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# FRDM-K64F Freedom Module User's Guide

## 1. Introduction

The NXP Freedom development platform is a set of software and hardware tools for evaluation and development. It is ideal for rapid prototyping of microcontroller-based applications. The NXP Freedom K64 hardware, FRDM-K64F, is a simple, yet sophisticated design featuring a Kinetis K series microcontroller, built on the ARM® Cortex®-M4 core.

FRDM-K64F can be used to evaluate the K64, K63, and K24 Kinetis K series devices. It features the MK64FN1M0VLL12 MCU, which boast the maximum operation frequency of 120 MHz, 1 MB of flash, 256 KB RAM, a full-speed USB controller, Ethernet controller, secure digital host controller, and analog and digital peripherals. The FRDM-K64F hardware is form-factor compatible with the Arduino™ R3 pin layout, providing a broad range of expansion board options. The onboard interface includes a six-axis digital accelerometer & magnetometer, RGB LED, SDHC, add-on Bluetooth module, add-on RF module, and Ethernet.

The FRDM-K64F platform features OpenSDAv2, the NXP open-source hardware embedded serial and debug adapter running an open-source bootloader. This circuit offers several options for serial communication, flash programming, and run-control debugging. OpenSDAv2 is an mbed™ HDK-compatible debug interface preloaded with the open-source CMSIS-DAP Interface firmware (mbed interface) for rapid prototyping and product development, with a focus on connected Internet of Things devices.

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## 2. FRDM-K64F Hardware Overview

The features of the FRDM-K64F hardware are as follows:

- MK64FN1M0VLL12 MCU (120 MHz, 1 MB flash memory, 256 KB RAM, low-power, crystal-less USB, and 100 LQFP)
- Dual role USB interface with micro-B USB connector
- RGB LED
- FXOS8700CQ – accelerometer and magnetometer
- Two user push buttons
- Flexible power supply option – OpenSDAv2 USB, K64 USB, and external source
- Easy access to MCU input/output through Arduino R3™ compatible I/O connectors
- Programmable OpenSDAv2 debug circuit supporting the CMSIS-DAP Interface software that provides:
  - Mass storage device (MSD) flash programming interface
  - CMSIS-DAP debug interface over a driver-less USB HID connection providing run-control debugging and compatibility with IDE tools
  - Virtual serial port interface
  - Open-source CMSIS-DAP software project: [github.com/mbedmicro/CMSIS-DAP](https://github.com/mbedmicro/CMSIS-DAP)
- Ethernet
- SDHC
- Add-on RF module: nRF24L01+ Nordic 2.4GHz Radio
- Add-on Bluetooth module: JY-MCU BT board V1.05 BT

*Figure 1* shows the block diagram of the FRDM-K64F design. The primary components and their placement on the hardware assembly are explained in *Figure 2*.

