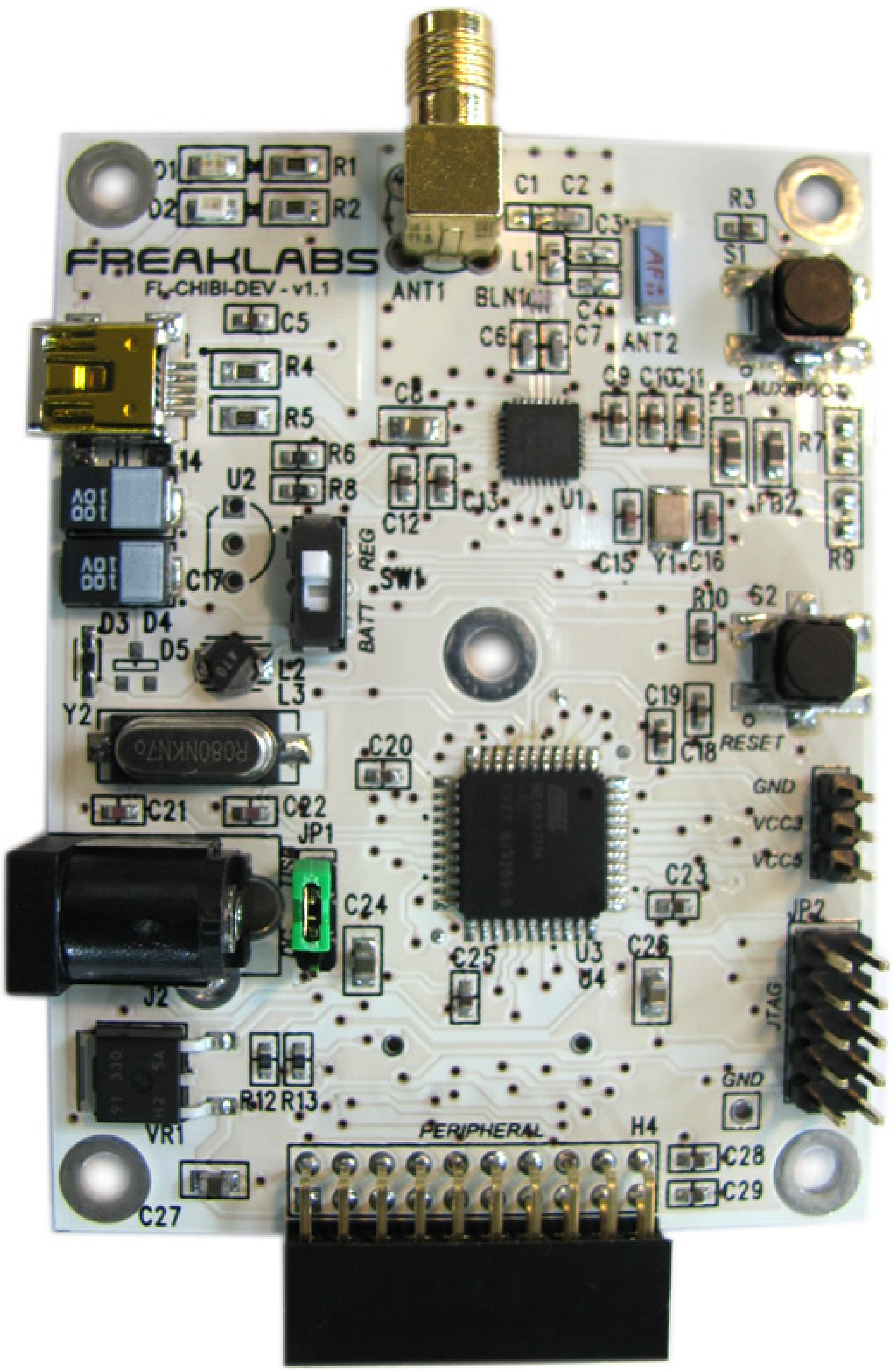
FREAKLABS

Chibi Integrated WSN Prototyping Platform
FL-CHIBI-DEV v1.1
User Guide v1.1A



Hardware Change List for v1.1

Section	*Description*
Power	Battery supply and regulation circuit has been added. Coin cell holder has been replaced with 2-AA battery holder. Regulated boost output provides better battery utilization.
Connectors	Universal Serial Connectors have been modified to add dedicated pins for timer/counters and PWM
Components	RF front end components changed to 0603 from 0402. 0402 tape and reel pitch requires special feeders.

Document Revision History

Date	*Description*
2010-03-31	v1.1A Document creation

Specifications

The FreakLabs Chibi 2.4GHz integrated WSN prototyping board is designed to be a low-cost development system for the rapid prototyping of wireless sensor circuits. It combines a complete MCU, radio, and portable power system for the wireless communication of sensor data. It also comes with a standardized universal serial connector interface for interfacing to FreakLabs peripheral boards or any other boards that are compatible with the interface.

The Chibi board was named because it was designed with the FreakLabs Chibi open source wireless stack in mind. The Chibi wireless software stack is a simplified wireless protocol stack with only three functions: init, read, and write. It was created to make it easy to send and receive data wirelessly for those that don't want to wade through hundreds of pages of protocol specifications.

The Chibi board is based on an Atmel ATMega32U4 AVR microcontroller with 32 kB of flash memory and 2 kB of RAM. It also has a bootloader in protected memory so that the board can always be recovered, even if the flash downloading is interrupted.

The board also contains an integrated 2.4 GHz wireless radio based on the IEEE 802.15.4 standard with an option to use an on-board surface mount antenna or an external antenna.

The MCU can be debugged with the Atmel AVR Dragon JTAG ICE which is a very low-cost (~$50) in-circuit debugger. Combining the JTAG debugger with open source GNU compiling tools creates a very low cost development environment for wireless sensing and wireless sensor network development.

Quick Specs

MCU: ATMega32U4

Radio: AT86RF230, 2.4 GHz, 802.15.4

Flash: 32 kB

RAM: 2 kB

Connectors: 1 USC, RP-SMA, USB

Power: Ext 5VDC, USB, Battery

Debug: JTAG

Program: JTAG, Bootloader

Power

The Chibi 2.4 GHz board can be powered by either the USB, external 5V DC power supply, or 2 AA batteries. The DC connector is a 2.1mm barrel jack and accepts standard 2.1mm DC plugs. The external voltage source can only be 5V. Any voltage higher than 5V can potentially damage the AVR microcontroller since the AVR's USB voltage regulator is connected to the 5V power rail.

