MATTEL, INC.

Mattel BLE Module Use Guide

IPN: 1100153650

Bruce Cordier

Version 1.2

Contents

Mattel BLE Module Use Guide

Front View

Rear View

1. Introduction

The Mattel Bluetooth Low energy (BLE) Module is a daughterboard that can be added to Mattel end products to allow Bluetooth Low Energy (also called Bluetooth Smart) connectivity to other Bluetooth Smart or Bluetooth Smart Ready devices. This document, along with the accompanying files are meant to be used as a Quick Start Guide for developing with the module, and for manufacturing products with the module. The module is based on Texas Instruments CC2541 IC, which contains an 8051-core microprocessor, and the necessary RF circuitry to enable Bluetooth Low Energy communications.

Each Mattel BLE Module has a unique MAC Address programmed into it during module manufacture. This unique address can be used to identify unique end products, and also as part of software security schemes to control access to end products.

NOTE: The Mattel BLE Module with the existing PCB antenna, and Texas Instruments BLE software stack are (will be) approved "as is" by the Bluetooth.sig. This also includes the exact components that are on the module. Any change to any of these items (Components, component manufacturers, output antenna, BLE software stack) are considered a design change by the Bluetooth.sig, and will require full compliance testing and new product listing by the Bluetooth.sig.

2. Module Block Diagram

Contained in subdirectory: **\Module Block Diagram**

3. Module Schematic and PCB layout

Contained in subdirectory: **\Module Schematic, Altium Library**

4. Altium Library containing Schematic Footprint for module, and PCB footprint for Module

Contained in subdirectory: **\Module Schematic, Altium Library**

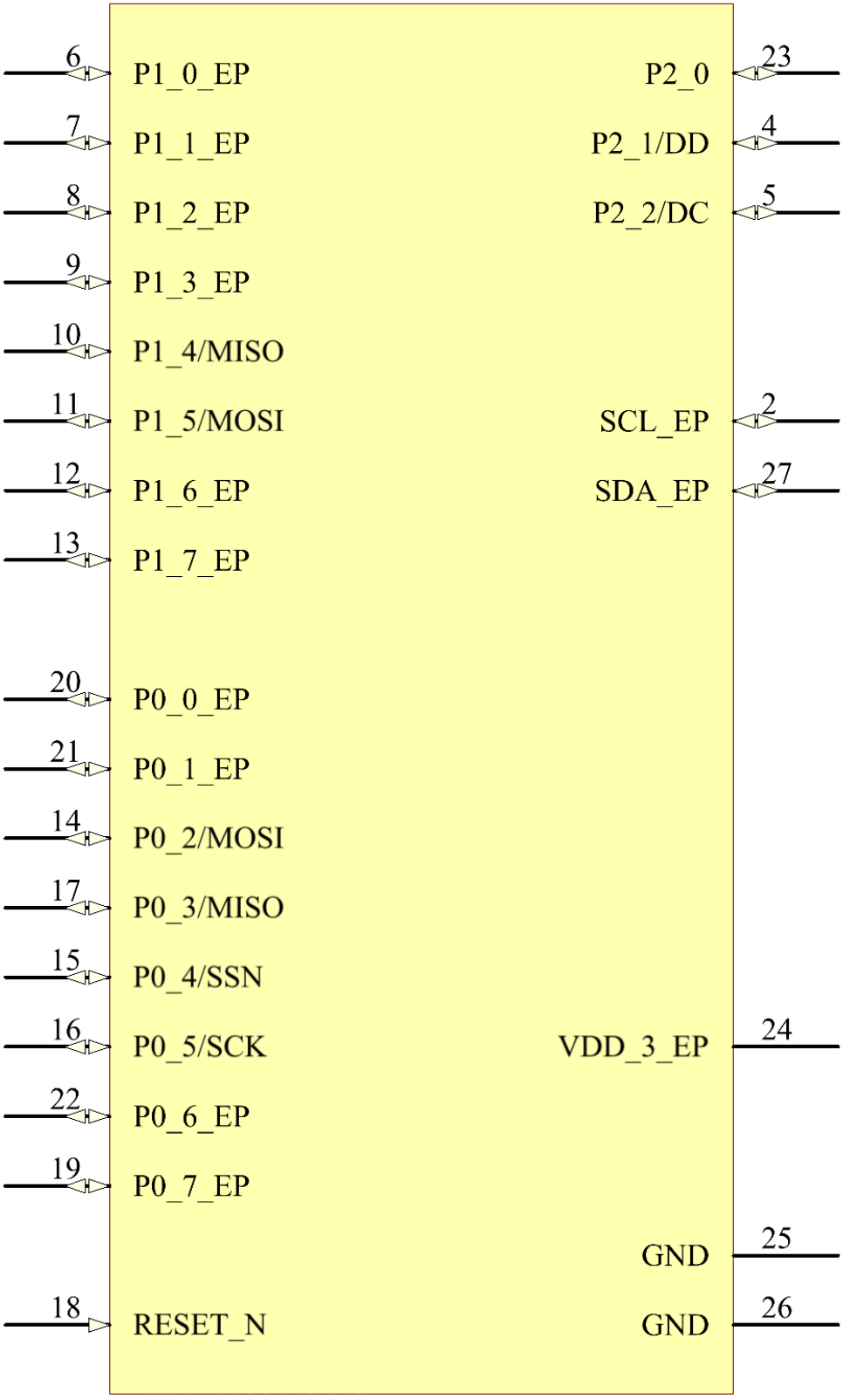
5. Datasheet and programming guides for the CC2541