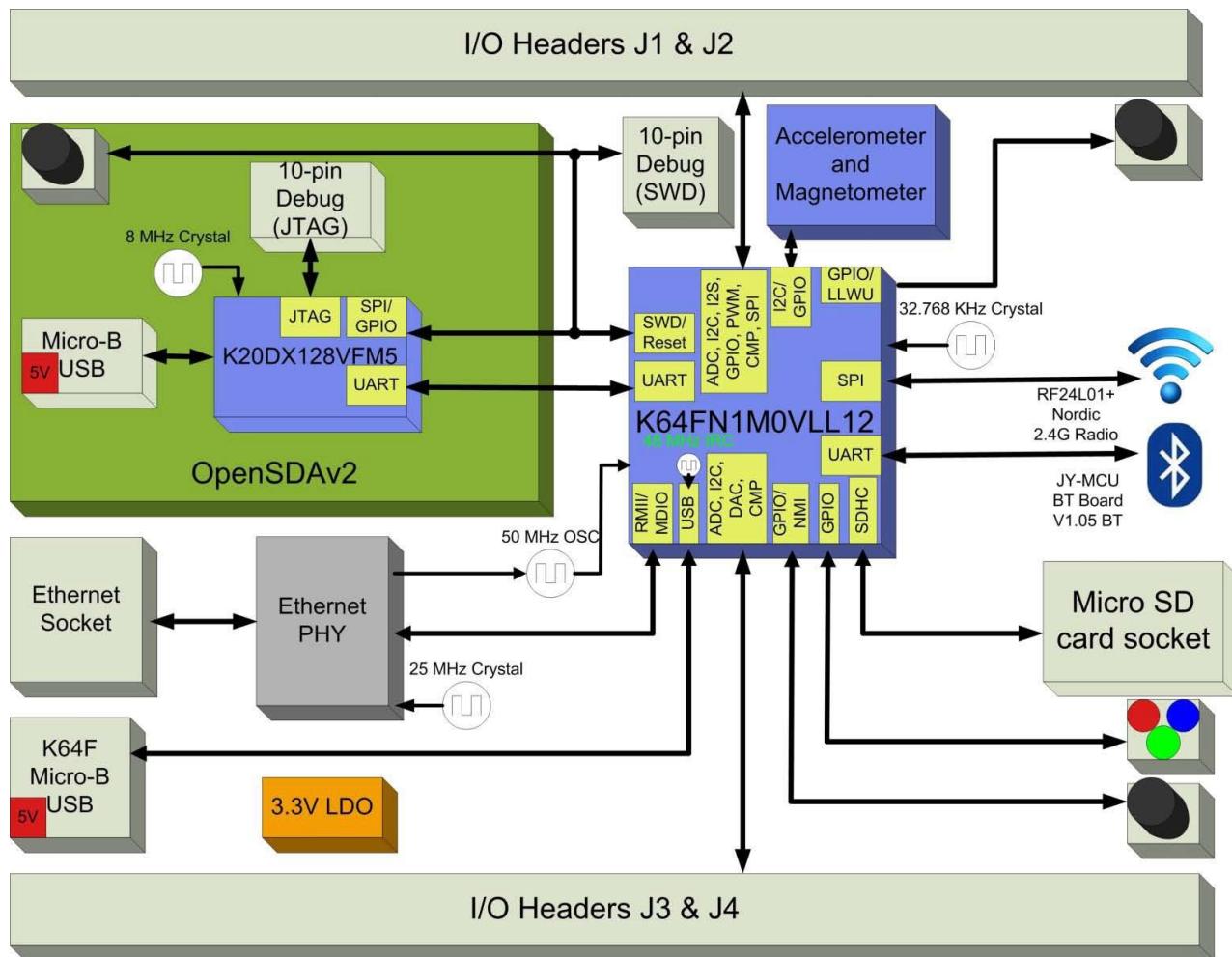


Figure 1. FRDM-K64F block diagram

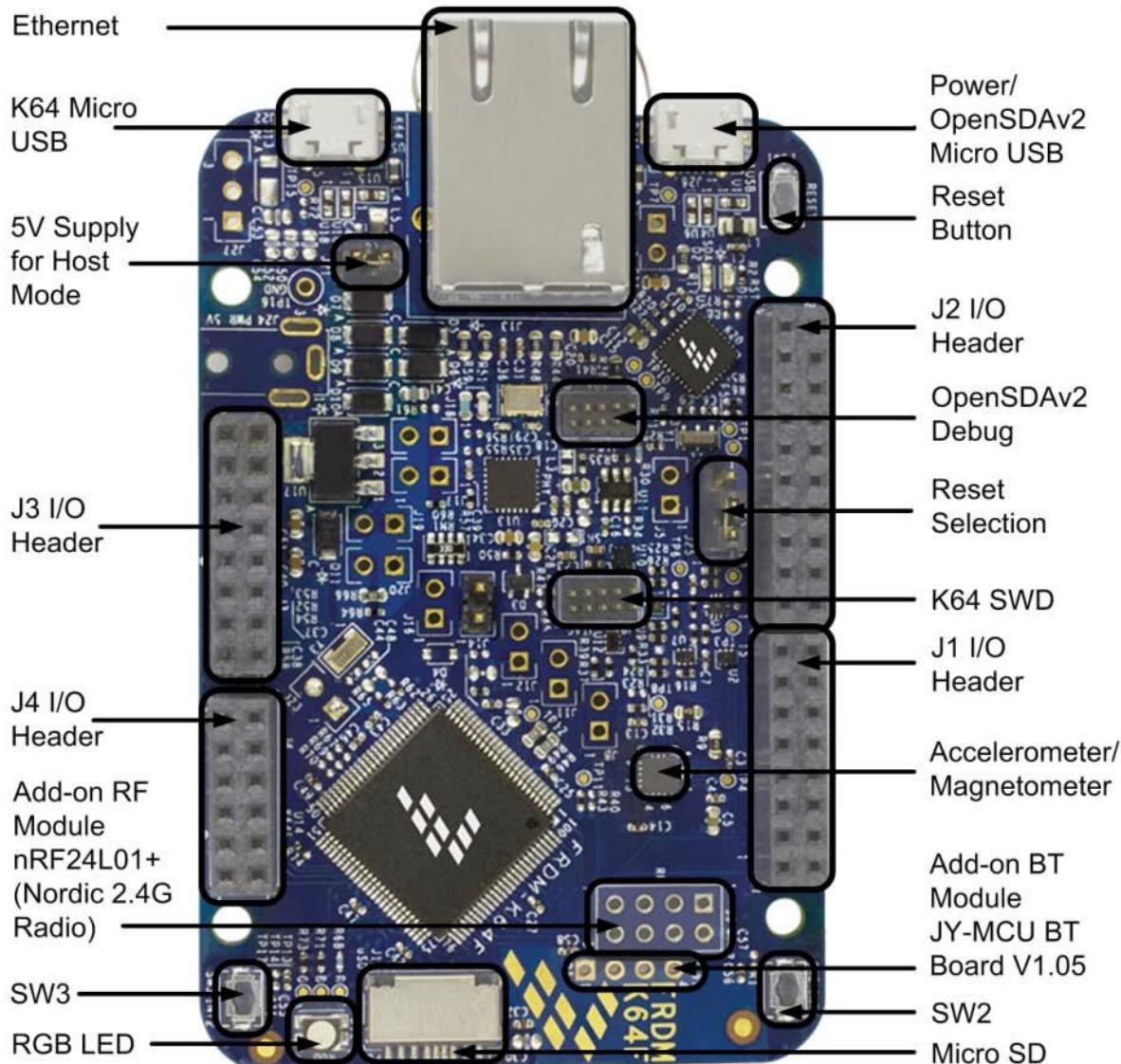


Figure 2. FRDM-K64F main components placement

### 3. FRDM-K64F Hardware Description

#### 3.1. Power supply

There are multiple power supply options on the FRDM-K64F board. It can be powered from either of the USB connectors, the VIN pin on the I/O header, DC Jack (not populated), or an offboard 1.71–3.6 V supply from the 3.3 V pin on the I/O header. The USB, DC jack, and VIN supplies are regulated onboard using a 3.3 V linear regulator to produce the main power supply. DC to DC linear regulator is not available in 3.3 V on J20 Header, however a direct supply to K64 MCU is available. [Table 1](#) provides the operational details and requirements for the power supplies.

Table 1. FRDM-K64F power requirements

| Supply source           | Valid range | OpenSDAv2 operational? | Regulated onboard? |
|-------------------------|-------------|------------------------|--------------------|
| OpenSDAv2 USB           | 5 V         | Yes                    | Yes                |
| K64 USB                 | 5 V         | No                     | Yes                |
| VIN Pin                 | 5-9 V       | No                     | Yes                |
| 3.3V Header (J20)       | 1.71-3.6 V  | No                     | No                 |
| DC Jack (Not Populated) | 5-9 V       | No                     | Yes                |

## NOTE

The OpenSDAv2 circuit is only operational when a USB cable is connected and supplying power to OpenSDAv2 USB. However, the protection circuitry is in place to enable multiple sources to be powered at once.

