



DLP-RF2 & DLP-RF2-Z

RF OEM Transceiver Module (Preliminary)

The DLP-RF2-Z combines a Freescale™ MC13193 2.4GHz Direct-Sequence, Spread-Spectrum RF Transceiver IC and Freescale MC9S08GT60 microcontroller to form an IEEE 802.15.4 compliant, ZigBee™ ready, short-range transceiver module. The DLP-RF2-Z connects to user electronics via a standard, 20-pin male header.



The MC9S08GT60 microcontroller is preprogrammed with DLP Design's Serial Interface Packet Processor (SIPP™ firmware) for accessing the transceiver functions via simple serial calls. Interface to an external serial host microcontroller/ DSP/FPGA, etc. is accomplished via a simple 2-wire (RX, TX, and ground) interface.

The SIPP firmware in the DLP-RF2-Z resides at the application layer and is based on Freescale's SMAC. The SIPP firmware provides basic access to DLP-RF2-Z functionality: Packet receive and transmit, transceiver settings, EEPROM access, etc. The DLP-RF2-Z can also operate without a serial host controller. Basic digital I/O, A/D conversions, temperature measurement, and latching/non-latching relay control are available via the SIPP firmware.

The MC9S08GT60 can be reprogrammed (if desired) with user-supplied firmware via a 6-pin BDM header that is compatible with the P&E USB-ML-12 and device programmers (purchased separately).

Application Areas:

- Remote control and wire replacement in industrial systems
- Wireless sensor networks
- Home automation and control
- Remote entertainment control
- Factory automation
- Heating and cooling systems
- Inventory management and RFID tagging
- Human interface devices
- Wireless toys

Features:

- IEEE 802.15.4 Compliant & ZigBee ready
- Microcontroller pre-programmed with SIPP firmware
- Twelve I/O lines that can be configured for digital input or output; seven lines can be configured for analog input
- Default reset via shorting two jumpers at power-up
- <35 microamp low-power mode
- Carrier-sense, multiple-access technology
- Range: >500 feet, outdoor line of sight
- Agency approvals for immediate deployment in the US, Canada, and Europe
- Modular approval – no additional agency testing required under certain conditions

1.0 System Overview

Using the pre-programmed SIPP firmware, the DLP-RF2-Z can be used in conjunction with other DLP-RF2-Z and/or DLP-RF1 modules to form simple point-to-point and star configuration systems. Both the DLP-RF1 and the DLP-RF2-Z can serve as host/system controllers. In the case of the DLP-RF1, the host is a user-supplied Windows, Linux, or Mac PC that is accessed via a USB interface and user-supplied, 6-foot USB cable. In the case of the DLP-RF2-Z, the host is a user-supplied microcontroller/DSP/FPGA/etc. that is accessed via a 2-wire serial interface—TX, RX, and ground. A host processor is not necessarily required by the DLP-RF2-Z. The SIPP firmware within the DLP-RF2-Z can be accessed remotely via another transceiver and can be used to both gain access to the MC9S08GT60's port pins for basic digital I/O and offer a few hardware-specific functions for measuring system power supply voltage, measuring temperature, and controlling relays. These functions require the presence of external hardware (purchased separately).

Using the ZigBee Protocol (licensed separately), the DLP-RF2-Z can be used in conjunction with other DLP-RF1/DLP-RF2-Z transceivers as well as other MC13193-based ZigBee-ready devices to form complex point-to-point, star, and mesh networks.

In a system using the preprogrammed SIPP firmware, each transceiver has a unique 16-bit ID yielding a theoretical maximum of 65,535 transceivers. Every data packet handled by the SIPP firmware must contain, at minimum, the number of bytes in the packet, the destination transceiver ID (packet destination), the source transceiver ID (packet origin), and a command byte.

As shipped from DLP Design, the DLP-RF2-Z has an ID of 2. If more than one DLP-RF2-Z is to be used in a system, then this ID must be changed to a value higher than 2. Upon reset or power up, the ID is read from non-volatile EEPROM memory. If JP1 is shorted at power up (or before a reset), the default ID for the DLP-RF2-Z is set to 2 and other transceiver settings are also returned to a default state in the EEPROM. (Refer to Section 2.2 for additional details.)

