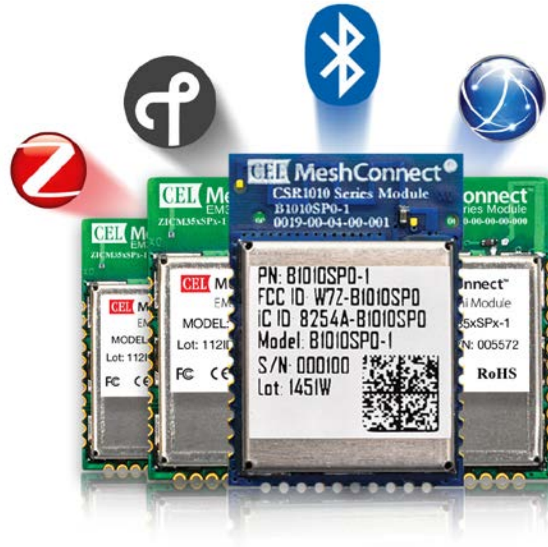
CEL MeshConnect™

Application Note

0011-00-16-09-000
Mini Module Hardware Design Guidelines

Document No:
0011-00-16-09-000 (Issue D)



INTRODUCTION

This application note provides module placement, schematic design examples and layout guidelines for the MeshConnect™ Mini Modules from California Eastern Laboratories (CEL). Mini Module design choices are presented along with example block diagrams and schematics demonstrating ZigBee, Thread, Bluetooth Smart, and MeshWorks implementations. Layout guidelines are also presented along with design guidelines checklists to aid developers wanting to quickly integrate the ZICM35xSPx and B1010SPx family into their product designs.

TABLE OF CONTENTS

MINI MODULE DESIGN OPTIONS – ZIGBEE, THREAD, BLUETOOTH, AND MESHWORKS

ZigBee/Thread

There are two main system configurations for CEL's ZICM35xSPx Mini Modules: System-on-Chip (SoC) and Network Co-Processor (NCP) mode. SoC mode, which uses the onboard processor in the EM35x to run the product application software, is recommended for simpler designs where specialized microprocessor functionality not included in the EM35x (e.g. a display driver) is not required. NCP mode is recommended for designers who are using an additional microprocessor as the host.

For ZigBee, there are two versions of the EmberZNet Serial Protocol (EZSP) used for NCP mode: (1) EZSP-SPI and (2) EZSP-UART. This refers to the hardware interface being either SPI or UART. Examples for both are provided.

For Thread, the Thread Management Serial Protocol (TMSP) is used for NCP mode. TMSP is currently supported as UART only.

For a detailed comparison of design approaches, please see *UG103.3 Application Development Fundamentals: Design Choices* from Silicon Labs.

Bluetooth Smart

It is possible to design either a standalone Bluetooth Smart design, or one which is drop-in compatible with ZigBee, Thread and MeshWorks.

MeshWorks

MeshWorks hardware designs are very similar to the MeshConnect USB SoC designs but do not require ISA3 debuggers or connectors, since they can be reconfigured using the MeshWorks GUI. MeshWorks currently supports only I2C on SC1 as its communication bus.

Drop-in Compatibility between ZigBee, Thread, Bluetooth, and MeshWorks

It is possible to develop one hardware design that is drop-in compatible between all the Mini Module product offerings, although care must be taking to follow our schematic examples in order to ensure compatibility.

Table 1 shows the available Mini Module families and the various wireless options supported: ZigBee PRO (SoC and NCP), Thread (Soc and TMSP), Bluetooth Smart, and MeshWorks. For up-to-date product information, we recommend visiting the CEL website.

Mesh Connect Mini Module	ZigBee PRO		Thread		Bluetooth Smart	MeshWorks
	SOC (Module µC)	NCP (Host µC)	SOC (Module µC)	TMSP (Host µC)		
ZICM357SPx	Yes	Yes	No	No	No	No
ZICM358xSPx	Yes	Yes	Yes	Yes	No	No
ZICM358xSPx - MW	No	No	TBD	No	No	Yes
ZICM357SPx - MW	No	No	No	No	No	Yes
B1010SPx	N/A	N/A	N/A	N/A	Yes	N/A

Table 1. Various wireless options supported for the Mini Module family.

Mini Module Software Development

- Software development and programming using the Ember Stack (for all ZICM35xSPx modules) requires the purchase of an EM35x-DEV(-IAR) kit and registration/approval from Silicon Labs.
- Software development for Bluetooth Smart requires purchasing a CEL MeshConnect µEnergy Starter Development Kit and product registration/approval with CSR.
- Software development for MeshWorks requires the purchase of a MeshWorks Development Kit and registration/approval on the CEL website.

MINI MODULE SCHEMATIC EXAMPLES

ZICM35xSPx UART (SoC), EZSP-UART (NCP), or Thread-UART (SoC or TMSP)

The ZICM357SPx modules contains two Serial Controller (SC) interfaces:

1. SC1 (EM35x GPIOs PB1, PB2, PB3 and PB4) can be used as a UART, SPI or TWI (aka I2C) bus.
2. SC2 (EM35x GPIOs PA1, PA2, PA3 and PA4) can be used as a SPI or TWI bus.

The ZICM358xSPx module contains two Serial Controller (SC) interfaces in additon to USB on SC2.

The following block diagram shows the ZICM35xSPx module with SC1 serial controller used as a UART. SC2 is being used for serial flash which is required for over-the-air updates using the ZICM357SPx product family. NCP can use the flash memory on the host microprocessor for storing over-the-air updates so serial flash is not required. Thread requires an EM358xSPx module. For ZigBee PRO EZSP-UART (NCP) and Thread-UART (TMSP), nRESET control is recommended from the host microprocessor.

For additional pin options and compatibility, please see the corresponding EM35x datasheet from Silicon Labs along with the module datasheet provided by CEL.

Radio hold off is provided as a special function pin when other radios are co-located with a CEL module and a customer would like to use CEL's FCC module certification. See *ZICM35xSPx Software Design Guidelines* ("Choosing to Use Co-located Transmitters" section) for more details.

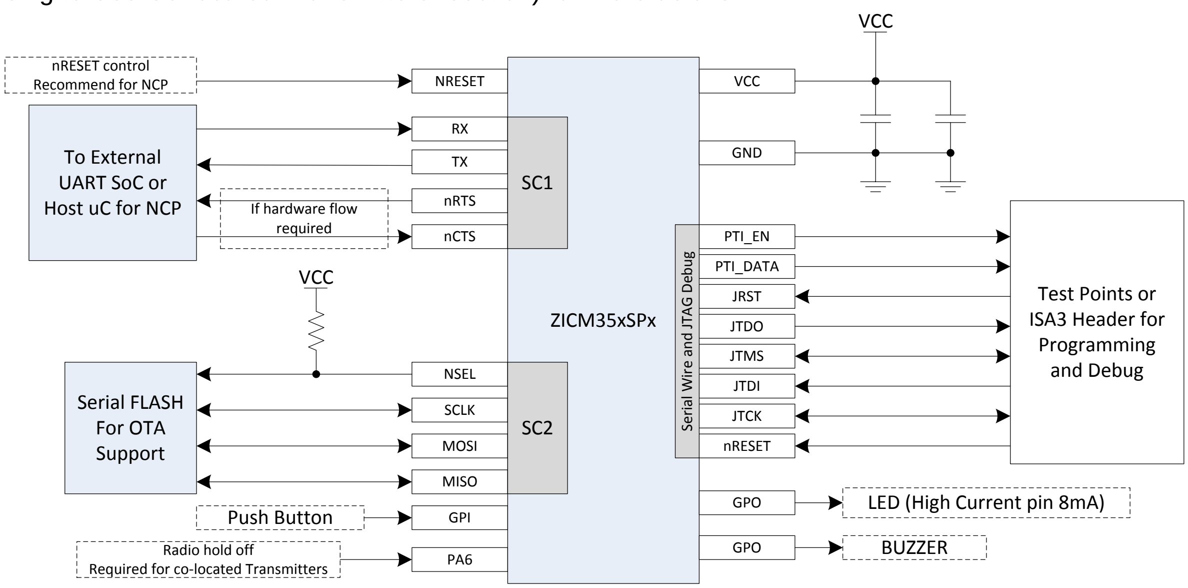


Figure 1. ZICM35xSPx configured with UART block diagram

Figure 1 shows an example block diagram with the ZICM35xSPx configured for UART communication. This is the most common configuration that customers currently use for ZigBee and Thread designs. Hardware flow control is optional but is available for NCP designs. RTS/CTS hardware flow control uses two signals (nRTS and nCTS) in addition to received and transmitted data (RX and TX). Flow control is used by a data receiver to prevent buffer overflow by signaling an external device when it is and is not allowed to transmit. Hardware flow control is available in NCP mode only. PA6 is a special purpose pin to allow co-located transmitters to operate with the CEL module certification. The ISA3 is used for serial wire and JTAG debug and programming. A push button is usually recommended for provisioning along with some form of feedback (either a buzzer or LED).