Contained in subdirectory: **\Datasheets**

6. Module Pin list and pin description

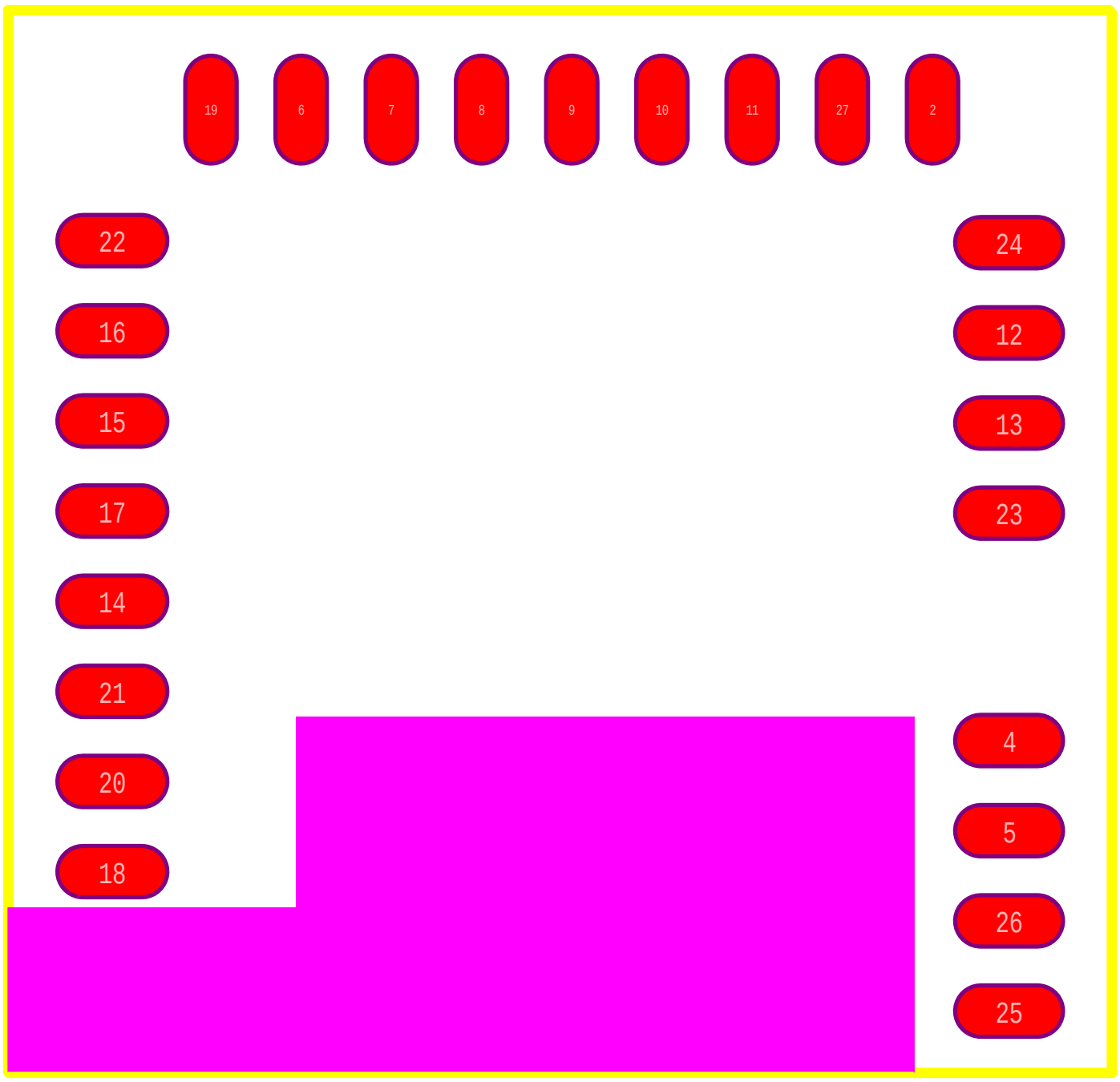
Pin	Pin Name	*Description*
6	P1_0	Digital I/O pin, Port 1, Bit 0 (20mA drive capability)
7	P1_1	Digital I/O pin, Port 1, Bit 1 (20mA drive capability)
8	P1_2	Digital I/O pin, Port 1, Bit 2
9	P1_3	Digital I/O pin, Port 1, Bit 3
10	P1_4	Digital I/O pin, Port 1, Bit 4
11	P1_5	Digital I/O pin, Port 1, Bit 5
12	P1_6	Digital I/O pin, Port 1, Bit 6
13	P1_7	Digital I/O pin, Port 1, Bit 7
20	P0_0	Digital I/O pin, Port 0, Bit 0
21	P0_1	Digital I/O pin, Port 0, Bit 1
14	P0_2	Digital I/O pin, Port 0, Bit 2
17	P0_3	Digital I/O pin, Port 0, Bit 3
15	P0_4	Digital I/O pin, Port 0, Bit 4
16	P0_5	Digital I/O pin, Port 0, Bit 5
22	P0_6	Digital I/O pin, Port 0, Bit 6
19	P0_7	Digital I/O pin, Port 0, Bit 7
18	RESET_N	
23	P2_0	Digital I/O pin, Port 2, Bit 0
4	P2_1/DD	Digital I/O pin, Port 2, Bit 1 (Also Debug data pin: **DD**)
5	P2_2/DC	Digital I/O pin, Port 2, Bit 2 (Also Debug clock pin: **DC**)
2	SCL	I2C clock pin (Also Digital I/O) ***[LEAVE FLOATING IF UNUSED]***
27	SDA	I2C data pin (Also Digital I/O) ***[LEAVE FLOATING IF UNUSED]***
24	VDD_3	Power to Module, 2.6v DC – 3.6v DC **(Nominal: 3.3v DC)**
25	GND	Ground
26	GND	Ground