In addition to basic packet processing and port-pin manipulation, the SIPP firmware in the DLP-RF2-Z offers a Low-Power Mode designed to conserve battery power. Holding PTC1 (Header Pin 16) low at power up enables the Low-Power Mode. Once enabled, the DLP-RF2-Z is in Sleep Mode until awakened by activity on digital inputs that have been enabled to wake the processor—or by a simple preset timeout. The setup parameters for this feature are also stored in the non-volatile EEPROM memory. If PTC1 is not held low, then the microcontroller and RF IC remain in full power mode, offering the fastest packet processing possible. (Refer to Section 2.2 for additional details.)

2.0 Preprogrammed Serial Interface Packet Processor (SIPP) Firmware

The source code for Freescale's SMAC is available as a free download from www.freescale.com. The SIPP firmware is based on the SMAC firmware.

A test program (DLP-RFTTestAp.exe) is available as a free download from www.dlpdesign.com that makes easy work of setting up the DLP-RF2-Z transceiver and testing its basic functionality. Use of the DLP-RFTTestAp.exe requires a serial interface between a host Windows PC and the DLP-RF2-Z. [For example, the USB interface available on the upcoming DLP-RF2-ZPROTO

(purchased separately).] Connection to the RF2-Z for the purpose of setup and test can also be made via RF from another RF1 or RF2-Z.

Under this communication protocol, it is the responsibility of the serial host application firmware to “Retry” transmissions that do not produce the anticipated reply.

2.1 Packet Structure

Each SIPP firmware packet is comprised of 6 or more bytes. The following table outlines the packet structure:

PACKET STRUCTURE

Byte	Description	Comments
0	Number of bytes in the packet following byte 0: 5-124	Each packet must contain (as a minimum) the number of bytes, a destination ID, Source ID and a command byte
1	Destination ID MSByte ID Range: 1-65535*	ID:1 default for new DLP-RF1 transceivers ID:2 default for new DLP-RF2-Z transceivers ID:0 reserved for broadcast to all transceivers
2	Destination ID LSByte	
3	Source ID MSByte Range: 1-65535	
4	Source ID LSByte	
5	Command Byte Command Range: 0xA0-0xDF	Both Command Packets and Reply Packets. Every packet must have a command byte.
6	Data Byte(s)	0-119 bytes of data are allowed in the packet

*Note: Each transceiver in the system must have a unique ID. ID:0 is reserved for broadcast packets sent by DLP-RF2-Z transceivers coming out of Sleep Mode.

2.2 Reserved EEPROM Locations

The EEPROM memory is a feature of the SIPP firmware and, as such, is only available if using the DLP-RF2-Z with its firmware as shipped from DLP Design.

The EEPROM memory used by the SIPP firmware consists of a block of 32 bytes that reside within the Flash program memory of the MC9S08GT60. The first 10 bytes (0-9) and the last byte (31) are reserved for storing transceiver settings and checksum. Bytes 10 through 30 (user area) are available for use by user's host software.

Whenever the data in any EEPROM location is changed, the checksum location (EEPROM Location 31) is automatically updated. At power up (or reset), if ever the calculated checksum for the first 31 bytes does not match the value at EEPROM Location 31, the Default Reset values for the transceiver settings are restored, and the checksum is recalculated and rewritten. The values in the user area are preserved.

Additionally, if JP1 is shorted at power up (or reset), the default values for the transceiver settings are restored, and the checksum is recalculated and rewritten. Again, values in the user area are preserved.

The following table outlines the usage of the reserved EEPROM locations. These values are read at power up, reset, or via SIPP firmware:

EEPROM CONTENTS

Byte	Description	Options	Default Reset
0	My ID MSB	Range: 1-65,535	1 for RF1; 2 for RF2-Z
1	My ID LSB		0 reserved for broadcast commands
2	Transceiver Channel	0-15 (2.405GHz to 2.480GHz)	7 (2.440 GHz)
3	RF Transmit Power	0-15 (-16.6 to +3.5dBm into the balun)	15 (+3.5dBm -Max Power)
4	Sleep Time Length MSB (DLP-RF2-Z Low-Power Mode Only)	Range: 1-65,535; 5-second increments, 3.8 days max <u>For Example:</u> 1=5 seconds, 12=1 minute, 120=10 minutes, 720=1 hour, 17,280=1day	5 seconds
5	Sleep Time Length LSB		
6	Wake from Sleep, Host Command Timeout after Check-in (DLP-RF2-Z in Low-Power Mode Only)	1-128 half-seconds	2 (4 half-second intervals)
7	Baud Rate for RF2-Z Serial Host Controller)	0-2400; 1-4800; 2-9600; 3-14400; 4-19200; 5-38400; 6-128000; 7-250000	2 (9600 baud)
8	Port Pin Bit Field (DLP-RF2/RF2-Z Only)	0x00-0xFF DLP-RF2: (A6B6B5B4 B3B2B1B0) DLP-RF2-Z: (A6B6A2A1 B3B2B1B0)	0x80 (A6 monitored)
9	DLP-RF2-Z Available Features (DLP-RF2-Z Only)	Bit 7 – Measures battery voltage Bit 6 – Temperature sensor Bit 5 – Relays Bit 4 – Reserved Bit 3 – Reserved Bit 2 – Reserved Bit 1 – Reserved Bit 0 – Reserved	All bits cleared; no features available
31	Checksum	EX-OR of bytes 0-30	Calculated

2.3 Command Set

This Command Set is a feature of the SIPP firmware and, as such, is only available if using the DLP-RF2-Z with its firmware as shipped from DLP Design.

Packets are broken down into two primary types: Command Packets and Reply Packets. The host controller/PC originates all Command Packets. In the case of the DLP-RF2-Z, the host is the user-supplied serial host microcontroller/DSP/FPGA, etc.

If a Command Packet is received by the DLP-RF2-Z via the serial host interface with a destination ID that matches the ID stored in the EEPROM of the DLP-RF2-Z, then the MC9S08GT60 will process the packet and reply to the serial host controller. If the ID in the packet does not match the ID stored in EEPROM, then the packet is intended for a different destination and is transmitted via the transceiver.

If a packet is received via the RF transceiver with the correct ID, then the packet is either processed by the MC9S08GT60 or forwarded on to the serial host. Commands between 0xA0 and 0xBF are Command Packets that are to be processed by the MC9S08GT60, while commands between 0xC0 and 0xDF are Reply Packets and are forwarded on to the serial host.

If a packet arrives via the RF transceiver with an ID of 0 (zero), then the packet is a “broadcast” packet intended for the system controller (the RF1/RF2-Z unit that is designated as system controller). ID:0 packets are always immediately forwarded on to the host micro/PC.

If a packet arrives via the RF transceiver with a non-zero ID that does not match the EEPROM, then the packet is ignored. The only exception to this is if “Return All Packets” Mode is enabled, in which case the DLP-RF2-Z is monitoring packet traffic, and all unsolicited packets are returned to the serial host.

*** Under this communication protocol, it is the responsibility of the serial host application firmware to “Retry” transmissions that do not produce the anticipated reply. ***

Cmd	Packet Recipient	Description	Expected Reply Cmd
0xA0	MC9S08GT60	Ping (no data)	0xC0
0xA1	MC9S08GT60	Set Transmit Power Level 1 Data Byte; Range: 0-15	0xC0
0xA2	MC9S08GT60	Set Transceiver Channel 1 Data Byte; Range: 0-15	0xC0
0xA3	MC9S08GT60	Set RF2-Z Baud Rate	0xC0
0xA4	MC9S08GT60	Release immediately to Sleep (DLP-RF2-Z only--no data)	0xC0
0xA5	MC9S08GT60	Measure energy on all channels (no data)	0xC3
0xA6	MC9S08GT60	Return all packets received to host (Packet Watch Mode—no data)	0xC0
0xA7	MC9S08GT60	Return only packets with correct ID to host (Default mode) (no data)	0xC0
0xA8	MC9S08GT60	Read EEPROM 1 Data Byte; Address: 0-31	0xC4
0xA9	MC9S08GT60	Write EEPROM and update checksum 2 Data Bytes; Address: 0-30; Data: 0-255	0xC5
0xAA	MC9S08GT60	Read I/O pin, 1 Data Byte: Port: 0-8 (Port 8 is PTC0)	0xC6
0xAB	MC9S08GT60	Set I/O pin direction, 2 Data Bytes: Port: 0-8 (Port 8 is PTC0), Direction: 1=Out, 0=In	0xC7