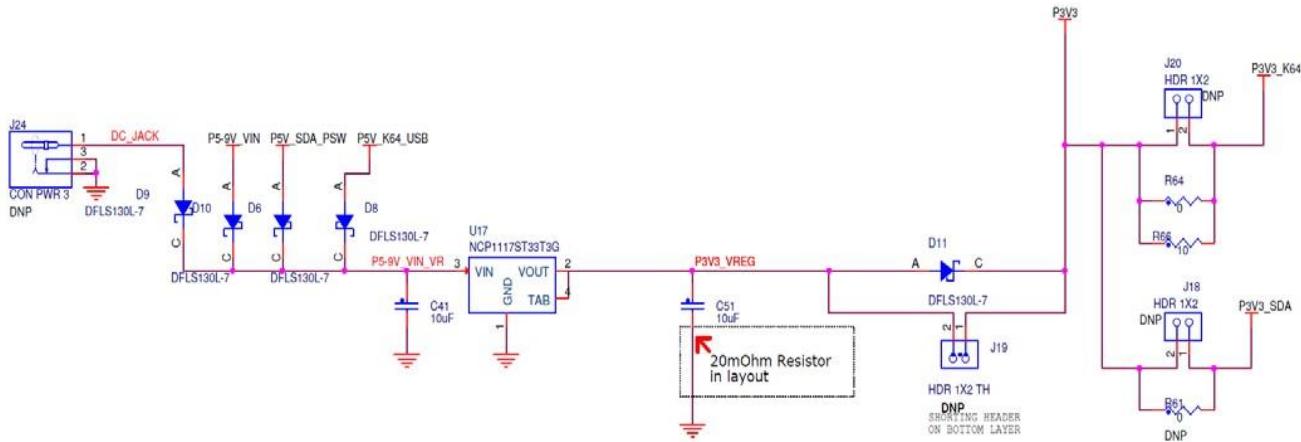


Figure 3. Power supply schematic

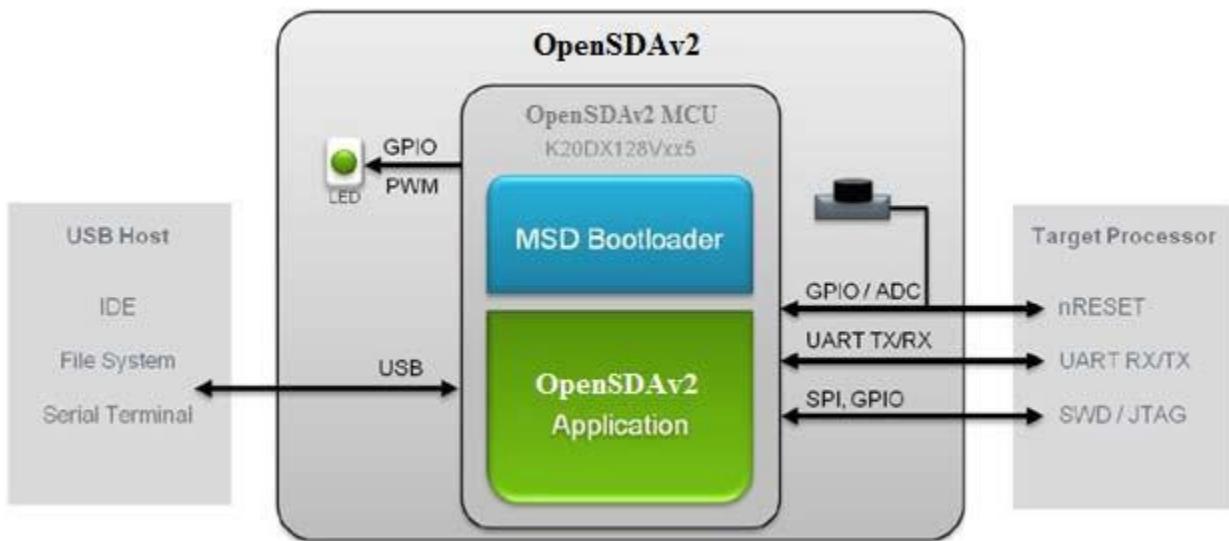
Table 2. FRDM-K64F power supplies

| Power supply name | Description   |
|-------------------|---|
| P5-9V_VIN         | Power supplied from the <b>VIN</b> pin of the I/O headers (J3 pin 16). A Schottky diode provides back drive protection.           |
| P5V_SDA_PSW       | Power supplied from the <b>OpenSDAv2 USB</b> connector. A Schottky diode provides back drive protection.                          |
| P5V_K64_USB       | Power supplied from the <b>K64 USB</b> connector. A Schottky diode provides back drive protection.                                |
| DC_JACK           | Power supplied from the <b>DC Jack</b> (not populated) connector. A Schottky diode provides back drive protection.                |
| P3V3_VREG         | <b>Regulated 3.3V supply.</b> Sources power to the P3V3 supply rail through a back drive protection Schottky diode <sup>1</sup> . |
| P3V3_K64          | <b>K64 MCU supply.</b> Header J20 provides a convenient means for energy consumption measurements <sup>2</sup> .                  |
| P3V3_SDA          | <b>OpenSDAv2 circuit supply.</b> Header J18 provides a convenient means for energy consumption measurements.                      |
| P5V_USB           | <b>Nominal 5 V supplied to the I/O headers</b> (J3 pin 10).   |

1. By default, the linear regulator, U17, is a 3.3 V output regulator. This is a common footprint that would allow the user to modify the assembly to utilize an alternative device, such as 1.8 V. The K64 microcontroller has an operating range of 1.71 V to 3.6 V.