7. Module Schematic Symbol

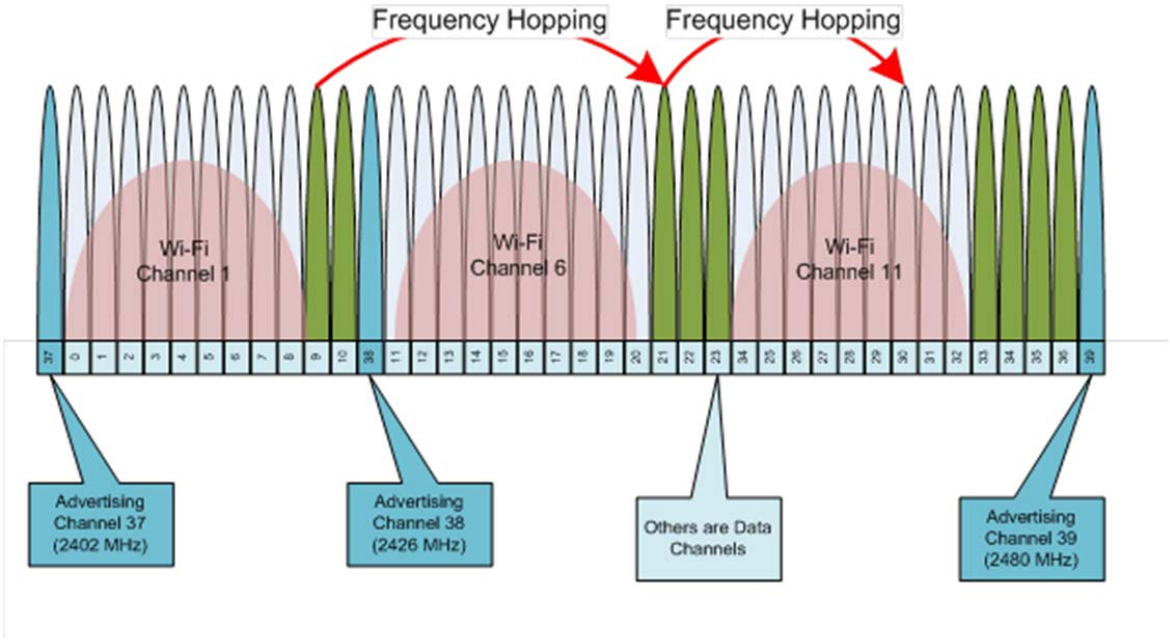


IPN: 1100153650

8. Module PCB pad Connections (Pink area shows keepout zone)



9. Bluetooth Low Energy Channels Spectrum



10. Flash Memory Size of CC2541

1) There are two FLASH memory sizes available for the CC2541 IC
    a. 128 Kbytes
    b. 256 Kbytes
2) For widest compatibility, the 256KByte ICs are on the default Mattel BLE Module
3) The 128Kbyte version of the IC is available for a savings of: ~$0.05 (US)
4) The default BLE software stack uses approximately 90 – 95 Kbytes of code space.
5) If Over The Air Updates of firmware are needed for product, the 256Kbyte module should be used, and the end product firmware should fit into 128Kbytes, allowing for 2 banks of code to be switched during firmware update.

11. Operating Conditions

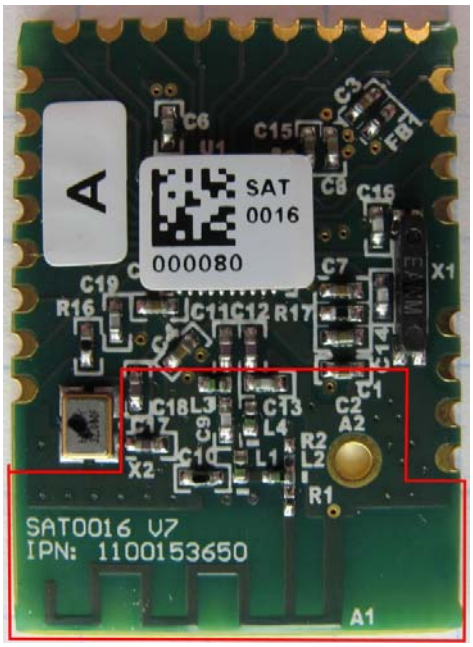
1) Power Supply connection to Module is Pin 24 (VDD_3)
2) Ground Connections to Module are Pins 25, 26
3) Power Supply Voltage Range: 2.6v DC – 3.6v DC (3.3v DC nominal)
4) Maximum Current draw (No peripherals connected to module IO pins): 25 mA @ 3.3v DC
5) Operating Temperature (Minimum): -17 ^{o}C
6) Operating Temperature (Maximum): +45 ^{o}C
7) For further details, refer to CC2541 datasheet

