz
IIP3			-24		dBm

TABLE 4-4: Transmitter AC Characteristics

Parameter	Condition	Min	Typ	Max	Units
Output power	0 dBm setting	-3	1	5	dBm
Note: to reduce the output power variation over temperature, it is suggested that different	+5 dBm setting	2	5	7	dBm
	T_A=-40 to 85°C, VDD=2.0 to 3.8 V, f_c =2394 to 2507 MHz	-3		8	dBm
	T_A=-40 to 85°C , VDD=1.8 to 3.8 V,				

settings are used at different temperatures. The on-chip temperature sensor can be used for this purpose. Please see section 5.11 for more information. Largest spurious emission at maximum output power. Texas Instruments CC2520 EM reference design complies with EN 300 328, EN 300 440, FCC CFR47 Part 15 and ARIB STDT-66. Transmit on 2480 MHz under FCC at +5 dBm is supported by duty-cycling, or by reducing output power. The peak conducted spurious emission might violate ETSI and FCC restricted band limits at frequencies below 1GHz. All radiated spurious emissions are within the limits of ETSI/FCC/ ARIB. Applications that must pass conducted requirements are suggested to use a simple 50	f_c =2394 to 2507 MHz	-4	8	dBm
	T_A=-40 to 125°C, VDD=2.0 to 3.8 V, f_c =2394 to 2507 MHz	-6	8	dBm
	T_A=-40 to 125°C, VDD=1.8 to 3.8 V, f_c =2394 to 2507 MHz	-9	8	dBm
	25 MHz – 1 GHz (outside restricted bands)		-40	dBm
	25 MHz – 1 GHz (within FCC restricted bands)		-53	dBm
	47-74, 87.5-118, 174-230, 470-862 MHz (ETSI restricted bands)		-42	dBm
	1800 MHz-1900 MHz (ETSI restricted band)		-56	dBm
	5150 MHz-5300 MHz (ETSI restricted band)		-54	dBm
	At 2483.5 MHz and above (FCC restricted band)		-37	dBm
	f_c=2480 MHz, +5 dBm		-41	dBm
	f_c=2480 MHz, 0 dBm			
	At 2·RF and 3·RF (FCC restricted band)		-54	dBm

Ω high pass filter between matching network and RF connector.			
Error Vector Magnitude (EVM)	[2] requires max. 35%. Measured as defined by [2]. +5 dBm setting. fc =IEEE 802.15.4 channels 0 dBm setting. fc =IEEE 802.15.4 channels	 6 2	 % %