The board can also be conveniently powered by the USB connection, hence only one cable can supply both power and communications.

Battery voltage depends on material and the amount of charge left. Two new alkaline batteries will provide 3V to the system but can drop to less than 2.5V over time as they discharge. Two NiMH rechargeable batteries top out at 2.4V and will also show a voltage droop as they discharge. To deal with this, the Chibi 2.4 GHz boards also come with a 3.3V boost converter.

The boost converter takes any input over 0.7V and boosts it up to 3.3V. This allows the system to stay at a constant voltage as the batteries discharge. This is especially important when dealing with sensors whose output voltage depends on the power supply. If the sensors aren't ratiometric to the supply, then the sensor inaccuracy will increase as the power supply drops.

The voltage source can be switched via a jumper between the DC source and the USB source. This jumper will choose which source to feed into the voltage regulator.

There is also a power switch that chooses between battery power and external DC power. If no battery is present, then that side of the switch will be the OFF position. The same is true if no DC power is connected.

There are two LEDs on the board to indicate power. The 5V LED is red and indicates that 5V is present. Since this would mean that there is an external power source, it is always connected to the 5V supply. There is also a green LED which can be used to indicate 3.3V power. This LED is connected to a general purpose IO of the MCU. This was done because having an LED that is always on is usually not desirable in a battery-powered circuit. Hence, its up to the user if they want the green LED to be used as a 3.3V power indicator and this function can easily be added through software.

Peripherals

The Chibi 2.4 GHz board has an integrated USB device controller for connecting it to a PC. The FreakUSB USB device protocol stack has already been ported to it and the Chibi protocol stack includes FreakUSB targeted for this platform. It will come up on most PCs as a serial port and can be accessed through a standard terminal program.

The board also contains a 2.4 GHz wireless radio based on the IEEE 802.15.4 standard. The radio is the Atmel AT86RF230 which is the same radio used on the Atmel Raven development systems. It's connected to the SPI bus of the MCU and contains an RF matching circuit to match the output of the radio to the antenna for maximum power transmission.

There are two antenna options, an external RP-SMA RF antenna connector and an on-board surface mount antenna. The board can also come with both antennas populated. The antenna is chosen via an option capacitor/resistor.

The recommended antenna choice is the external RP-SMA antenna connector. This allows the most flexibility because the connector itself radiates enough to be used as a short range antenna and if more range is desired, various high gain antennas can be connected to it to meet the range requirements.

Connectors

The universal serial connector (USC) interface is standard between FreakLabs MCU boards which all carry at least one USC port with a right angle female connector. All peripheral boards will have similar USC ports with at least one right angle male connector to interface to MCU boards. With this type of setup, its possible to mix and match peripheral boards with MCU boards. This is especially helpful when looking for a combination of MCU, radios, and sensors/peripherals to meet the desired application requirements.

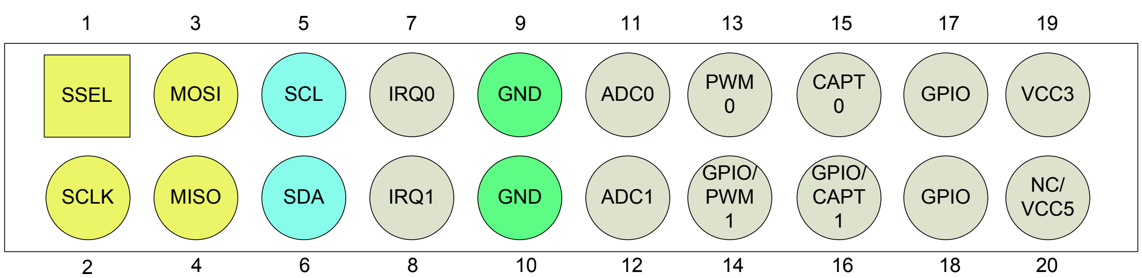
Universal Serial Connector Pinouts

The Chibi 2.4 GHz board supports the Universal Serial Connector (USC) v1.1. It contains an SPI bus, I2C bus, 2 interrupts, 2 analog inputs, 1 PWM output, 1 timer/capture input, 6 GPIOs, 3.3V supply, and optional 5V supply. All pins except power pins can also be used as GPIO if there is no need for the principal function.

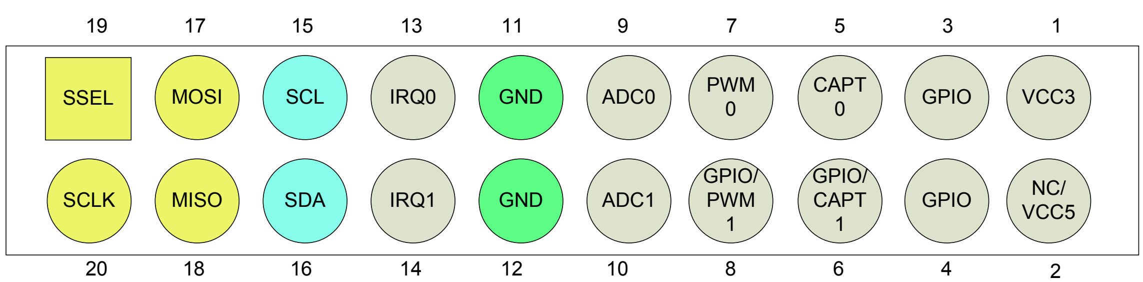
The connector consists of a host side which is a 20-pin, female, right-angle header and a peripheral side which is a 20-pin, male, right-angle header. The host side connector will always be on MCU boards and the peripheral connector will be found on peripheral boards that interface to the MCU boards.

The reason right angle connectors were chosen was so that the complete system can be level. This makes it easier to access individual signals and pins, as well as make modifications to the circuit, ie: using the breadboard peripheral. The following diagram shows the pinouts of the connectors:

Universal Serial Connector v1.1 – Host (MCU) side



Universal Serial Connector v1.1 – Peripheral side



The specific pin functions were chosen to create a generic connector optimized for wireless sensor/actuator circuits. Most radios interface through some sort of serial bus such as SPI or I2C. Also, most sensors use either a digital serial interface such as I2C, an analog output, or generate a frequency that can be measured using the timer/capture pins. The PWM outputs can be used to actuate devices such as motors or lighting.