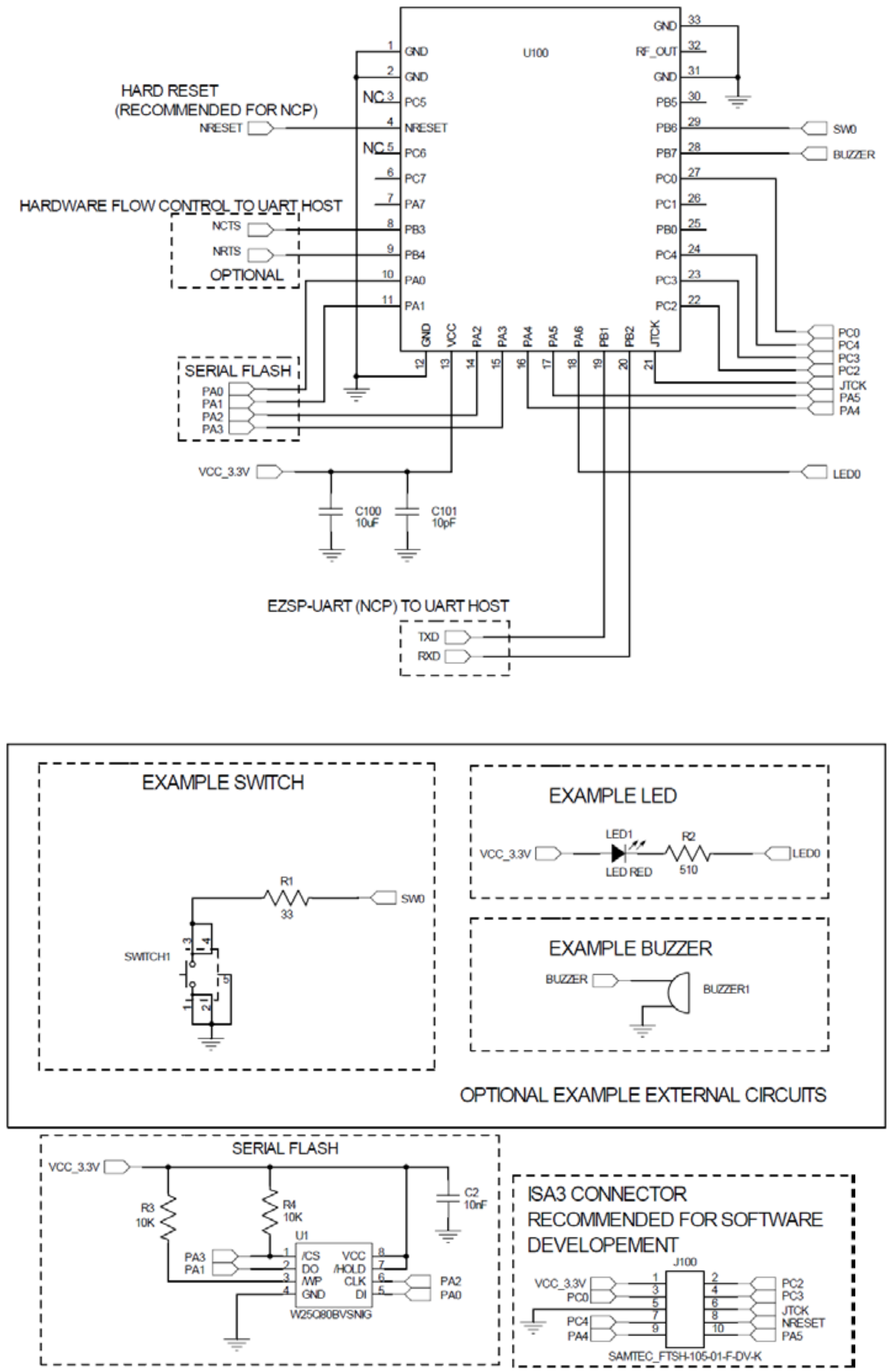


Figure 2. ZICM35xSPx configured with UART and FLASH schematic example

The schematic in Figure 2 shows the ZICM35xSPx configured as ZICM35xSPx UART (SoC), EZSP-UART (NCP), or Thread-UART (SoC or TMSP).

ZICM35xSPx SOC with SPI or I2C, MeshWorks

The following block diagram shows SPI or TWI connections on SC1 and SC2. SC2 is being used for serial flash which is required for over-the-air updates using the EM357SPx product family.

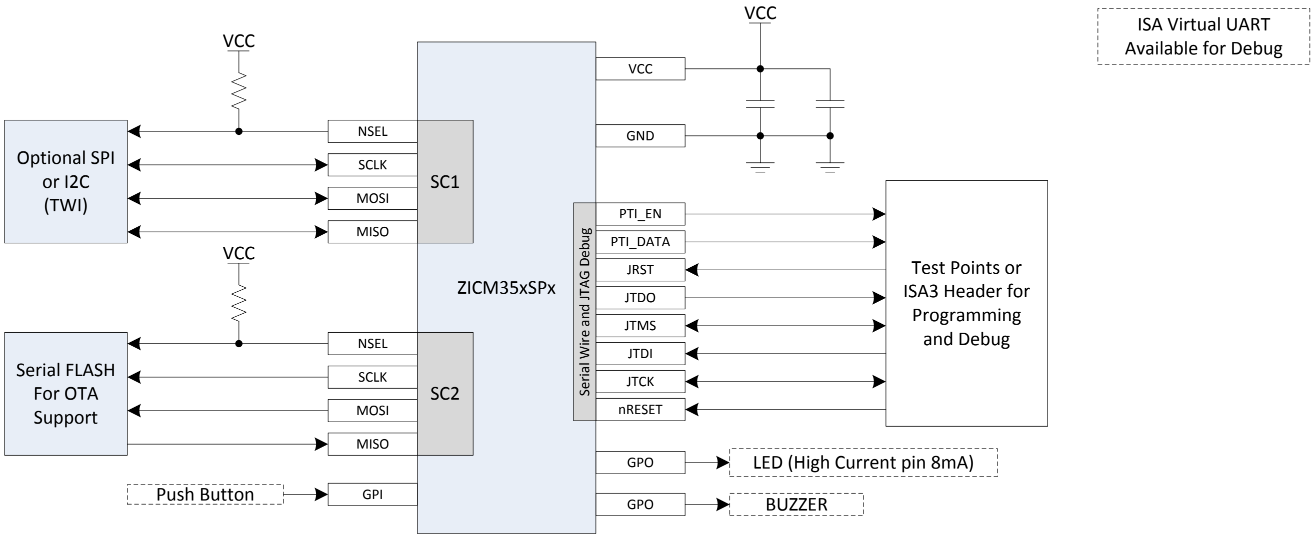


Figure 3. ZICM35xSPx configured with SPI or I2C block diagram

Figure 3 shows an example block diagram with the ZICM35xSPx configured for SPI or I2C communications. External flash memory is connected to SC2. This design example is also suitable for MeshWorks module designs.

Note: In modules running MeshWorks, SC1 currently only supports I2C.

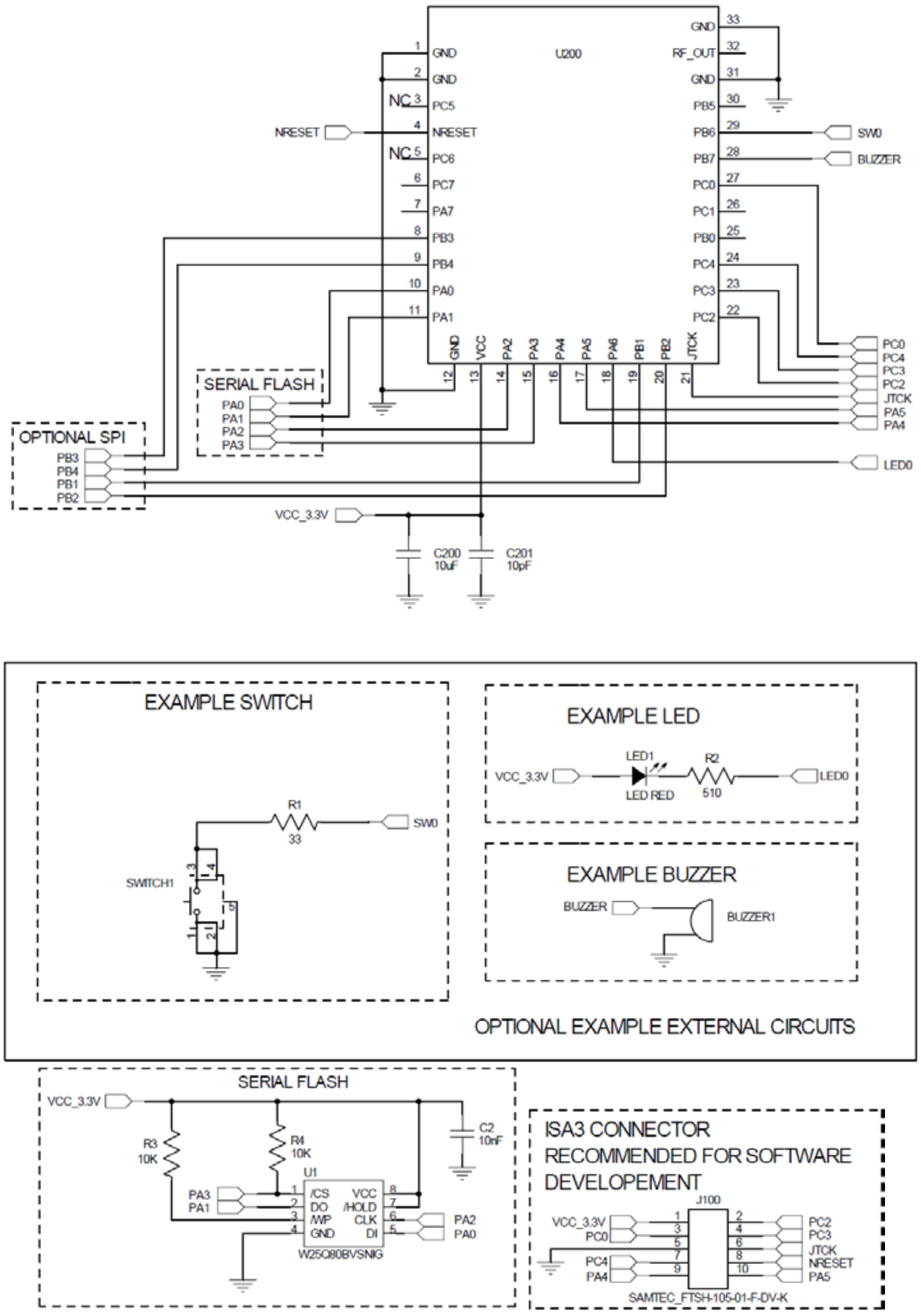


Figure 4. ZICM35xSPx configured with SPI or I2C schematic example

Figure 4 shows an example of the ZICM357SPx configured to communicate with SPI flash and an optional SPI and I2C port.