12. Bluetooth Protocols and Profiles Supported by Module

1) Bluetooth Protocols supported by Module:
    a. RFPHY
    b. LL
    c. 4.0 HCI
    d. L2CAP
    e. GAP
    f. ATT
    g. GATT
    h. SM
2) Bluetooth Profiles supported by Module:
    a. ANP
    b. BAS
    c. BLP
    d. BLS
    e. CSCP
    f. CSCS
    g. DIS
    h. FMP
    i. HIDS
    j. HOGP
    k. HRP
    l. HRS
    m. HTP
    n. HTS
    o. IAS
    p. LLS
    q. PASP
    r. PXP
    s. RSCP
    t. RSCS
    u. SCPP
    v. SCPS
    w. TIP
    x. TPS

13. Designing End Products for use with Module Trace Antenna

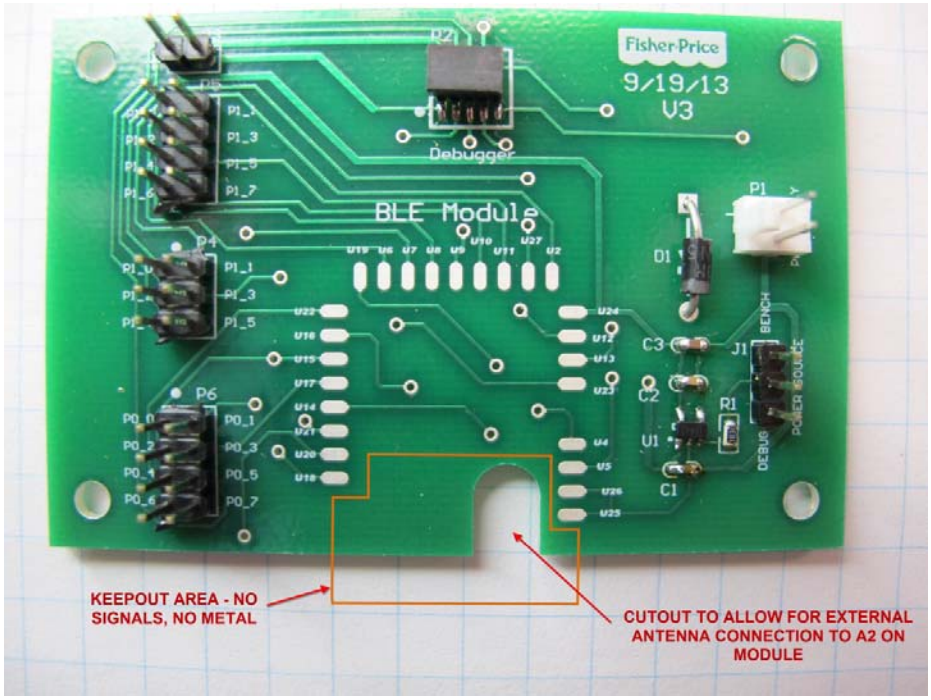
1) Antenna Keepout:
    a. In order to ensure proper operation of the PCB trace antenna that is on the BLE module (Labeled as A1 on the Top layer silkscreen), any metal on nearby PCBs or inside the end product should be kept as far away as possible from the Antenna area. This area is shown by the Red outlines in the pictures below.
    b. For example, if the BLE module is to be directly soldered to another PCB, the second PCB should not have any traces, Power/Ground planes, or any metal under or above this area.



Front View

Rear View

c. Below is a picture of the Breakout PCB (Experimenter's board) that can be used with the Module. Please note how it was designed to have no traces or metal in the keepout area near the Module antenna.



2) Other rules to follow to allow for best operation of the BLE module

a. Avoid locating the module near battery compartments or batteries. The electrical mass of batteries can have a large detrimental effect on antenna performance.

b. Avoid locating the module near electrically noisy components:
    i. Motors
    ii. High speed microprocessors
    iii. Crystals
    iv. Any components/circuits that create high frequency electrical noise

3) The trace antenna on the module is designed to be as omnidirectional as possible, meaning that it can be mounted in end products in different orientations (horizontal, vertical) and still work well.

14. External Antenna Connection

PLEASE NOTE: Use of any antenna other than the trace antenna on the module will require full regulatory compliance testing of the end product with the new antenna design. (I.e. Bluetooth.SIG, FCC, IC, etc.)

1) If a product design or use requires the use of an external antenna, this can be easily accomplished with the BLE module. Use the following steps:
    a. Remove 0 Ohm resistor at R1
    b. Place 0 Ohm resistor at R2

c. Connect external antenna at A2

15. Smart Device Compatibility

1) The Mattel BLE Module communicates via single mode Bluetooth Smart (Bluetooth Low Energy) protocol. For a Smart Device (iOS Device, Android Device) to communicate with the Module, it must meet the following requirements:

Device Type	Minimum Operating System Version	Minimum Hardware Required
iOS Phone	iOS Version 5	iphone 4S (or newer)
iOS Tablet	iOS Version 5	ipad 3 (or newer)
ipod Touch	iOS Version 6	ipod Touch 5 (or newer)
Android phone or tablet	Android Version 4.3	Varies *(must test for compatibility)*

16. Software

1) Starter Module Firmware (Module IO Test)
    a. We have created a firmware load for the module that contains the Texas Instruments BLE Stack software, as well as some simple operating code that:
        i. Allows the Module to connect to another BLE device.
            1. Upon powerup, the Module tries to connect to the smart device test app for 30 seconds.
            2. If after 30 seconds, no connection is made, it stops the attempt. At that point, power will have to be removed and re-applied to the module to attempt connection.
        ii. Reports RSSI value to the connected device
        iii. Toggles all the Module IO pins High or Low with a Toggle command from the Connected BLE device

1. IO pins adjacent to each other will toggle HIGH/LOW reverse of each other, each time the Toggle command is issued. (i.e. P0.0, P0.2, P0.4, P0.6 output will go HIGH at the same time P0.1, P0.3, P0.5, P0.7 will go LOW) This is done so that the user can easily tell if two adjacent pins are shorted.