The secondary GPIO/PWM and GPIO/CAPT pins are pins that for most purposes should be considered GPIO. However a best effort attempt to put extra PWM or timer/capture pins in those positions will be performed. Unfortunately, this is dependent on the microcontrollers which have varying amounts of those pins. It is not recommended to expect that these pins will always have PWM or timer/capture across all MCU boards. The dedicated PWM and timer/capture pins should be used instead.

For people integrating the connector into their designs, it's not recommended to assume that a 5V supply will always be available. This is because on battery powered boards, 5V will not be present due to the requirement for a boost regulator. If 5V is required, its best to build in the circuitry for a boost converter from 3.3V to 5V on to the peripheral board directly. All MCU boards can only guarantee the presence of 5V when the board is being powered by the USB or a 5VDC power supply.

USC Port 1 Pinout (H4)			
Pin	*Description*	*Pin*	*Description*
1	PC6/OC3A (SPI Select)	2	PB1/SCLK
3	PB2/MOSI	4	PB3/MISO
5	PD0/SCL	6	PD1/SDA
7	PD2/RXD1/INT2	8	PD3/TXD1/INT3
9	GND	10	GND
11	PB4/ADC11	12	PD4/ADC8
13	PB7/OC0A//OC1C	14	PB6/OC1B/OC4B
15	PD6/T1/ADC9	16	PD7/T0/ADC10
17	PB5/OC1A/ADC12	18	PD5/XCK1o
19	VCC3	20	VCC5

Jumpers

There are multiple jumpers that need to be set in order to select the correct operating mode for the board. The following should be chosen based on the use case:

Power Jumper		
Jumper	*1-2*	*2-3*
JP1	External 5VDC input	VBUS 5V Input
The power jumper chooses between the power source for the board. It is marked "VBUS" or "DC IN". If in the VBUS position, the board will be powered by the power derived from the USB interface. Otherwise, it will be powered by the DC input from the external DC barrel jack.		

Power Switch		
Jumper	BATT	REG
SW1	Battery	External Power
The power switch determines the power source for the board. The positions are labelled as shown "BATT" and "REG". The "BATT" is a mnemonic for the battery output. The "REG" input is a mnemonic for the regulator output. The input to the regulator is the 5VDC source chosen by the power jumper.		

Downloading Code

Having an integrated USB interface makes it much easier to download code to the AVR's flash memory. Atmel's chips have a dedicated hardware boot section in their flash. That means that the board is basically unbrickable by interrupted firmware downloads or bugs that hang the system.

Atmel FLIP

To download code to the flash, you will first need to get Atmel's FLIP application. There are versions for both Linux and Windows and it's a Java based application. You can find it here:

http://www.atmel.com/dyn/products/tools_card.asp?tool_id=3886

Bootloader sequence

Once you have the FLIP application installed, you need to perform a button sequence to jump to the boot section of flash. Basically, the hardware boot enable pin is sampled on reset. If it's low, then the microcontroller will go to the boot section.

This is the sequence to download the flash using the bootloader:

1. *Hold down the BOOT button*
2. *While keeping the BOOT button down, press and de-press the RESET button (S1)*
3. *If you're using Windows and it's your first time using the bootloader on your computer, it will ask you for the hardware driver. You can find this in the directory <Atmel Flip Install Dir>/Atmel/Flip/usb.*

> **Note:** Fuse settings cannot be changed via the bootloader. You must use a JTAG device such as the AVR Dragon or the JTAG ICE MK-II to change the fuses. When shipped, the JTAG fuse is enabled for debugging. The CLKDIV8 fuse is disabled so that it can run at full speed.

AVR Dragon

Alternatively, its possible to use the AVR Dragon In Circuit Emulator to program and debug the board. The AVR Dragon has a JTAG connector which connects to the JTAG on the Chibi 2.4 GHz board. Once connected, the emulator behaves as a normal In-System Programmer and you would use AVR Studio to download code to the device. Fuse settings can also be changed using this device.

JTAG ICE MK-II

The JTAG ICE MK-II is the professional debugging tool and interfaces to the board via the JTAG interface. Downloading code via the JTAG ICE MK-II is the same as via the AVR Dragon. Once connected to the JTAG interface, downloading is accomplished via AVR Studio. Fuse settings can also be changed using this device.

Debugging

There was a lot of thought put into this board because it was designed to be low cost. The cost of the board isn't the only consideration and one important detail is the cost of the tools. Hence, the ATMega32U4 MCU was chosen because it has the maximum memory size that is still compatible with the low cost AVR Dragon emulator.

Both the AVR Dragon and the Atmel JTAG ICE MK-II in-circuit emulators connect to the baord via the board's JTAG connector.

If you are using the JTAG interface, you will need to ensure that the JTAGEN fuse is set. The JTAGEN fuse is set by default so the only way this would be unset would be with a JTAG ICE or other hardware programmer.