ZICM35xSPx NCP EZSP-UART

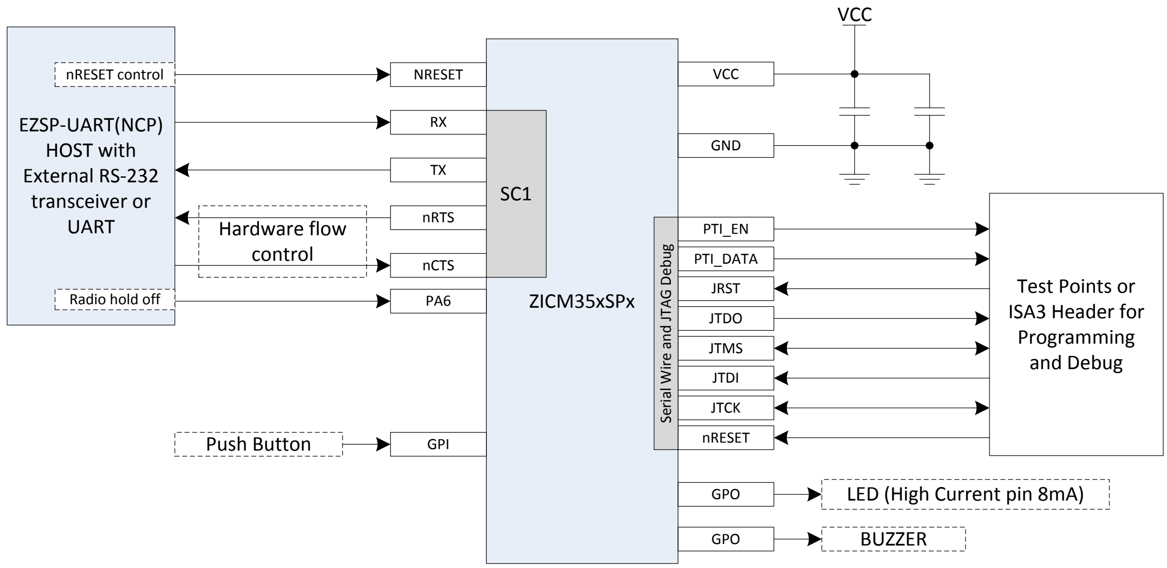


Figure 5. ZICM35xSPx configured for NCP (EZSP-UART) block diagram

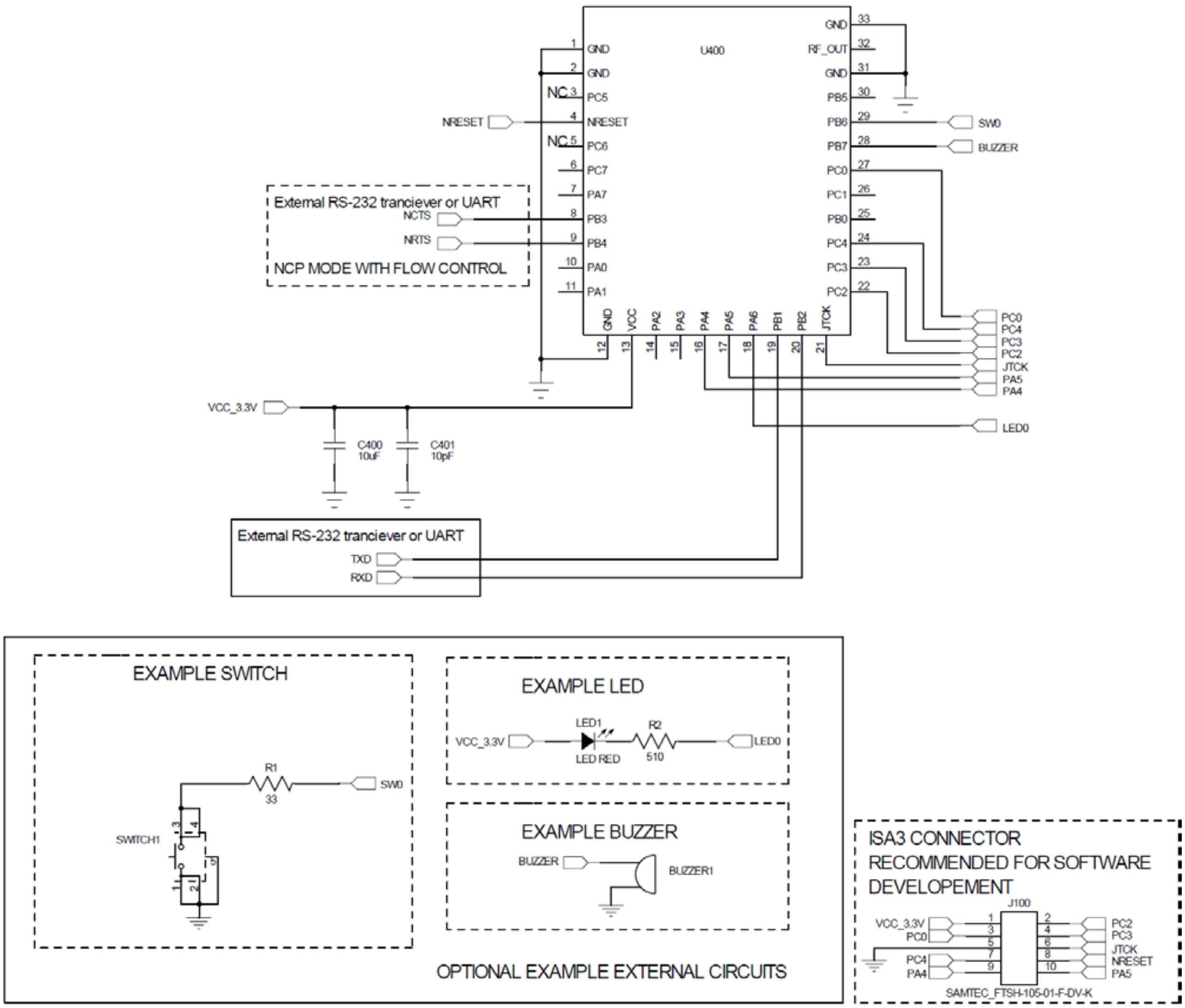


Figure 6. ZICM35xSPx configured for NCP (EZSP-UART) schematic

ZICM35xSPx NCP EZSP-SPI

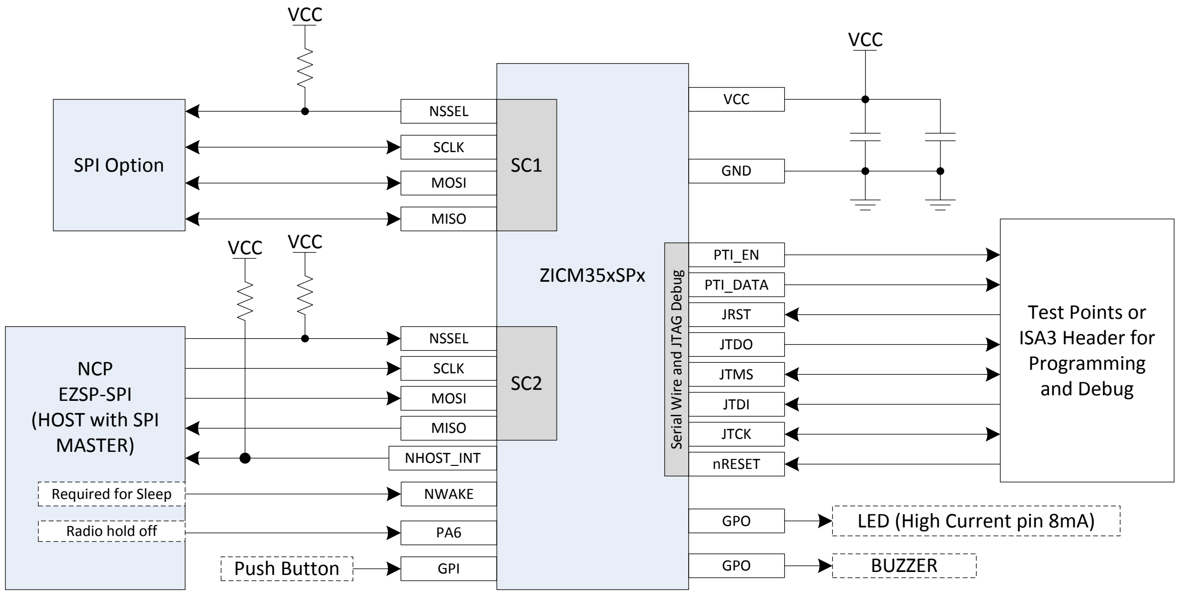


Figure 7. ZICM35xSPx NCP EZSP-SPI block diagram

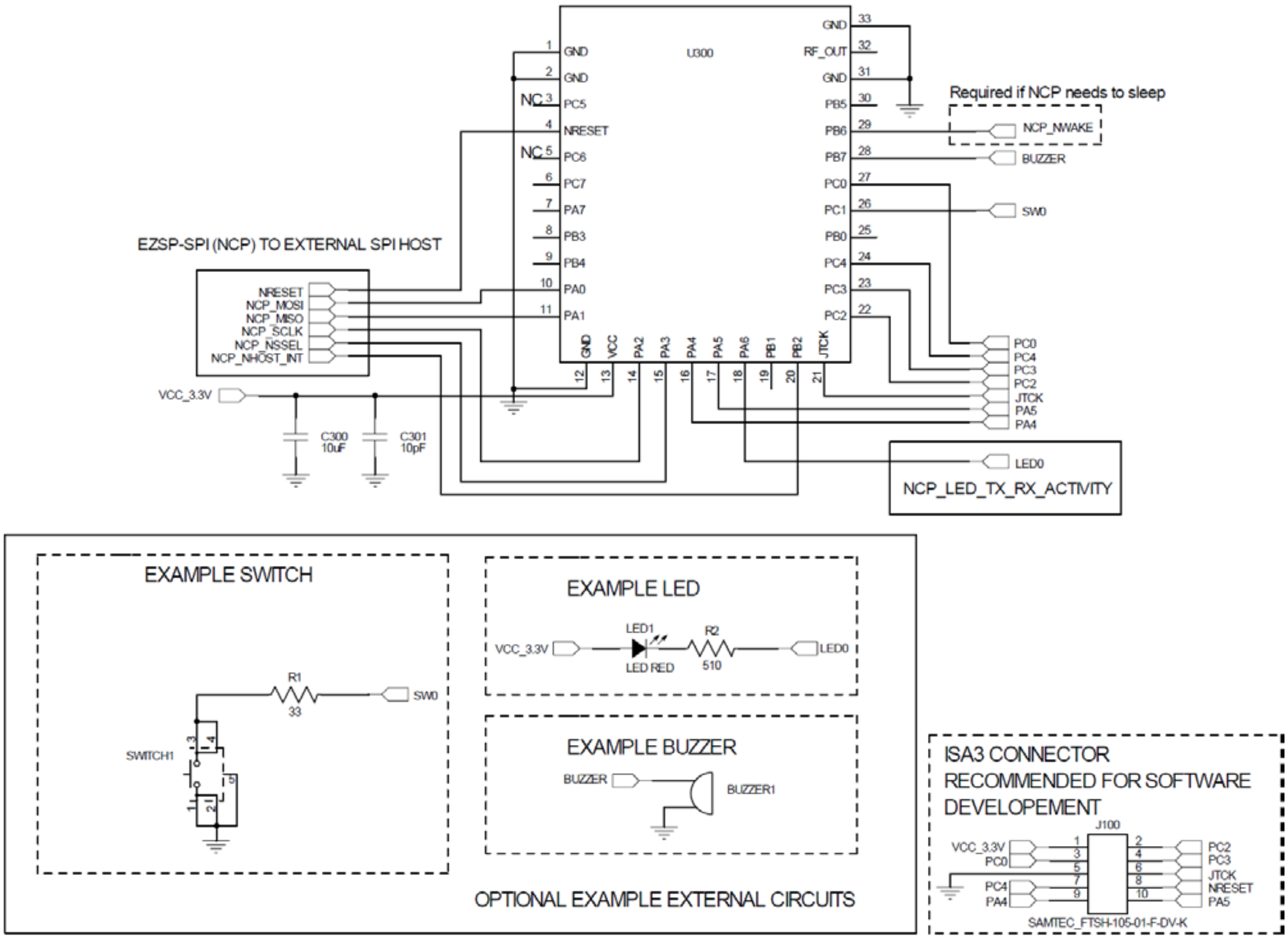


Figure 8. ZICM35xSPx NCP EZSP-SPI schematic

ZICM358xSPx ZigBee Pro SoC (USB or UART), NCP (USB or UART), and Thread TSMP (USB or UART)