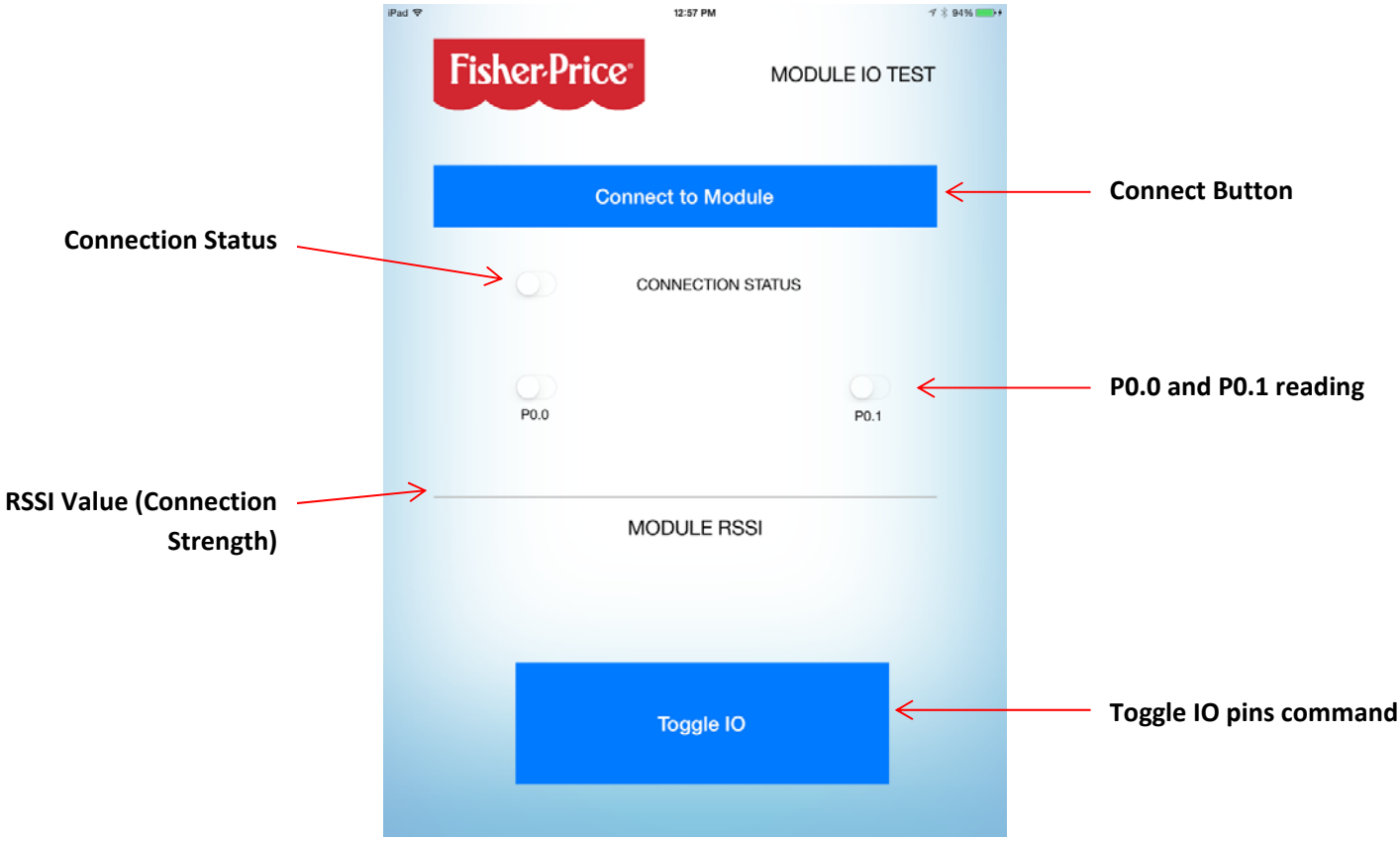
b. HEX file and Source Code

Contained in subdirectory**: \Module Test, Module Firmware**

2) Starter iOS App

a. To Connect to the Module IO Test Firmware on the BLE Module, we have created a simple iOS App called ModuleTest. The app contains:

i. Button for Connecting to BLE Module
ii. Connection Status Indicator
iii. P0.0 and P0.1 readback indicators
iv. Bar Graph representing RSSI of connection
v. Toggle IO Pins Button



b. iOS App Installation

i. Due to Apple itunes store requirements, we can not widely distribute the IPA installation file for the iOS app. Instead, the app installation is handled through a distribution system called Testflight.
ii. For access to the ModuleTest app, please contact the Fisher-Price Advanced Technology Research team.

c. Source Code

i. The iOS version of the ModuleTest app is a native Xcode program.
ii. For access to the source code for the ModuleTest app, please contact the Fisher-Price Advanced Technology Research team.