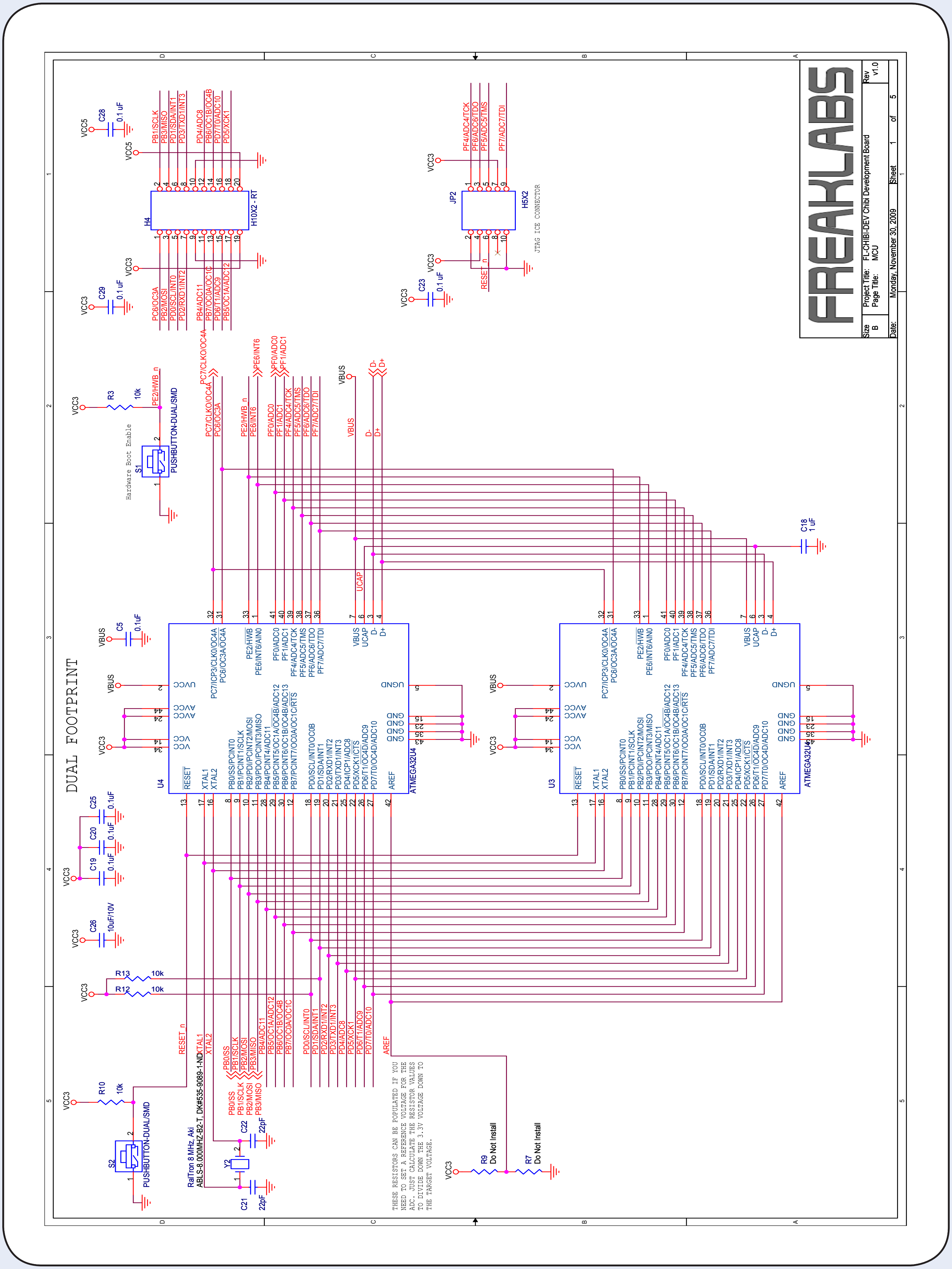
To debug the code, you will need to download Atmel's AVR Studio tool and follow the instructions on project setup and debug. The AVR Studio software debugger will connect via USB to the AVR Dragon or JTAG ICE MK-II. Please see the relevant manufacturer documentation for details on debugger hardware setup.