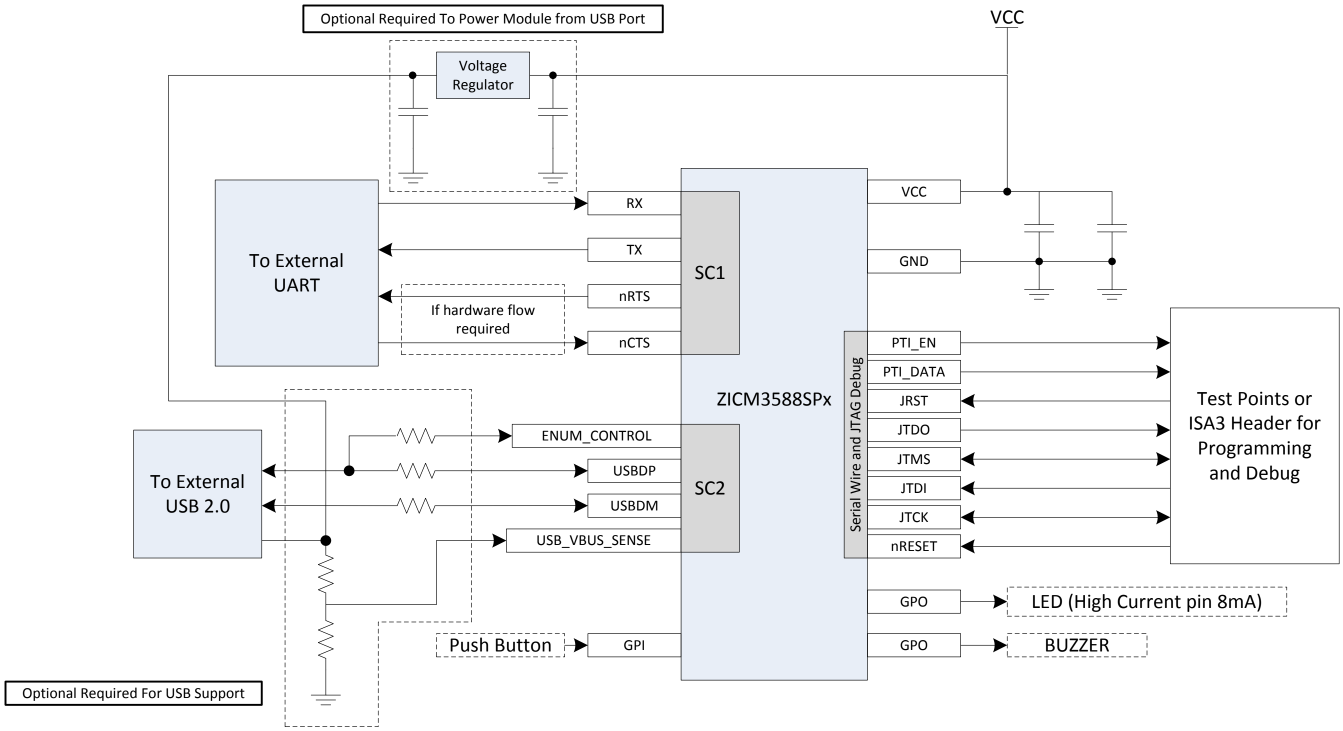


Figure 9. ZICM358xSPx SoC (USB or UART), NCP (USB or UART) block diagram

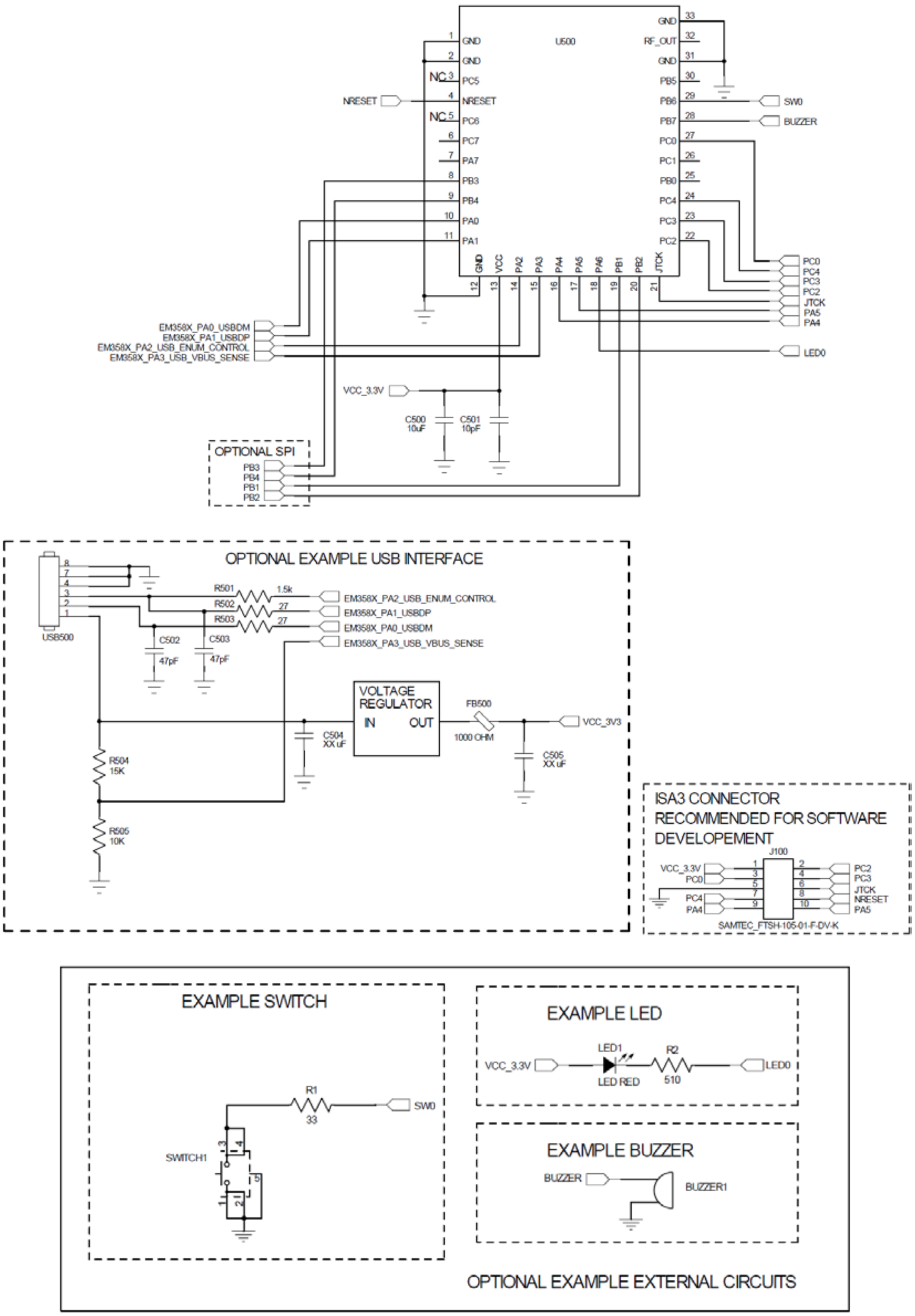


Figure 10. ZICM358xSPx SoC (USB or UART), NCP (USB or UART) Schematic

B1010SPx

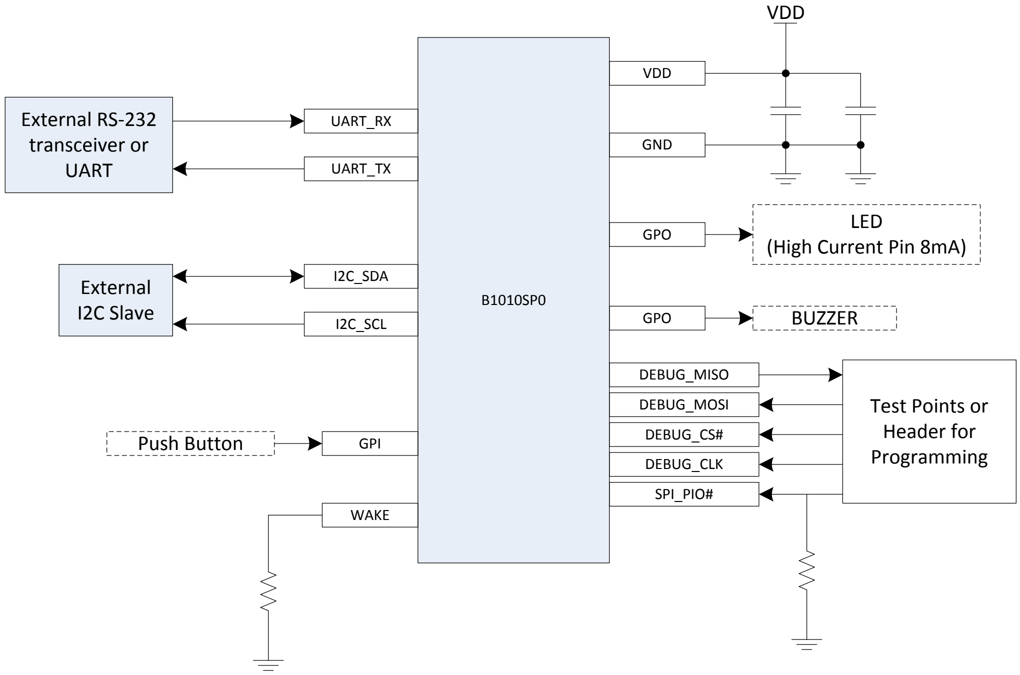


Figure 11. B1010SPx I2C block diagram

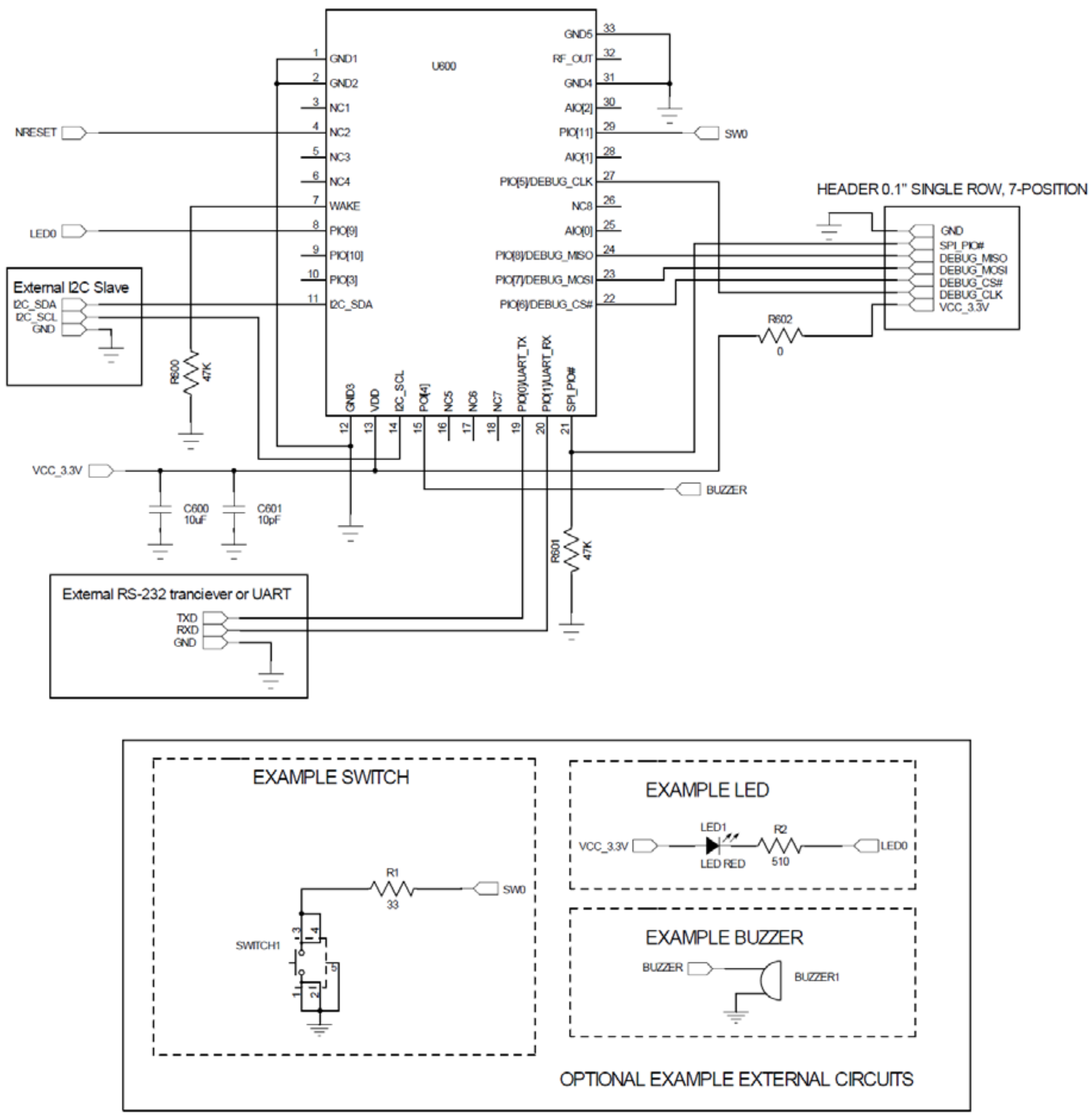


Figure 12. B1010SPx schematic example

ZICM35xSPx and B1010SPx Drop-in Replacement

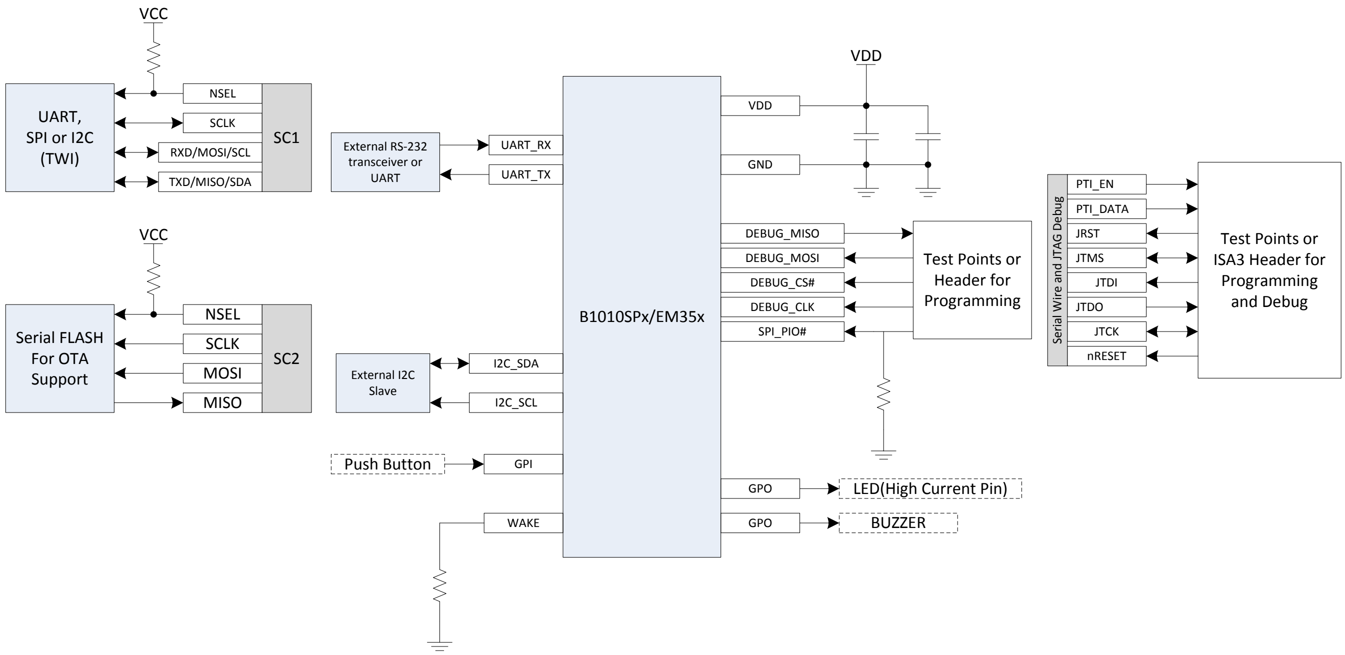


Figure 13. ZICM35xSPx and B1010SPx Drop-in Replacement block diagram

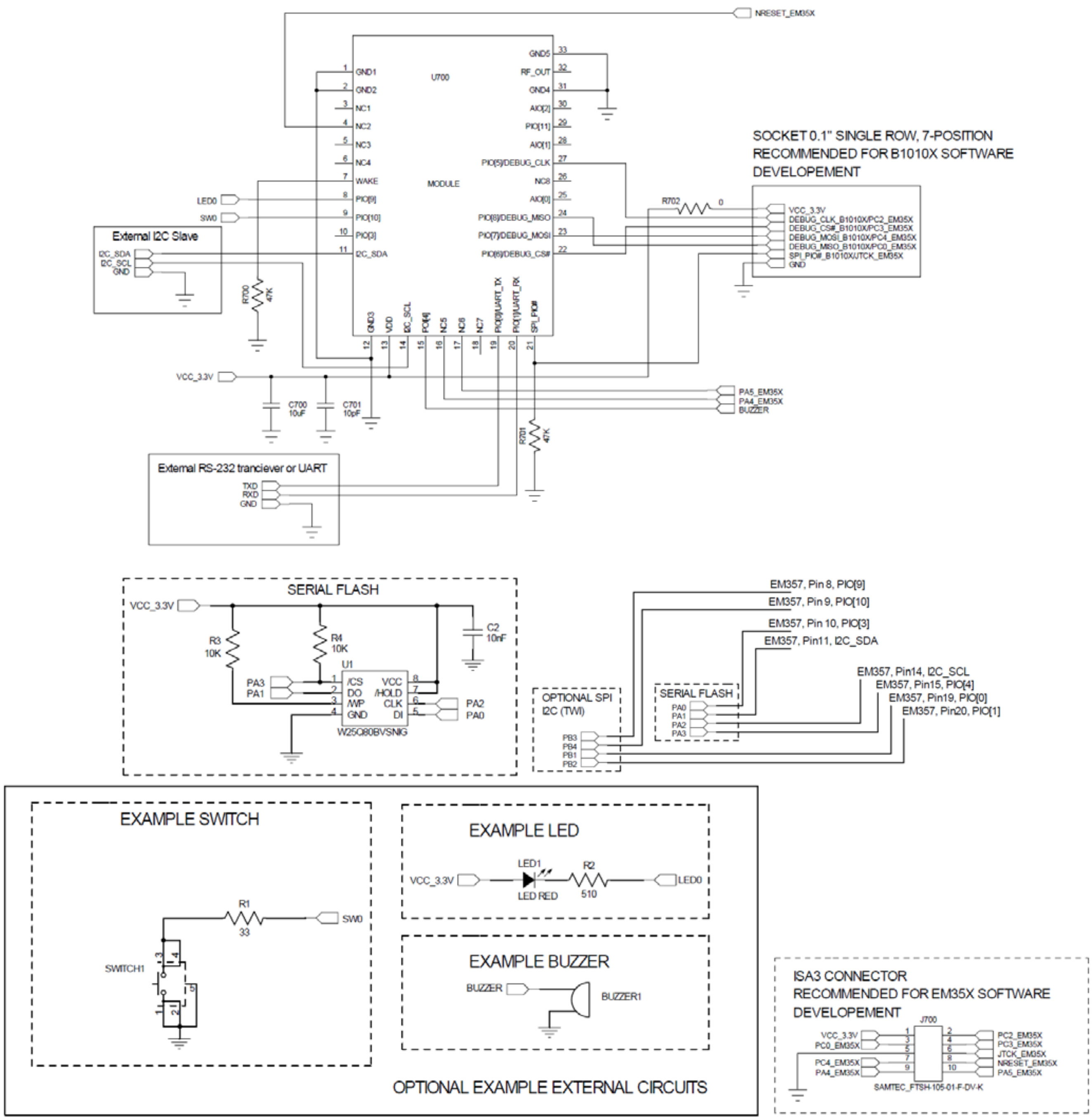


Figure 14. ZICM35xSPx and B1010SPX Drop-in Replacement Schematic

BILL OF MATERIALS FOR SCHEMATIC EXAMPLES

Qty	Reference	Value	Part Number	Manufacturer	Description	Tolerance
7	C100 C200 C300 C400 C500 C600 C700	10uF	GRM21BR61C106KE15L	MURATA	CAP CER 10UF 16V X5R 0805	±10%