0xAC	MC9S08GT60	Set/Clear I/O pin, 2 Data Bytes: Port: 0-8 (Port 8 is PTC0), State: 0/1	0xC8
0xAD	MC9S08GT60	Setup A/D, 2 Data Bytes: Port: 0-6, Mode: 0=Off, 1=On	0xC9
0xAE	MC9S08GT60	Read A/D, 1 Data Byte: Channel: 0-6	0xCA
0xAF	MC9S08GT60	Read VBAT (no data)	0xCB
0xB6	MC9S08GT60	Request Board Type (DLP-RF1, RF2-Z), ROM and RFIC versions (no data)	0xCD
0xB7	MC9S08GT60	Return Board ID (not available through RF transceiver, physical connection only) (destination ID ignored) (no data)	0xCF
0xB8	MC9S08GT60	Pulse high/low with delay while high (For DLP-RF2-ZRELAY Only; additional hardware required) 2 Data Bytes: Relay Number: 1/2, State: 0/1 (RST/SET)	0xC0
0xB9	MC9S08GT60	Read Temperature and Humidity (DLP-RF2-Z only; additional hardware required) (no data) Refer to RFTTestAp source code for data processing details	0xCC
0xC0	Serial / USB	Generic Reply or "ACK" for selected non-broadcast commands	
0xC1	Serial / USB	Check-in from DLP-RF2-Z due to monitored port pin input change. 2 Data Bytes: Current I/O pin state (A6, B6:0), Bit-field with bits set for the port pins that changed state (A6, B6:0)	
0xC2	Serial / USB	Check-in from DLP-RF2-Z due to wake from sleep (no data)	
0xC3	Serial / USB	Measured energy data, 16 Data Bytes: Channel 0 – channel 15 energy levels, Refer to RFTTestAp source code for data processing details	
0xC4	Serial / USB	EEPROM read reply, 1 Data Byte: EEPROM Read data	
0xC5	Serial / USB	Write EEPROM reply (no data)	
0xC6	Serial / USB	Read I/O pin reply, 1 Data Byte: pin state	
0xC7	Serial / USB	Set direction reply (no data)	
0xC8	Serial / USB	Set/Clear I/O pin reply (no data)	
0xC9	Serial / USB	Setup A/D reply (no data)	
0xCA	Serial / USB	Read A/D reply, 2 Data Bytes: ATD1RH, ATD1RL, voltage result = $((ATD1RH \ll 8) ATD1RL) * V_{ref} / 1024$	
0xCB	Serial / USB	Read VBAT reply, 2 Data Bytes: ATD1RH, ATD1RL, Refer to RFTTestAp source code for data processing details	
0xCC	Serial / USB	Read Temperature & Humidity reply, Refer to RFTTestAp source code for data processing details	

0xCD	Serial / USB	Return board type--uC ROM and RF IC versions, 3 Data Bytes: Module Mode: 100:RF1, 101:RF2-Z, ROM Version: divide by 10 for version, RF IC Version byte	
0xCF	Serial / USB	Return ID, 2 Data Bytes: Board ID MSByte, LSByte	
0xD0	Serial / USB	Generic packet send	
0xD1	Serial / USB	Generic packet reply	

Example: Below is a simple C program illustrating the Ping (0xA0) Command. This assumes the presence of a transceiver with an ID of 1 issuing the Ping command and a second transceiver with an ID of 0x13 (19 decimal) to receive and respond to the Ping command:

```
int m_DestID = 0x0013;
int m_SourceID = 0x0001;
unsigned char rx[126], tx[126];
int pos=1; //init packet index
tx[pos++] = (unsigned char)((m_DestID&0xff00)>>8); //Destination ID MSB
tx[pos++] = (unsigned char)(m_DestID&0x00ff); //Destination ID LSB
tx[pos++] = (unsigned char)((m_SourceID&0xff00)>>8); //Source ID MSB
tx[pos++] = (unsigned char)(m_SourceID&0x00ff); //Source ID LSB
tx[pos++] = 0xA0; //Command byte: Ping
tx[0] = pos-1; //assign number of bytes in packet to position zero
PutBuffer(tx, pos); //send tx out serial port
GetBuffer(rx, 6, TIMEOUTWAIT); //wait up to timeout for 6 bytes to return
if(rx[5] != 0xC0) //if Buffer Position 5 is not the expected reply (0XC0)
{
    //No reply to the Ping command
    //either retry the command or process the error
}
```

2.4 Antenna Switch Control

The antenna switch used on the DLP-RF2-Z is of single-pole, double-throw configuration and is controlled by microcontroller port pins. The following truth table shows the port pin states required to enable the transmit and receive functions.