3) Software Development
    a. **Please Note: The BLE Module is approved by the Bluetooth.SIG organization with the following limitations:**
        i. **The Texas Instruments BLE Stack software is included in the firmware build, and is not modified in any way.**
        ii. **No electronic hardware modifications are made to the module.**
        iii. **If either of these items is modified, the module and it's end product will have to be re-tested, and re-listed with the Bluetooth.SIG as a new product.**
    b. Potentially any software developer can be used to create a firmware load for the BLE module, given that they adhere to the restrictions listed above.

17. Using Module Test Firmware on Module and ModuleTest App on an iOS Device

1) Program Module IO Test firmware onto BLE Module.
2) iOS Device must meet minimum hardware and software requirements for BLE as shown in Compatibility table in this document.
3) Install ModuleTest app on iOS Device
4) Ensure that Bluetooth is enabled on iOS Device
5) Start ModuleTest app on iOS Device.
6) Apply Power to the BLE Module (Module firmware will attempt to connect to app for next 30 seconds)
7) Press the "Connect to Module" button in the test app. At this time, a progress indicator above the connect button will start animating during the connection attempt.
8) After a few seconds, if the connection is successful, the following should happen in the app:
    a. The Connection Status indication in the app should turn blue
    b. The "Connect to Module" button label should change to "Disconnect" (Pressing the button at this time will disconnect the module from the app)
    c. The RSSI graph should fill relative to the connection signal strength
9) If the connection attempt is not successful (the progress indicator stops, and the Connection Status indicator stays gray), you may press the connect button again to attempt to connect.
10) Once a connection is established Pressing the "Toggle IO" button in the app will send a command to the BLE module to toggle the output state of all of its IO pins This can be verified in 2 ways:
    a. Connect an oscilloscope or voltmeter to any of the module IO pins. When the Toggle command is sent, the measured pin should change state (High to low, or low to high)
    b. The P0.0 and P0.1 indicators in the app read back the actual values of those IO pins as reported by the CC2541. (They are a live indicator of the output values of those 2 hardware pins).

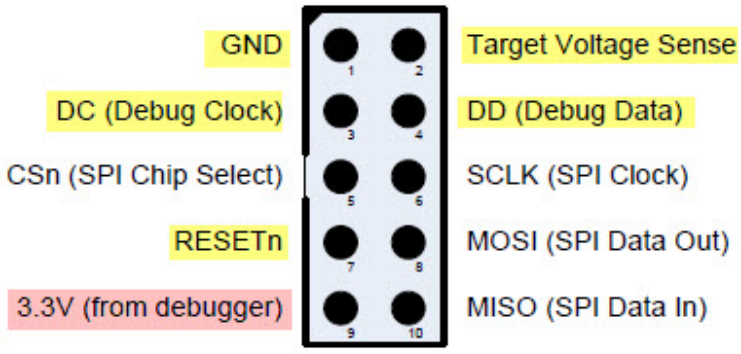
18. Programming the Mattel BLE Module

1) Development Programming Tools
    a. Texas Instruments CC Debugger Programmer
        i. The CC Debugger is shown here:
            http://www.ti.com/tool/cc-debugger
        ii. Please reference the CC Debugger User's Guide found here:
            http://www.ti.com/lit/pdf/swru197
    b. Texas Instruments SmartRF Flash Programmer PC program

2) How to program
    a. When Using the Breakout PCB (Please refer to diagram in "Breakout PCB" section of this document)
        i. Set jumper J1 on Breakout PCB to "DEBUG", so that module will be powered from CC Debugger
        ii. Connect CC Debugger to programming header P2
        iii. Start SmartRF flash programming software on PC
        iv. Press RESET button on CC Debugger

v. Status LED on CC Debugger should turn green. (If LED is RED, there is either a connection problem with the programmer, or possibly a software driver error for the programmer)
vi. Load HEX file into programmer software
vii. Program firmware onto device
viii. Disconnect CC debugger connector
ix. Set Jumper J1 on Breakout PCB to "BENCH" to power module and connected circuits through connector P1

b. When not using the Breakout PCB
   i. If not using the Breakout PCB for connections to the module, the following diagram lists the connections needed to connect to the CC debugger for programming.
   ii. The minimum signal setup for programming with the CC debugger is highlighted in yellow. The picture is taken from the CC Debugger User's Guide (SWRU197).



   iii. **NOTE**: If using the CC Debugger to power the target, the red signal is also needed.
   iv. **NOTE 2**: Pin 2, Target Voltage Sense: This is an input to the CC Debugger's level shifters. The CC debugger uses this sense to verify that the target and the CC debugger are operating at the same voltage levels. It should reflect the target VDD (often the same as pin 9 if powering the target from the CC Debugger).
   v. **NOTE 3**: When creating the target circuit design, ensure that there is no power supply conflict with the CC debugger and BLE module power supply. (For example, on the Breakout PCB design there is a Power supply jumper for the BLE module, 1 position of the jumper disconnects the main circuit power from the BLE module, and only power the module through the CC debugger connector for programming. The other jumper position disconnects the Debugger connector power pin from the Module, and powers the module only through the Main circuit.)
   vi. Once the electrical connections are made, follow the same software programming procedures as shown in the previous section.