7	C101 C201 C301 C401 C501 C601 C701	10pF	GRM1555C1H100JZ01D	MURATA	CAP CER 10PF 50V 5% C0G 0402	±5%
2	C502 C503	47pF	GRM1555C1H470JZ01D	MURATA	CAP CER 47PF 50V 5% C0G 0402	±5%
1	C504, C505	XX uF			USER DEFINED BASED ON POWER SUPPLY	
1	FB500	1000 OHM	BLM18RK102SN1D	MURATA	FERRITE CHIP 1000 OHM 200MA 0603	
2	J100 J700	CONN 10p	FTSH-105-01-F-DV-K	SAMTEC	HEADER CONNECTOR,PCB MNT,RECEPT,10 CONTACTS,PIN,0.050 PITCH	
1	LED1	LED RED	LNJ214R82RA	PANASONIC	LED RED USS TYPE 0603	
3	R505	10K	RC0402JR-0710KL	YAGEO	RES 10K OHM 1/16W 5% 0402 SMD	±5%
1	R501	1.5k	CRCW04021K50FKED	VISHHAY	RES 1.5K OHM 1/16W 1% 0402	±1%
2	R502 R503	27	RC0402JR-0727RL	YAGEO	RES 27 OHM 1/16W 5% 0402 SMD	±5%
1	R504	15K	RC0402FR-0715KL	YAGEO	RES 15K OHM 1/16W 1% 0402 SMD	±1%
6	R600 R601 R602 R700 R701 R702	47K	RC0402FR-071KL	YAGEO	RES 1.00K OHM 1/16W 1% 0402 SMD	1%
5	U100 U200 U300 U400 U500 U600 U700	MODULE	ZICM35xSPx, ZICM3588SPx, B1010SPx	CEL	CEL Mini Module	