If using the SIPP firmware as shipped from DLP Design, the DLP-RF2-Z will set the correct mode automatically. This information is only made available in the event that the user wishes to reprogram the microcontroller with custom firmware.

	Port Pin PTA7	Port Pin PTD4
TX Mode	0	1
RX Mode	1	0

3.0 Low-Power Mode (RF2-Z Only)

At power up, if MC9S08GT60 Port Pin PTC1 (Header Pin 16) is held low, the module will check the initial state of selected port pins and immediately enter Low-Power Mode. This mode is a feature of the SIPP firmware and is only available if using the DLP-RF2-Z with its firmware as shipped from DLP Design. Total current draw for the DLP-RF2-Z module in this state is specified at less than 40 microamps at 3V. If pull-ups are enabled and a corresponding port pin is held low, then shutdown current will be higher. Also, if the user electronics draw any current from port pins in Sleep Mode, then the shutdown current will be higher. In this state, the MC13193 transceiver IC is in Hibernate Mode, and the MC9S08GT60 is in Stop Mode.

The data byte stored at EEPROM Location 8 contains a bit field that is used to select which port pins are to be watched for any change while in Low-Power or Idle Mode. For example, if a “1” is set for Bit 7 at EEPROM Location 8, and if Port Pin PTA6 is set up as a digital input, and the state of PTA6 changes (low to high, or high to low), then the MC9S08GT60 is brought out of Low-Power Mode, and a packet is sent as a broadcast packet (Source ID=0) containing Command 0xC1.

Bit Position:	D7	D6	D5	D4	D3	D2	D1	D0	EEPROM [8]
Port Pin (RF2):	A6	B6	B5	B4	B3	B2	B1	B0	
Port Pin (RF2-Z):	A6	B6	A2	A1	B3	B2	B1	B0	

The data bytes stored at EEPROM Locations 4 and 5 hold values that, when combined, are used to set the length of time that the DLP-RF2-Z will remain asleep or in Low-Power Mode. The range of time that the DLP-RF2-Z can be left asleep is from 5 seconds to 3.8 days. When this amount of time has elapsed, the MC9S08GT60 is brought out of Low-Power Mode, and a packet is sent as a broadcast packet (Destination ID=0) containing Command 0xC2.

The DLP-RF2-Z transmits a broadcast packet (Destination ID=0) for either wake from sleep or change of a selected digital input. It is the user's responsibility to establish a DLP-RF1 or DLP-RF2-Z transceiver as a system controller to receive and process this packet. (Note that multiple transceivers can be set up as system controllers as long as only one responds to a wake-from-sleep packet from a specific DLP-RF2-Z.) If the DLP-RF2-Z does not receive a reply to this packet after a preset length of time, it will return to Sleep Mode to conserve battery power. Command 0xA4 can be sent to the DLP-RF2-Z to instruct it to return to Sleep Mode immediately, or the system controller can first request data from the DLP-RF2-Z before instructing it to return to sleep.