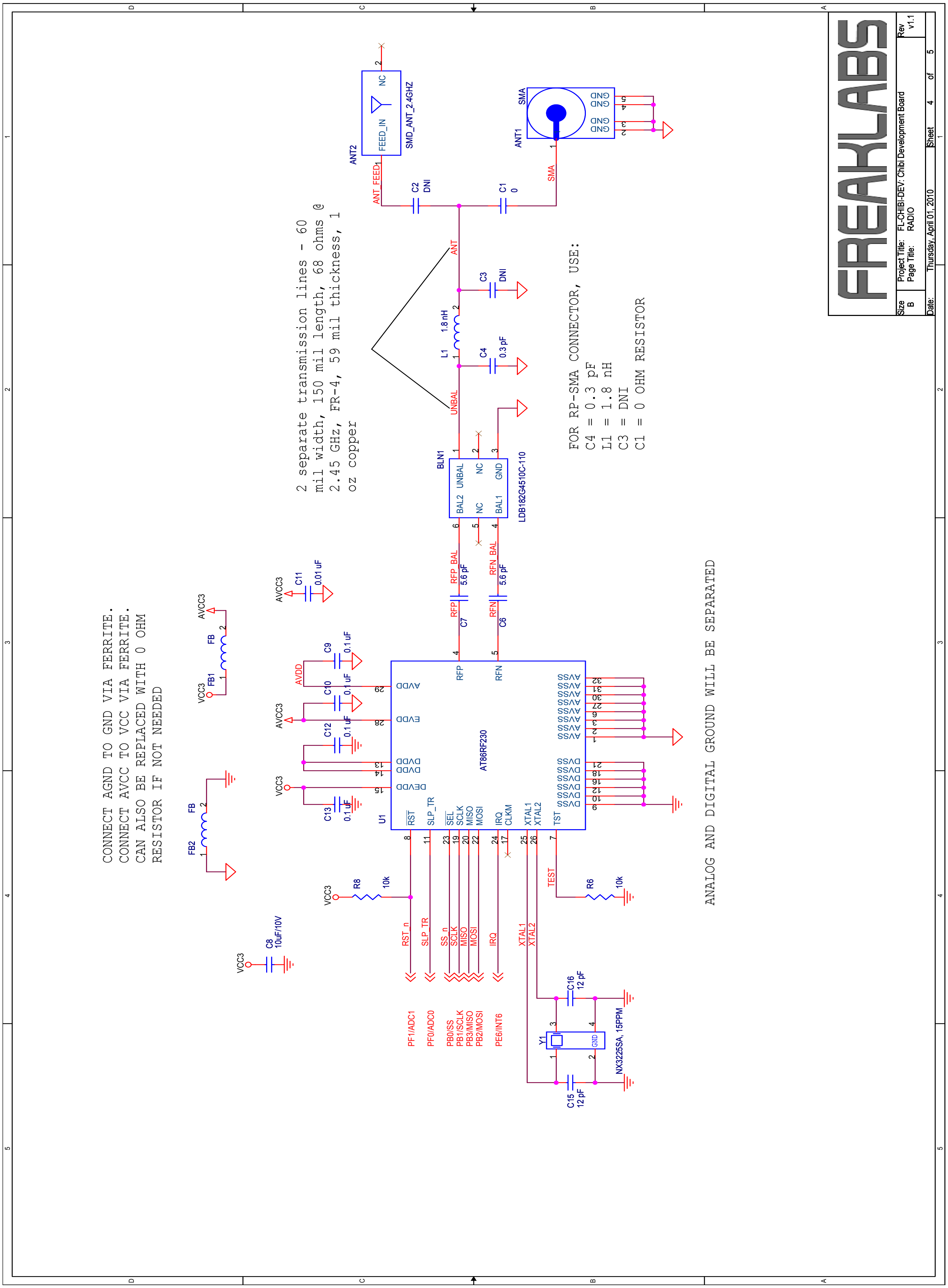
Disclaimer

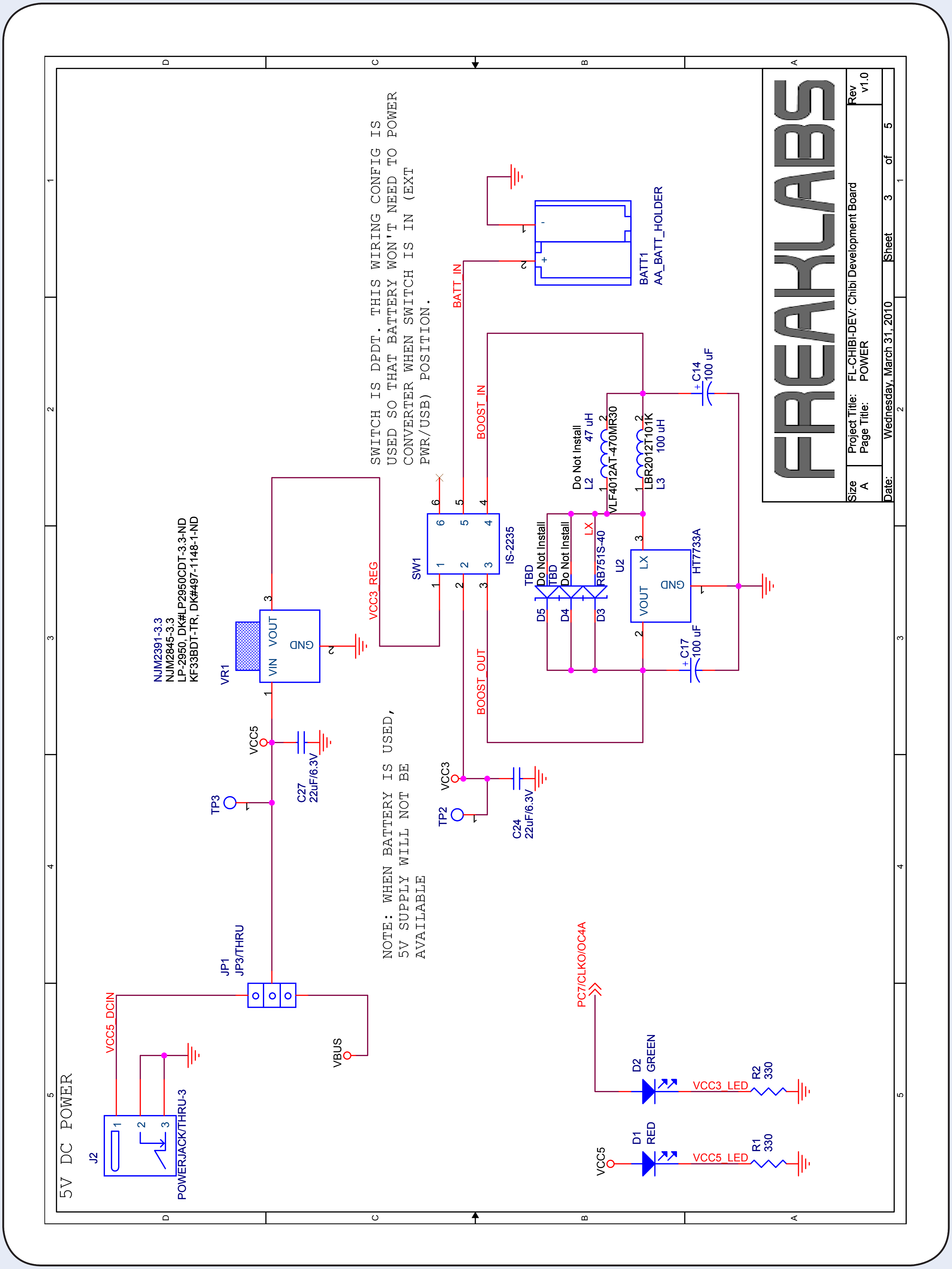
The FL-CHIBI-DEV board is NOT FCC approved. It is designed to comply with FCC Part 15 rules. However this board is not in a finished product form and is only intended for experimental and research/development purposes. If you wish to use this board in an actual product, you will need to attain certification with the appropriate local regulatory body for the complete system. Additionally, please use the wireless equipment in a responsible manner with regard for others and your surroundings.