1	USB1	USB CONN	932	Keystone Electronics	CONN PLUG USB A-TYPE	
1	BUZZER1	76dB	CEP-1160	CUI	BUZZER PIEZO 4KHZ 14MM EXT DRIVE	
1	C2	10nF	GRM155R71E103KA01D	MURATA	CAP CER 10000PF 25V 10% X7R 0402	±10%
1	R1	33	RC0402JR-0733RL	YAGEO	RES 33 OHM 1/16 W 5% 0402 SMD	5%
1	R2	510	RC0402JR-07510RL	YAGEO	RES 510 OHM 1/16W 5% 0402 SMD	5%
3	R3 R4	10K	RC0402JR-0710KL	YAGEO	RES 10K OHM 1/16W 5% 0402 SMD	±5%
1	SWITCH1	TACTILE SWITCH	B3S-1100P	OMRON	MOMENTARY LIGHT TOUCH SMT SWITCH W/ ESD GND	

Table 2. Bill of Materials for Schematic Examples

MECHANICAL HOUSING AND PLACEMENT GUIDELINES

Module Ground Planes and Keepouts

There are two recommended module placement options:

1. Antenna overhanging PCB (this option is preferred)
2. Antenna with copper keepout along PCB edge

The module placement options are shown below. Refer to the MeshConnect EM35x Mini Modules and B1010SPx datasheet for keepout dimensions.