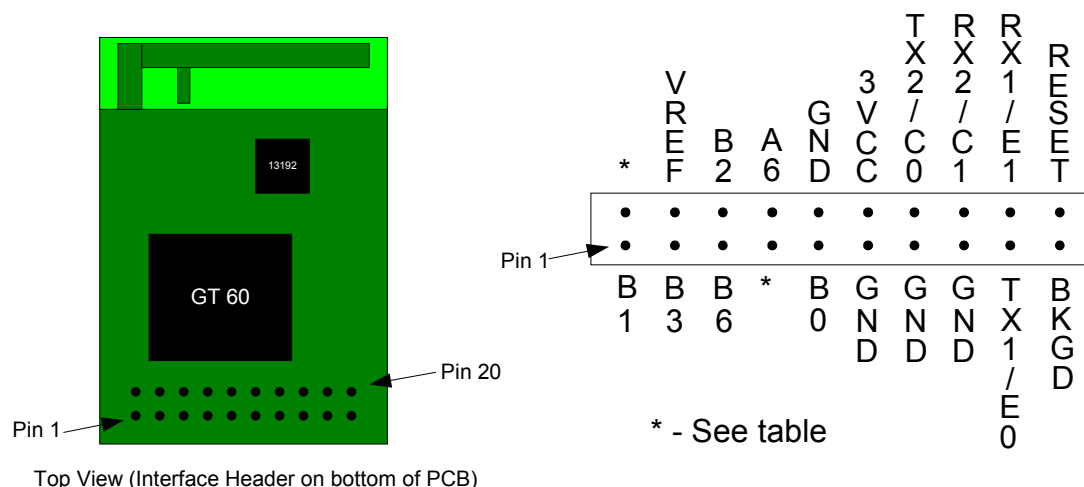
The data byte stored at EEPROM Location 6 contains a value that determines how many half-seconds a DLP-RF2-Z will remain awake waiting for a response from the system controller. If this value is set to 2 (for example), then the DLP-RF2-Z will transmit its wake-from-sleep packet, wait for 500 milliseconds for a reply, and retry one additional time before giving up and returning to sleep.

3.1 Reserved Mode

At power up, if MC9S08GT60 Port Pin PTE0 (Header Pin 17) is held low, the module will be set up for operation in a dedicated usage mode. (Products currently under development by DLP Design will utilize this mode.)

Note: Care must be taken to ensure PTE0 is not held low at power up (or reset) by user electronics.