Schematics

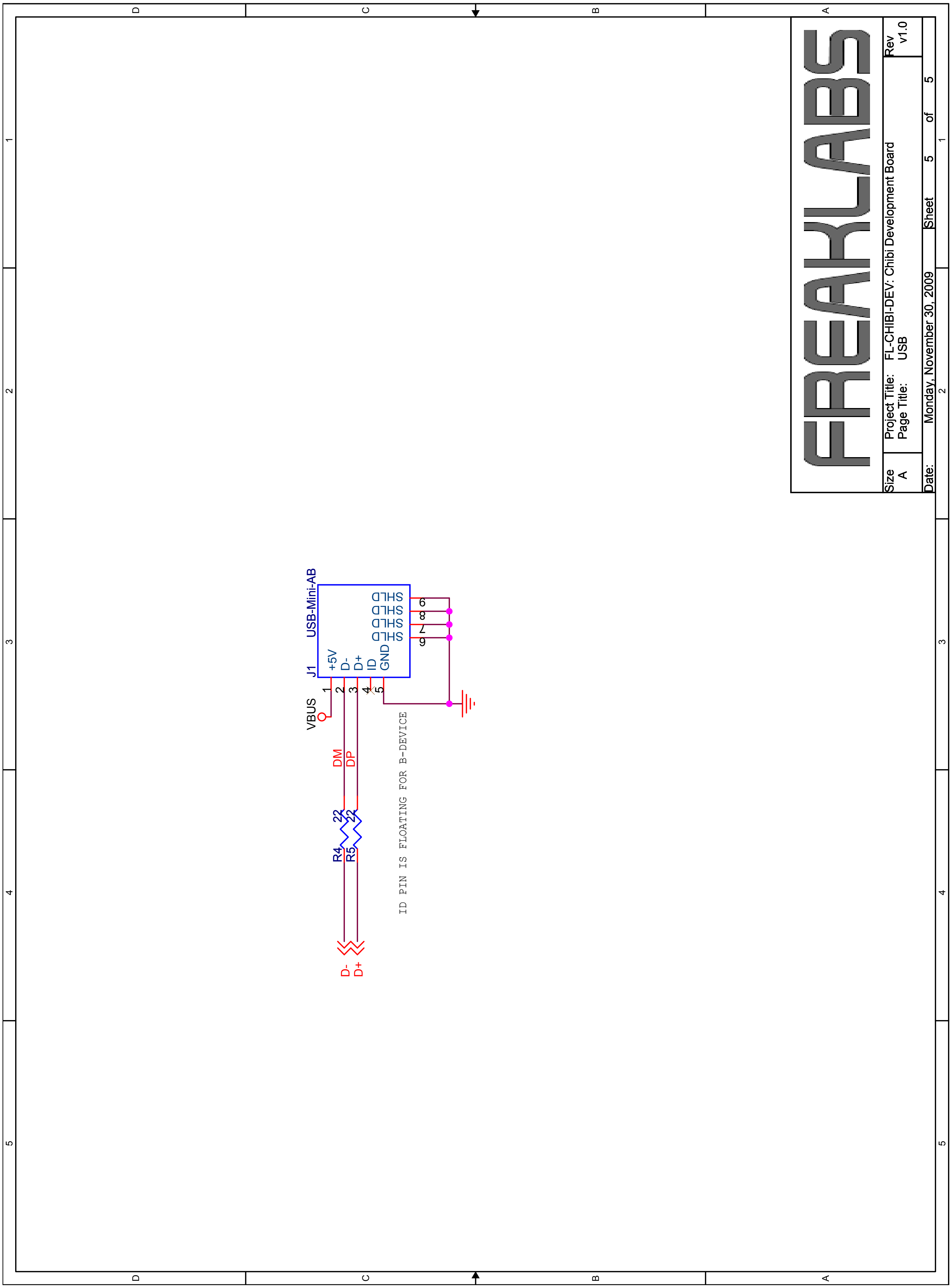
Schematics can be found on the following page:

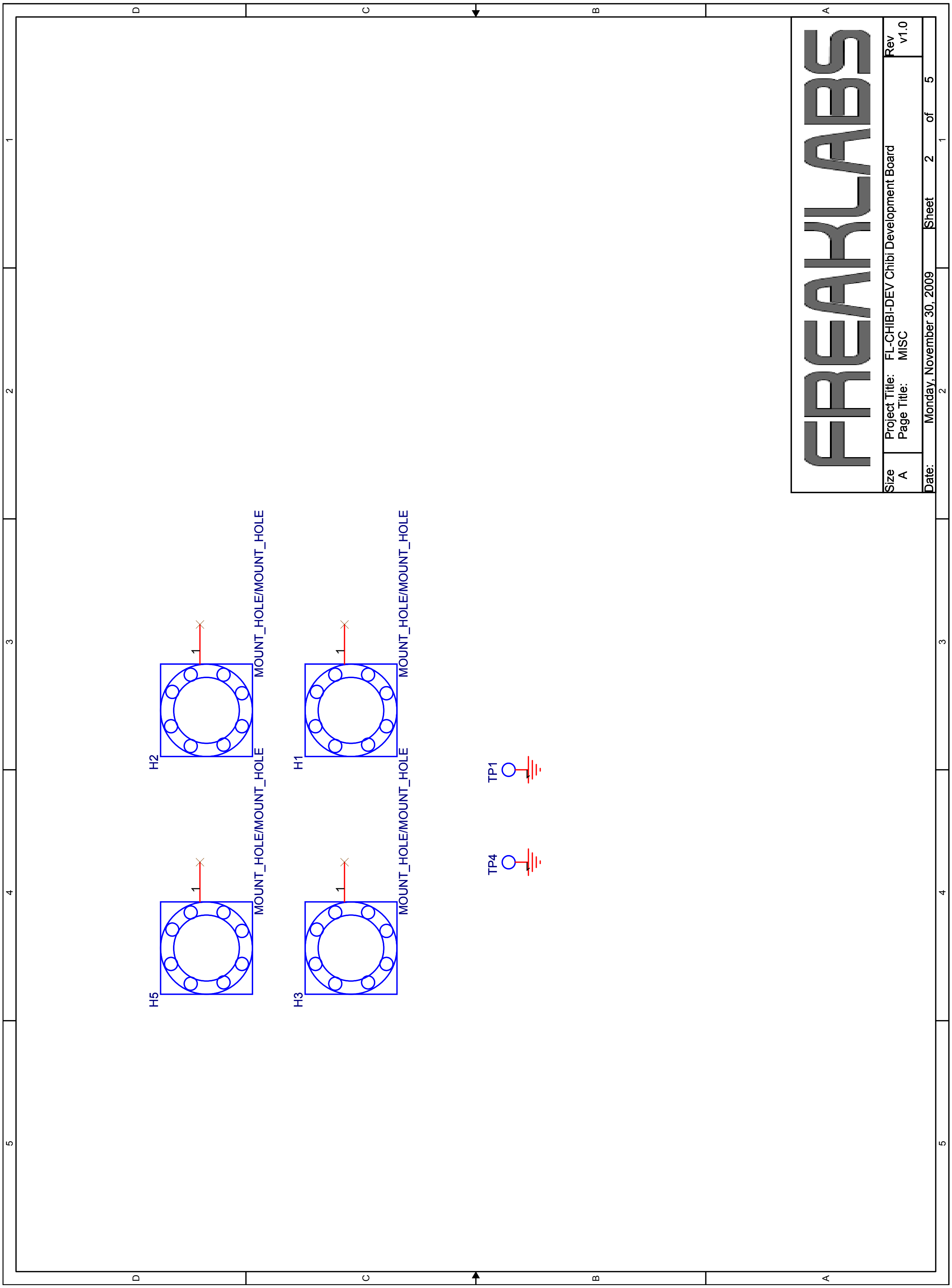

DUAL FOOTPRINT
FREAKLABS
Project Title: FL-CHIBI-DEV Chibi Development Board
Page Title: MCU
Size B
Rev v1.0
Date: Monday, November 30, 2009
Sheet 1 of 5
THESE RESISTORS CAN BE POPULATED IF YOU NEED TO SET A REFERENCE VOLTAGE FOR THE ADC. JUST CALCULATE THE RESISTOR VALUES TO DIVIDE DOWN THE 3.3V VOLTAGE DOWN TO THE TARGET VOLTAGE.
JTAG ICE CONNECTOR
Hardware Boot Enable
U4 ATMEGA32U4
U3 ATMEGA32U4
H4 H10X2 - RT
JP2 H5X2
S1 PUSHBUTTON-DUAL/SMD
S2 PUSHBUTTON-DUAL/SMD
Y2 RalTron 8 MHz, Aki ABLS-8.000MHZ-B2-T, DK#535-9089-1-ND
R9 Do Not Install
R7 Do Not Install


FREAKLABS
Project Title: FL-CHIBI-DEV: Chibi Development Board
Page Title: RADIO
Size B
Rev v1.1
Date: Thursday, April 01, 2010
Sheet 4 of 5
2 separate transmission lines - 60 mil width, 150 mil length, 68 ohms @ 2.45 GHz, FR-4, 59 mil thickness, 1 oz copper
FOR RP-SMA CONNECTOR, USE:
C4 = 0.3 pF
L1 = 1.8 nH
C3 = DNI
C1 = 0 OHM RESISTOR
CONNECT AGND TO GND VIA FERRITE.
CONNECT AVCC TO VCC VIA FERRITE.
CAN ALSO BE REPLACED WITH 0 OHM
RESISTOR IF NOT NEEDED
ANALOG AND DIGITAL GROUND WILL BE SEPARATED
AT86RF230
U1
BLN1
LDB182G4510C-110
ANT1
SMA
ANT2
SMD_ANT_2.4GHZ
Y1
NX3225SA, 15PPM
PF1/ADC1
PF0/ADC0
PB0/SS
PB1/SCLK
PB3/MISO
PB2/MOSI
PE6/INT6



5V DC POWER
J2
POWERJACK/THRU-3
VCC5_DCIN
JP1
JP3/THRU
VBUS
TP3
VCC5
C27
22uF/6.3V
VR1
NJM2391-3.3
NJM2845-3.3
LP-2950, DK#LP2950CDT-3.3-ND
KF33BDT-TR, DK#497-1148-1-ND
VIN
VOUT
GND
VCC3_REG
NOTE: WHEN BATTERY IS USED, 5V SUPPLY WILL NOT BE AVAILABLE
SW1
IS-2235
TP2
VCC3
C24
22uF/6.3V
BOOST_OUT
BOOST_IN
BATT_IN
SWITCH IS DPDT. THIS WIRING CONFIG IS USED SO THAT BATTERY WON'T NEED TO POWER CONVERTER WHEN SWITCH IS IN (EXT PWR/USB) POSITION.
BATT1
AA_BATT_HOLDER
D5
TBD
Do Not Install
D4
TBD
Do Not Install
D3
RB751S-40
LX
U2
HT7733A
L2
Do Not Install
47 uH
VLF4012AT-470MR30
L3
LBR2012T101K
100 uH
C14
100 uF
C17
100 uF
PC7/CLKO/OC4A
D2
GREEN
VCC3_LED
R2
330
VCC5
D1
RED
VCC5_LED
R1
330
FREAKLABS
Size
A
Project Title: FL-CHIBI-DEV: Chibi Development Board
Page Title: POWER
Rev
v1.0
Date: Wednesday, March 31, 2010
Sheet 3 of 5

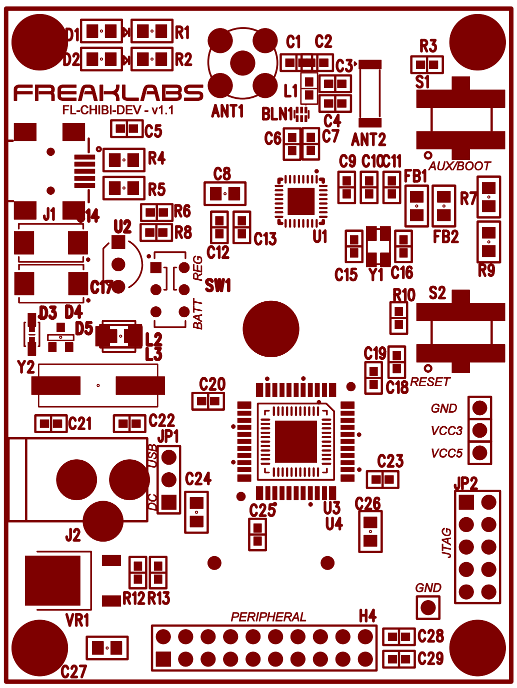

FREAKLABS
Size
A
Project Title: FL-CHIBI-DEV: Chibi Development Board
Page Title: USB
Rev
v1.0
Date: Monday, November 30, 2009
Sheet 5 of 5
J1
USB-Mini-AB
+5V
D-
D+
ID
GND
SHLD
SHLD
SHLD
SHLD
VBUS
DM
DP
R4
22
R5
22
D-
D+
ID PIN IS FLOATING FOR B-DEVICE