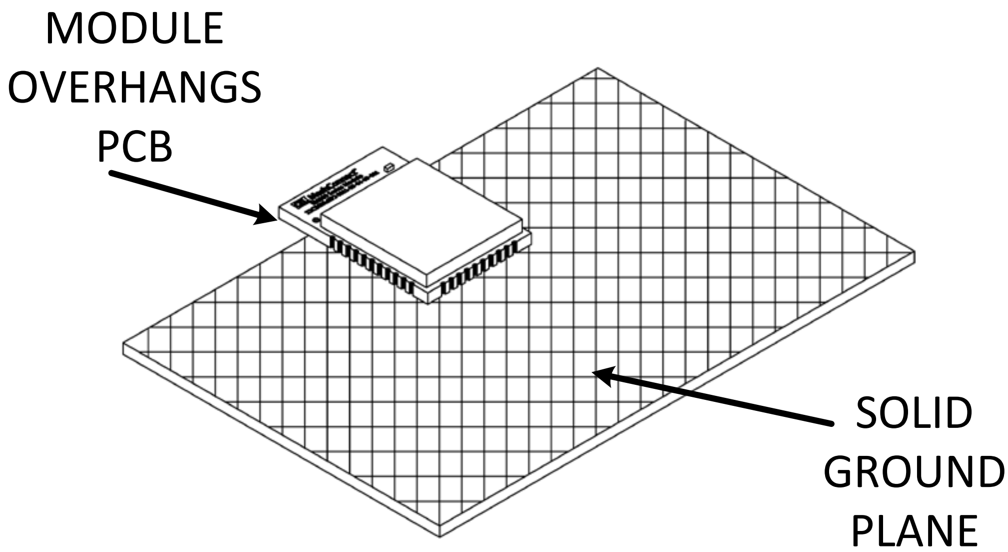


Figure 15. Example module placement with antenna overhanging PCB

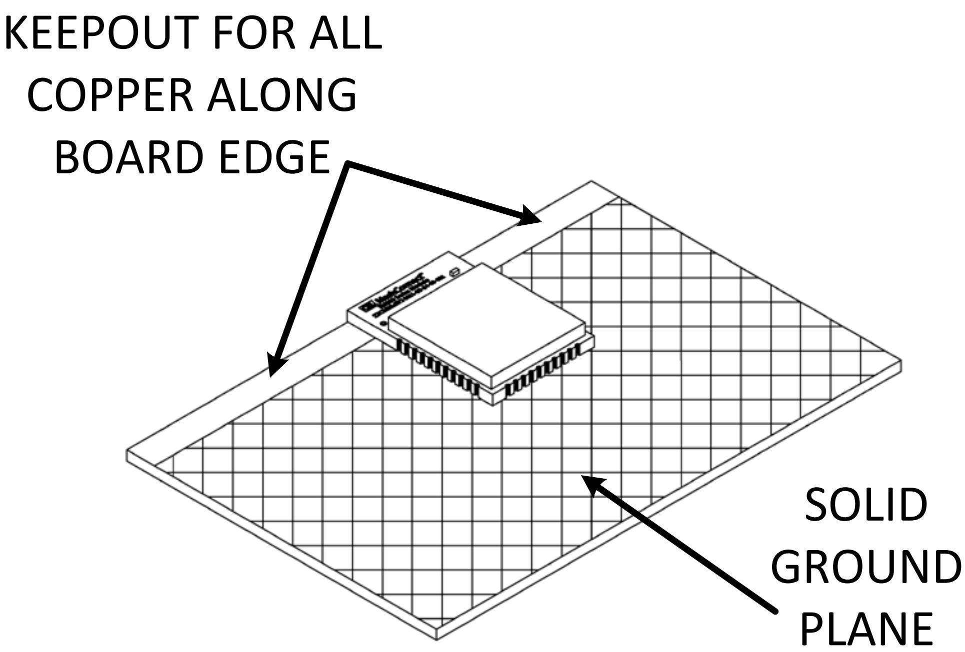


Figure 16. Example module placement with copper keepout along PCB board edge

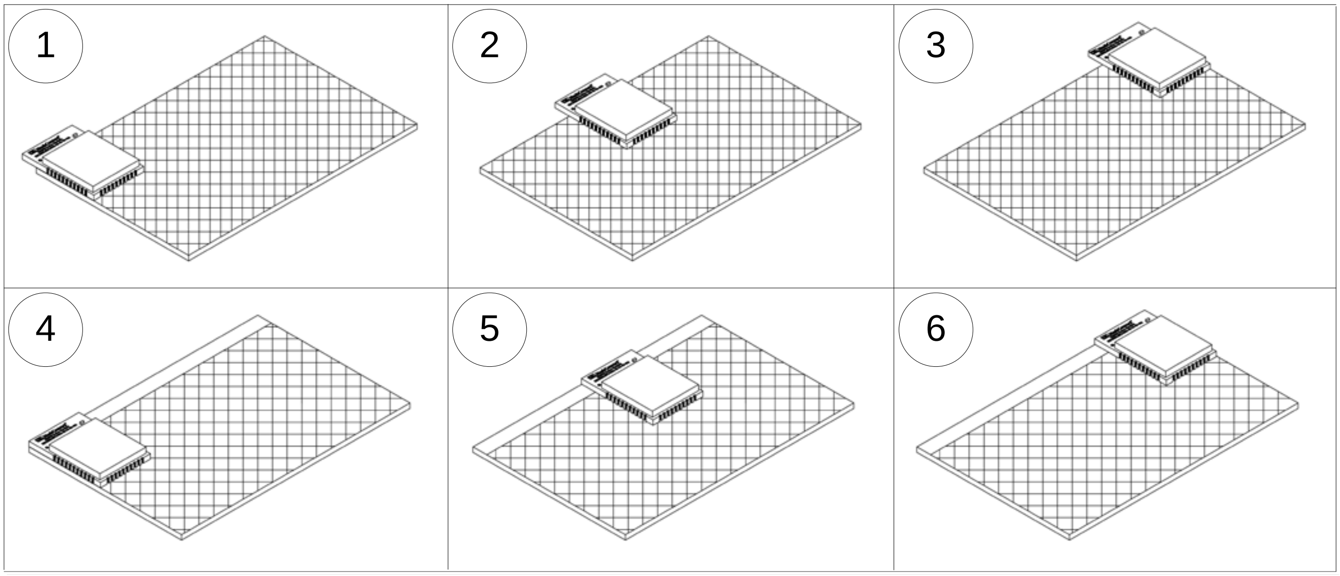


Figure 17. Example Mini Module placements

Figure 17 shows various allowed module placement options. In options 1, 2 and 3, the antenna is overhanging the module and in options 4, 5 and 6, there is a copper keepout along the PCB edge under the antenna. Options 1-3 are preferred. If the product requirements do not allow for the module to overhang the PCB, options 4-6 can be used, with option 4 preferred.

Note: *The RF performance will be impacted slightly due to the presence of PCB material underneath the antenna.*

Mechanical Housing and Antenna Concerns

- If a system housing is required, an enclosure suitable for 2.4GHz RF should be used. Plastic is recommended with no metallic coatings. As with all RF circuitry, mounting the module in and around metals will have significant effect on the radiation pattern of the antenna and needs to be tested on a case-by-case basis. If a metal housing is required, using the integrated trace antenna is not recommended. Instead, use an external antenna. See CEL's Application Note *Mini Module Castellation Pin Layout Guidelines* for layout recommendations when using an external antenna. Ferrous materials should be placed as far from the antenna as possible.

- Any objects other than air near the antenna will have an impact on it. While it may seem obvious that the antenna will be affected by any metal objects near the antenna, it is also true that any objects which do not have the dielectric constant of air, such as a plastic case or a human hand, will also detune the antenna. A separation of 0.075" (1.905mm) or greater is recommended between the antenna and the housing in all directions.

LAYOUT DESIGN GUIDELINES

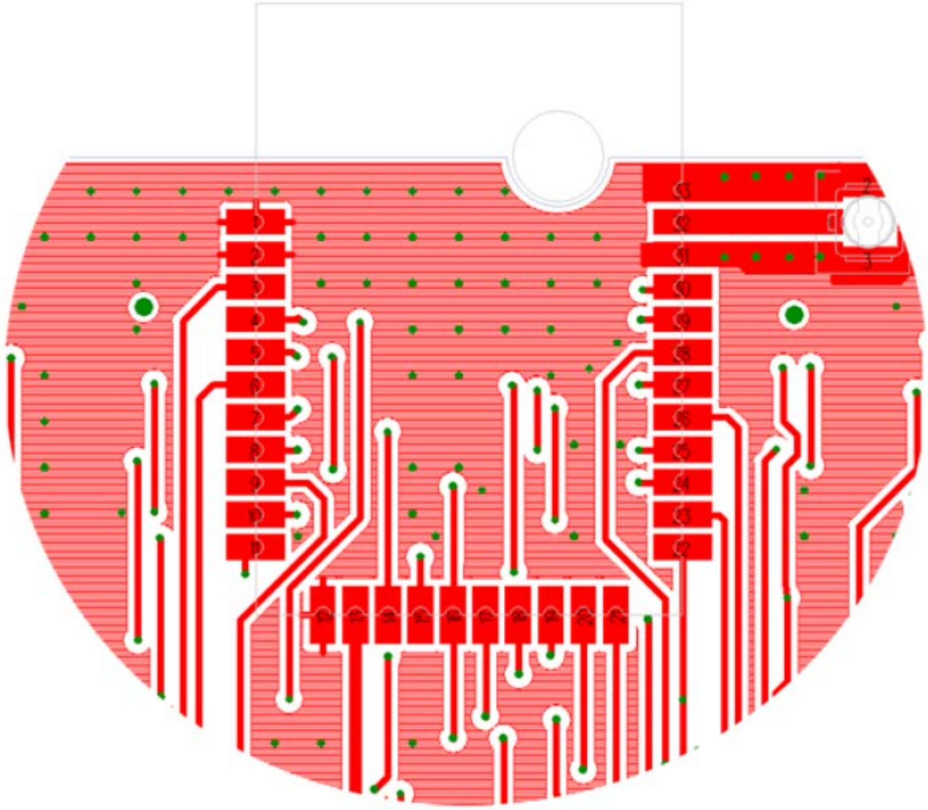


Figure 18. Example top layer layout using the ZICM35xSPx Module

Internal Antenna vs. External Antenna

If the design uses the Mini Module integrated antenna, then an external antenna trace is not needed. The antenna trace is only needed if you have decided to use an external antenna. An external antenna is typically used because the product housing or surrounding environment is blocked by metal or other materials. The antenna trace must be routed to a suitable connector and connected to an antenna or wire tuned to 2.4GHz.

Note: *It is possible to add a trace antenna to a connector for the purpose of testing if needed. To convert from integrated trace antenna to the antenna port requires rotating the single capacitor 90° that is outside the shield wall. Any modification to the hardware will void your warranty, but some designers find it useful for testing provided they have the board space.*

RF antenna design is outside the scope of this documentation. For more information, please see our *Mini Modules Castellation Pin Layout Guidelines - For External Antenna* and our *Mini Module Antenna Implementation Guide*.