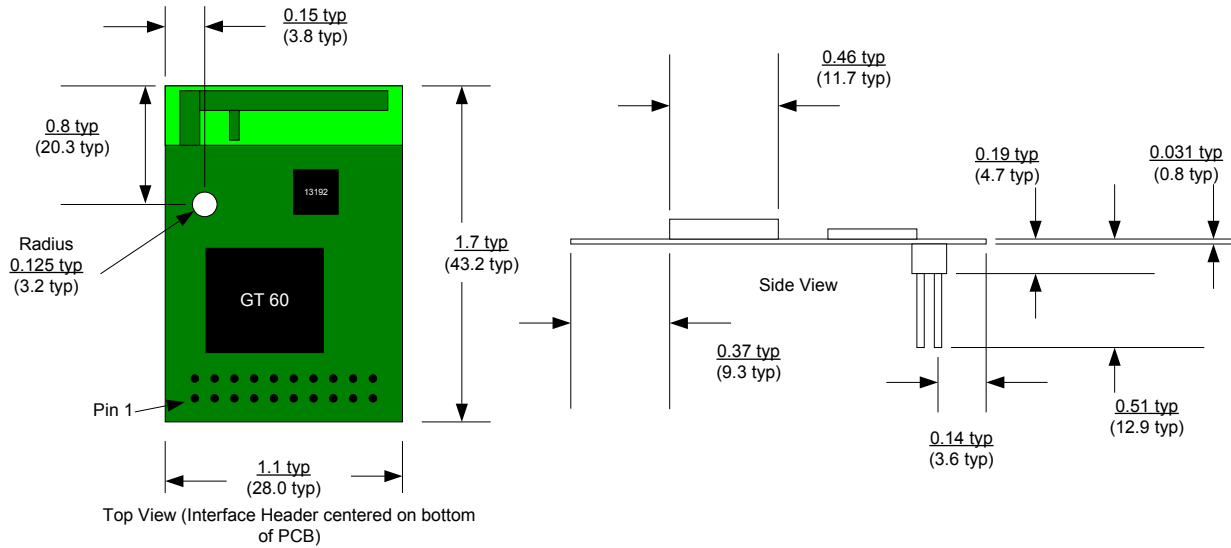
4.0 DLP-RF2 & DLP-RF2-Z User Interface



Pin #	Header Pin Description
1	PTB1 (I/O) Port Pin B1 connected to the microcontroller; A/D Channel 1
2	DLP-RF2: PTB4 (I/O) Port Pin B4; A/D Channel 4 DLP-RF2-Z: PTA1 (I/O) Port Pin A1
3	PTB3 (I/O) Port Pin B3 connected to the microcontroller; A/D Channel 3
4	Vref for A/D Converter (2.08V-VCC)
5	PTB6 (I/O) Port Pin B6 connected to the microcontroller; A/D Channel 6
6	PTB2 (I/O) Port Pin B2 connected to the microcontroller; A/D Channel 2
7	DLP-RF2: PTB5 (I/O) Port Pin B5; A/D Channel 5 DLP-RF2-Z: PTA2 (I/O) Port Pin A2
8	PTA6 (I/O) Port Pin A6 connected to the microcontroller
9	PTB0 (I/O) Port Pin B0 connected to the microcontroller. A/D Channel 0
10,11,13,15	Ground
12	Power Supply --connect external power supply: 2.0 (MIN) to 3.4 Volts (MAX)
14	PTC0 (I/O) Port Pin C0 connected to the microcontroller; Tx/D2
16	PTC1 (I/O) Port Pin C1 connected to the microcontroller; low power enable for SIPP firmware if held low at reset/power up
17	PTE0 (I/O) Port Pin E0 connected to the microcontroller; Tx/D1
18	PTE1 (I/O) Port Pin E1 connected to the microcontroller; Rx/D1
19	BKGD Background Debug
20	RESET# Microcontroller Reset Input

5.0 Mechanical Drawing

INCHES (MILLIMETERS)



6.0 Regulatory Agency Considerations

6.1 Agency Identification Numbers

Compliance with the appropriate regulatory agencies is essential in the deployment of all transceiver devices. DLP Design has obtained modular approval for this RF product such that an OEM need only meet a few basic requirements in order to utilize their end product under this approval. Corresponding agency identification numbers are listed here:

<u>Part Number</u>	<u>US/FCC</u>	<u>CAN/IC</u>
DLP RF2	SX9000RF2	5675A-000RF2

6.2 Integral Antenna

The DLP-RF2-Z is approved for use with the integral antenna only. Modifying the DLP-RF2-Z's PCB antenna or modifying the PCB to use an external antenna will void all agency compliance.

6.3 FCC/IC Requirements for Modular Approval

Any changes or modifications to the DLP-RF2-Z's printed circuit board could void the user's authority to operate the equipment.

6.3.1 Warnings

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 undesirable operation.

This device is intended for use under the following conditions:

1. The transmitter module may not be co-located with any other transmitter or antenna.
2. The module is approved using the FCC "unlicensed modular transmitter approval" method.

As long as these two conditions are met, further transmitter testing will not be required. However, the OEM integrator is still responsible for testing their end product for any additional compliance measures necessitated by the installation of this module (i.e. digital device emissions, PC peripheral requirements, etc.).

Note: In the event that these conditions cannot be met (i.e. co-location with another transmitter), then the FCC authorization is no longer valid and the corresponding FCC ID may not be used on the final product. Under these circumstances, the OEM integrator will be responsible for re-evaluating the end product (including the transmitter) and obtaining a separate FCC authorization.

6.3.2 OEM Product Labeling

The final end product must be labeled in a visible area with the following text:

"Contains TX FCC ID: SX9000RF2"

6.3.3 RF Exposure

Note: In order to comply with FCC RF exposure compliance requirements, the antenna used for this transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.

6.3.4 Additional Information for OEM Integrators

The end user should NOT be provided with any instructions on how to remove or install the DLP-RF2-Z.

7.0 Disclaimer

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This product and its documentation are supplied on an as-is basis, and no warranty as to their suitability for any particular purpose is either made or implied. DLP Design will not accept any claim for damages whatsoever arising as a result of use or failure of this product. Your statutory rights are not affected.

This product or any variant of it is not intended for use in any medical appliance, device, or system in which the failure of the product might reasonably be expected to result in personal injury.

This document provides preliminary information that may be subject to change without notice.

8.0 Contact Information

DLP Design, Inc.
1605 Roma Lane
Allen, TX 75013
Phone: 469-964-8027
Fax: 415-901-4859
Email: support@dlpdesign.com
Internet: <http://www.dlpdesign.com>

Mouser Electronics

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