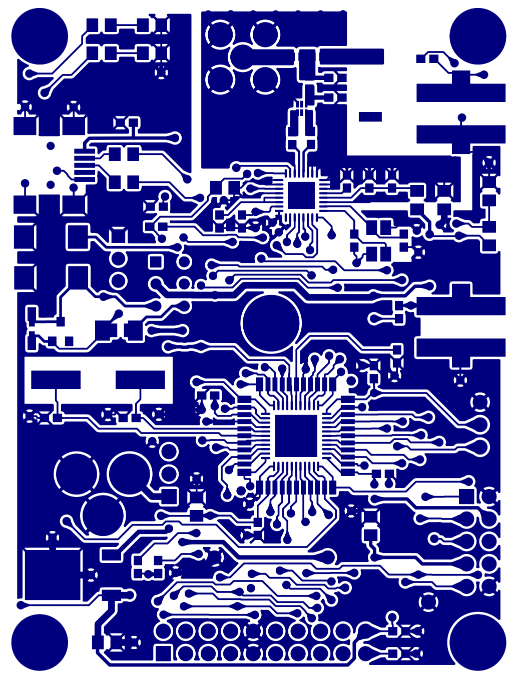
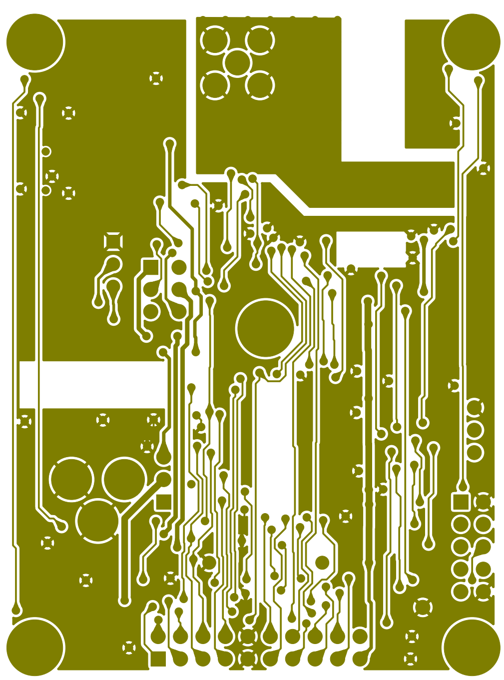
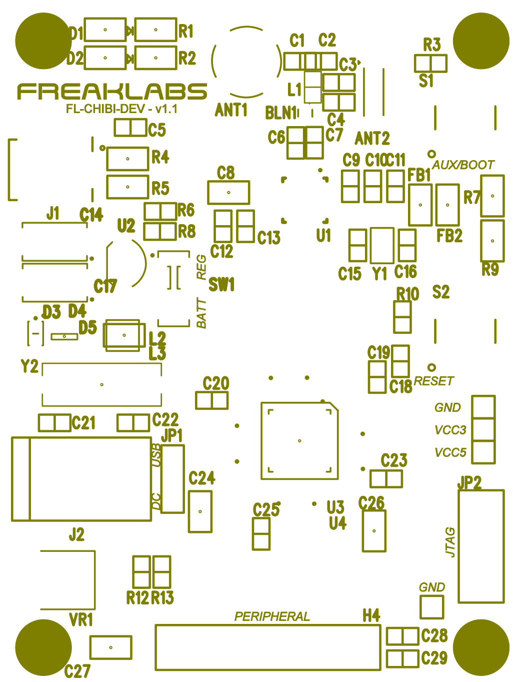

FREAKLABS
Project Title: FL-CHIBI-DEV Chibi Development Board
Page Title: MISC
Size A
Rev v1.0
Date: Monday, November 30, 2009
Sheet 2 of 5
H1
H2
H3
H5
MOUNT_HOLE/MOUNT_HOLE
MOUNT_HOLE/MOUNT_HOLE
MOUNT_HOLE/MOUNT_HOLE
MOUNT_HOLE/MOUNT_HOLE
TP1
TP4

PCB Layout

PCB layout file order:

1. *Assembly drawing*
2. *Top Layer*
3. *Bottom Layer*
4. *Silkscreen*



Bill of Materials

Quantity	Reference	Manufacturer	Part Number	Description
1	ANT1	ChangHong	SMA-02-113-TGG	RP-SMA Connector
1	ANT2	Linx	ANT-2.4-CHP	SMD Antenna
1	BATT1	COMF	BH321-1P24	AA Battery Holder
1	BLN1	Murata	LDB-182G4510C-110	2.4 GHz Balun
1	C1	Various		0 ohm resistor used
2	C2,C3	N/A		Not Installed
1	C4	Taiyo Yuden	UVK-105CH0R3BW-F	0.3 pF/50V, 0402, high freq
2	C6,C7	Taiyo Yuden	UMK105C-G5R6DW-F	5.6 pF/50V, 0402, high freq
2	C8,C26	Various		10uF/10V, 0805, MLCC
11	C5, C9, C10, C12, C13, C19, C20, C23, C25, C28, C29	Various		0.1uF/50V, 0603
1	C11	Various		0.01 uF/50V, 0603
2	C14,C17	Various		100 uF/10V, Case-D, Tantalum
2	C15,C16	Various		12 pF/50V, 0603
1	C18	Various		1 uF/50V, 0603
2	C21,C22	Various		22pF/50V, 0603
2	C24,C27	Various		22uF/6.3V, 0805, MLCC
1	D1	Various		Red LED, 0805
1	D2	Various		Green LED, 0805
1	D4	Sanyo	SB1003M3	Schottky Diode
2	D3,D5	N/A		Not Installed
2	FB1,FB2	Various		Ferrite Bead, 0805
1	H4	Various		10x2 Right angle header, female, 0.100”
1	JP1	Various		1x3 Straight male header, 0.100”
1	JP2	Various		5x2 Straight male header, 0.100”

Quan-tity	Reference	Manufac-turer	Part Number	Description
1	J1	4UCON	09558	USB Mini-AB Connector
1	J2	4UCON	05537	DC Power Jack, 2.0 mm center conductor
1	L1	Taiyo Yuden	HK1005-1N8S-T	1.8 nH, 0402, high freq
1	L2	TDK	VLF4012AT	47 uH/360 mA SMD inductor
1	L3	N/A		Not Installed
2	R1,R2	Various		330 ohms, 0805
8	R3, R6, R7, R8, R9, R10, R12, R13	Various		10 kohms, 0603
2	R4,R5	Various		22 ohms, 0805
1	SW1	Switronic	IS-2235	DPDT slide switch
2	S1,S2	Various		SMD SPST Tactile Switch/ Pushbutton
1	U1	Atmel	AT86RF230	2.4 GHz, 802.15.4 radio
1	U2	Holtek	HT7733A	3.3V boost switching regulator, 200 mA
2	U3,U4	Atmel	ATMEGA32U4	AVR MCU, 32 kB flash, 2 kB RAM
1	VR1	NJRC	NJM2391-3.3	3.3V LDO voltage regulator, 1A
1	Y1	NDK	NX3225SA	16 MHz crystal, 15 ppm
1	Y2	Raltron	AS-8.000-20-F-SMD	8 MHz HC-49 SMD crystal, 30 ppm