Note: *To use CEL's FCC certification, you will need to use the antenna specified in the module datasheet or equivalent.*

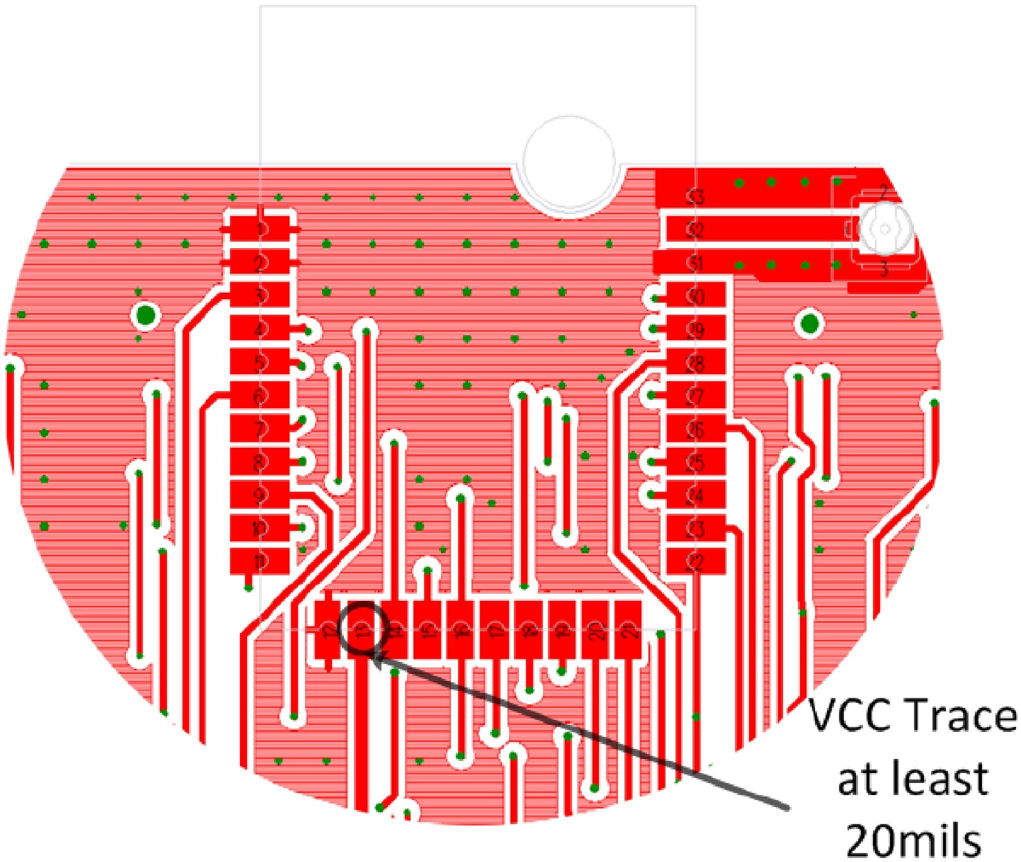


Figure 19. Layout highlighting VCC trace thickness

Power Supply and Battery Operation

ZICM35xSPx Mini Modules

CEL recommends a power supply design of 3.3V with a ripple of no more than +/- 0.3Vpp. Supply range is 2.1V to 3.6V for the ZICM35xSPx. The supply or battery for the ZICM35xSP0 Module should be capable of sourcing at least 50mA. The supply or battery for the ZICM35xSP2 Module should be capable of sourcing at least 200mA.

B1010SPx Mini Modules

The B1010SPx has a supply range of 1.8V to 3.6V. The supply or battery for the B1010SPx should be capable of sourcing 75mA.

VCC and Bypass Capacitors

- VCC trace should be thick, at least 20 mils to 40 mils
- VCC bypass capacitor (typically 10uF CERAMIC 16V X5R 0805). Bypass capacitors are present within the ZICM35xSPx and B1010SPx Mini Modules as well.
- We recommend a 10 pF RF bypass capacitor close to VCC.

GROUNDING PINS AND PLANES

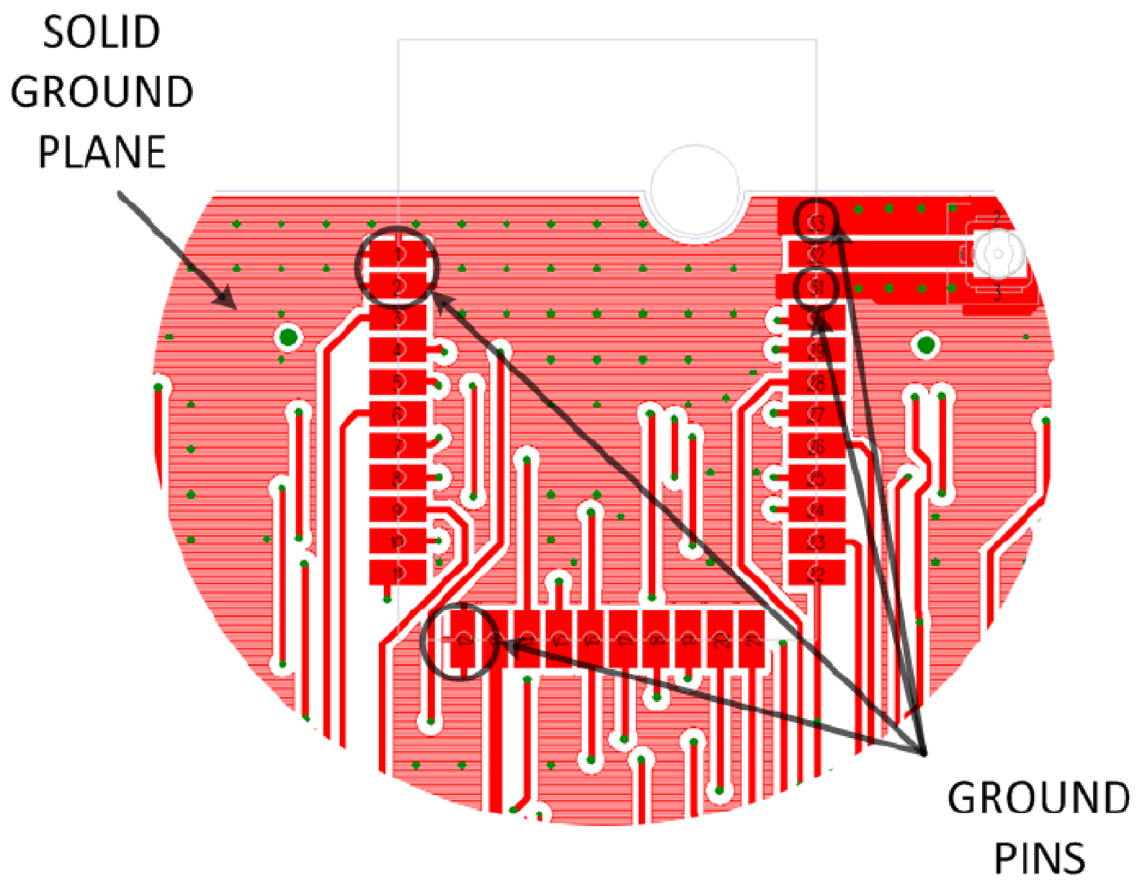


Figure 20. Layout highlighting ground pins

GROUNDING CHECK LIST

- All ground pins should be connected to the ground plane. If thermals are used, we recommend combining webs no smaller than 20 mils.
- Thermal relief should be kept to a minimum on the RF pin and surrounding ground pins (pin 31, 32 and 33).
- The module relies on the ground plane of its host printed circuit board for proper performance. A flooded ground plane at least 1.5" x 1.5" is recommended for the top and bottom layers of the PCB. The 1.5" includes the flooded ground plane under the module and the surrounding ground plane (the total ground plane is larger than the module). This means a ground flood of 1.5" X 1.5" is recommended on layer 1 and 4 of a four layer board.
- We also recommend ground vias from top to bottom layers in a grid spaced every 200 mil or less.

REFERENCES

Reference Documents	Download
California Eastern Laboratories	
0011-00-07-00-000 EM357 Mini Module Datasheet	Link
0019-00-07-00-000 B1010SP0 Mini Module Datasheet	Link
0011-00-16-10-000 ZICM35xSPx Software Design Guidelines	Link
0011-00-17-03-000 Mini Module Castellation Pin Layout Guidelines – For External Antenna	Link
0011-00-16-02-000 Using an External Flash Memory with ZICM357SPx Mini Module	Link
0011-00-17-03-000 Mini Module Antenna Implementation Guide	Link
Silicon Labs	
UG103.3 Application Development Fundamentals: Design Choices	Link
EM351/EM357 High-Performance, Integrated ZigBee/802.15.4 System-on-Chip Datasheet	Link
EM358x: High-Performance, Integrated ZigBee/802.15.4 System-on-Chip Family Datasheet	Link
CSR	
CSR µEnergy® CSR1010 Datasheet	Link

REVISION HISTORY

Previous Versions	Changes to Current Version	Page(s)
0011-00-16-09-000 (Issue A) July 15, 2013	Initial Release	N/A
0011-00-16-09-000 (Issue B) August 15, 2013	Updated figures 5 and 7 for better viewing / printing	5, 6
0011-00-16-09-000 (Issue C) March 17, 2014	Re-labeled LED circuits in Figures 5 and 7	5, 6
0011-00-16-09-000 (Issue D) August 14, 2015	Edited to incorporate Bluetooth Mini Module design options	ALL

DISCLAIMER

FOR MORE INFORMATION

For more information about CEL MeshConnect products and solutions, visit our website at meshconnect.cel.com.

TECHNICAL ASSISTANCE

For Technical Assistance, visit meshconnect.cel.com/tech-support