19. Development Tools

1) Software IDE and Compiler: IAR Embedded Workbench for Texas Instruments 8051 (Keil also supplies compile software for the CC2541)
   a. Contact Texas Instruments or IAR Systems (www.iar.com) for support on how to purchase these tools.

20. Using the CC2541 SPI interface

1) The CC2541 IC on the BLE Module can communicate to other IC's (Toy processors) via SPI interface
2) The CC2541 can act as either the Master of the slave device in an SPI connection.
3) An example of how to connect to another microcontroller via SPI is included in the documentation
   Contained in subdirectory**: \SPI Connection Information**

21. Module Manufacturer

1) MAC Address Programming and Module Testing Procedures:
   Contained in subdirectory**: \Module Manufacture**
2) After component assembly onto the BLE module, the Module manufacturer next:
   a. Programs unique MAC addresses onto each BLE Module
   b. Programs ModuleTest firmware onto Module
   c. Tests Module
3) MAC Address Programming - Every Mattel BLE Module has a unique MAC Address programmed into it during module manufacture.
   a. The list of available and used MAC addresses for the BLE Modules (and other MAC addresses products) is maintained by Mattel/Fisher-Price Engineering.
      i. For a set of MAC addresses to be used during the manufacture of the BLE modules, please contact the Fisher-Price Advanced Technology Research team.
   b. Please refer to the MAC Address programming section of the SOP document in the Module Manufacture directory.
4) Automated Testing (module manufacture)
   a. Please refer to the testing section of the SOP document in the Module Manufacture directory.
5) ModuleTest App Testing
   a. Sample testing of connection
      i. During production, lot testing (1 out of every 100 modules) should be tested to verify its ability to connect with the ModuleTest app, to verify proper operation of the Module.
      ii. To perform this test, please follow the procedure detailed elsewhere in this document, in the section titled: "Using Module Test Firmware on Module and ModuleTest App on an iOS Device"
   b. Supply current check
      i. During the ModuleTest testing, the supply current of the BLE Module should be monitored during the test.
         1. If the maximum supply current draw of the module is < 30 mA during the Moduletest test, the Module current draw is considered good.
         2. If maximum supply current draw is > 30 mA, this is considered a fail, and the module should undergo diagnosis to determine why the current draw is above the limit.

22. Manufacturing products with the Mattel BLE Module

1) Overall Process Description:

   Contained in subdirectory: **\BLE End Product Overall Electronics and Testing Process**

2) Programming
   a. Programming procedures for the BLE Module in final end products are to be defined by the Project's Development Electrical Engineer
3) Testing procedures/requirements,
   a. Testing environment
      i. No cell phones, radios, wifi, within a range of 10m of device under test
      ii. Screen room is not required for testing
      iii. ipad 4th generation (or newer), iOS 5.1 (or higher)
   b. Testing of BLE Module in End Product
      i. Testing procedures for the BLE Module in final end products are to be defined by the Project's Development Electrical Engineer
      ii. Example testing plan for BLE Module in End Product (The first planned end product for the BLE Module is a Fisher-Price Swing platform. Please find below the example test plan for the BLE Module inside the swing end product)
         1. Use a single iOS device with custom Test app that can talk to multiple end units (swings) at once
         2. Tester places Swing into Test Mode
         3. Test App will broadcast a value to all BLE devices
         4. The swing will receive the broadcast values and display on front panel LEDs (BLE module in swing will receive data, pass over SPI connection to W567 IC in swing, W567 controls front panel LEDs) [This confirms that both the BLE connection, and the SPI connection between IC's are properly transferring data.]
         5. Tester will verify LEDs are expected pattern.
         6. W567 in Swing will generate data payload to BLE module, module will send payload back to iOS app (Possibly echo, or new data, TBD)
         7. As part of return data, BLE module will send unique MAC address of Module as part of payload. The test app can use this to uniquely identify test results.
         8. RSSI Limits (Tester will read RSSI value reported in test app. If value is in range of defined range, RSSI is good)
            a. Distance? TBD (This value will be determined with early test samples at manufacture)
            b. Orientation? TBD (This value will be determined with early test samples at manufacture)
            c. Acceptable Range of RSSI values? TBD (This value will be determined with early test samples at manufacture)

23. BT SIG qualification information

1) **Please Note: The BLE Module is approved by the Bluetooth.SIG organization with the following limitations:**

   a. **The Texas Instruments BLE Stack software is included in the firmware build, and is not modified in any way.**
   b. **No electronic hardware modifications are made to the module.**
   c. **If either of these items is modified, the module and it's end product will have to be re-tested, and re-listed with the Bluetooth.SIG as a new product.**
2) Where to find listing
   a. After regulatory testing is completed, and the first end product using the BLE Module is listed with Bluetooth.sig, this section will be updated with the listing information.
3) Intentional radiator testing
   a. After regulatory testing is completed for the first end product using the BLE.sig, this section will be updated with the test information.

24. FCC, Industry Canada, Bluetooth.SIG Test Reports

Contained in subdirectory**: \Test Reports (FCC, Industry Canada, Bluetooth_SIG)**

25. BQE information (for further RF testing)

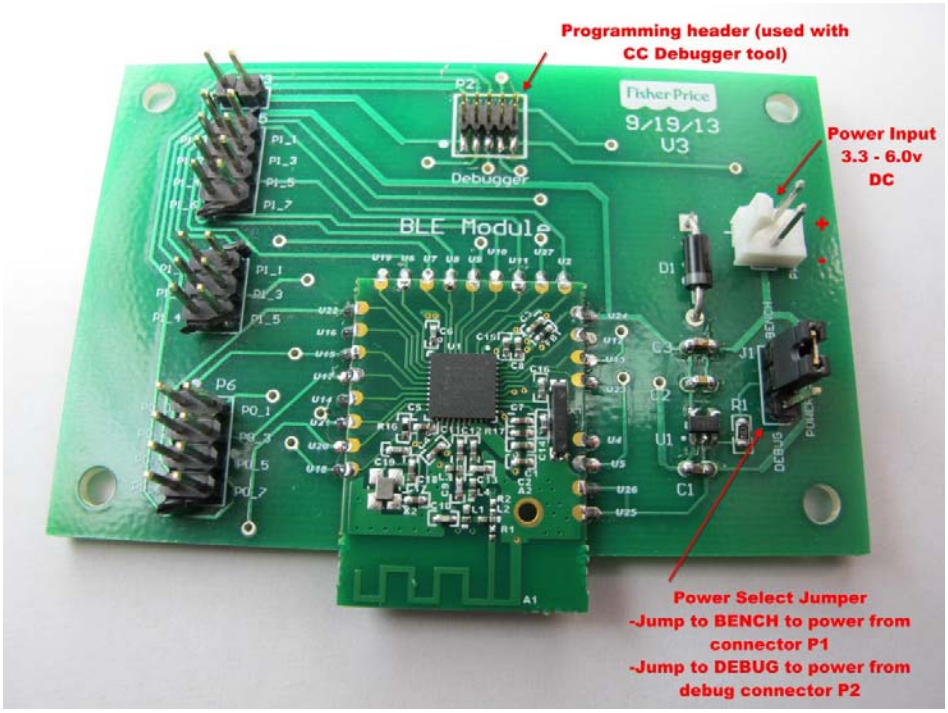
1) All testing and certification for the module was conducted through a Bluetooth Qualification Expert: Jean Chin, Global Certification.
   a. Her email address: jeanchin@globcert.com

26. Texas Instruments Engineering Support

1) To obtain Engineering support from Texas Instruments, please contact: Chris Yorkey, Texas Instruments Application Engineer.
   a. His email address: chris.yorkey@ti.com

27. Breakout PCB (Experimenter's Board)

1) To aid in development with the Mattel BLE Module, we have created a Breakout PCB to allow easy connections to the IO pins on the module. The breakout PCB contains:
    a. Power Input connector P1 (to allow module and connected circuit to be powered with an external power supply)
    b. Voltage regulator circuit (Regulates voltage input on P1 to +3.3v DC to power module and external circuits)
    c. Debug header (to allow programming of Module with CC Debugger)
    d. Headers P3, P4, P5, P6 (to allow access to regulated power and module IO pins for connection to external circuits)
    e. Solder connections for Module (allows Module to be soldered to Breakout PCB)
2) Schematic and PCB
    a. Contained in subdirectory**: \Breakout board Schematic, PCB**



28. FCC/Industry Canada Statement (to be placed on End Products)

Federal Communications Commission (FCC) Statement

You are cautioned that changes or modifications not expressly approved by the part responsible for compliance could void the user's authority to operate the equipment.

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 into 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.

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 of the device.

FCC RF Radiation Exposure Statement:

This equipment complies with FCC radiation exposure limits set forth for an uncontrolled environment. End users must follow the specific operating instructions for satisfying RF exposure compliance. This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.

Industry Canada (IC) Statement

This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Canada, avis d'Industry Canada (IC)

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes:

(1) l'appareil ne doit pas produire de brouillage, et
(2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Notice to OEM integrator

The OEM integrator has to be aware not to provide information to the end user regarding how to install or remove this RF module in the user's manual of the end product which integrates this module.

The end user manual shall include all required regulatory information/warning as show in this manual.

The OEM integrator is responsible for testing their end-product for any additional compliance requirements required with this module installed.

L'intégrateur OEM doit être conscient de ne pas fournir des informations à l'utilisateur final quant à la façon d'installer ou de supprimer ce module RF dans le manuel de l'utilisateur du produit final qui intègre ce module.

Le manuel de l'utilisateur final doit inclure toutes les informations réglementaires requises et avertissements comme indiqué dans ce manuel.

Note: The end product shall haves the words "Contains Transmitter Module FCC ID: CCT-CBV76-14, IC: 4390A-CBV76"

29. Revisions

1) Version 1.1
    a. Updated minimum and maximum operating voltages and minimum and maximum operating temperatures in section “Operating Conditions”

2) Version 1.2
    a. Added FCC/IC Warning statement in section: “FCC/Industry Canada Statement (to be placed on End Products)”
    b. Added link to End Product manufacturing and testing process document in Section: “Manufacturing products with the Mattel BLE Module”
    c. Added link to Module Block Diagram in Section: “Module Block Diagram”
    d. Added link to FCC, IC, Bluetooth.SIG Test reports in Section: “FCC, Industry Canada, Bluetooth.SIG Test Reports”
    e. Added notes for Flash memory sizes and Over The Air Firmware Updates in section: “Flash Memory Size of CC2541”