2. By default, the J18 and J20 headers are populated. P3V3\_K64 rail is connected with two resistors, R64 and R66. To measure the energy consumption of the K64 MCU, the trace between J20 pin 1 and 2 must be first cut. A current probe or shunt resistor and voltage meter can then be applied to measure the energy consumption on these rails.

### 3.2. Serial and Debug Adapter version 2 (OpenSDAv2)

OpenSDAv2 is a serial and debug adapter circuit which includes an open-source hardware design, an open-source bootloader, and debug interface software. It bridges serial and debug communications between a USB host and an embedded target processor as shown in *Figure 4*. The hardware circuit is based on an NXP Kinetis K20 family microcontroller (MCU) with 128 KB of embedded flash and an integrated USB controller. OpenSDAv2 comes preloaded with the CMSIS-DAP bootloader – an open-source mass storage device (MSD) bootloader and the CMSIS-DAP Interface firmware (aka mbed interface), which provides a MSD flash programming interface, a virtual serial port interface, and a CMSIS-DAP debug protocol interface. For more information on the OpenSDAv2 software, see [mbed.org](http://mbed.org) and <https://github.com/mbedmicro/CMSIS-DAP>.

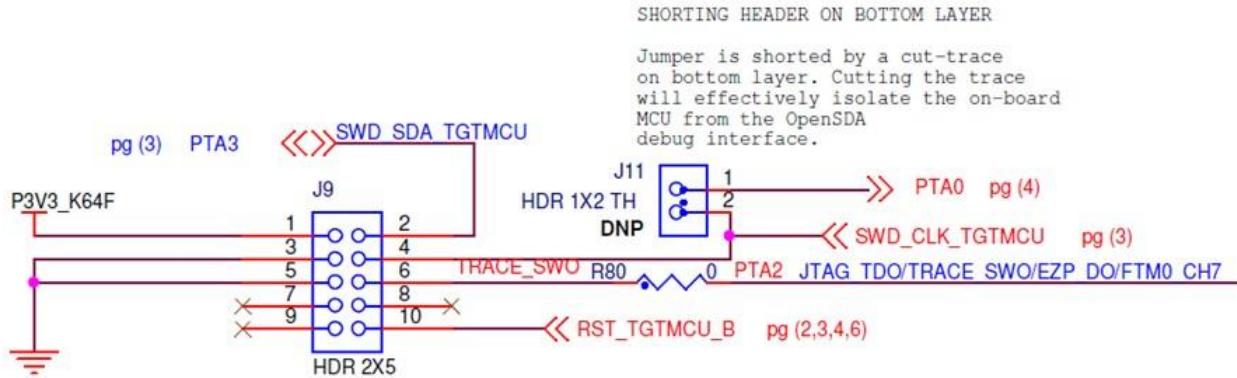


**Figure 4. OpenSDAv2 high-level block diagram**

OpenSDAv2 is managed by a Kinetis K20 MCU built on the ARM Cortex-M4 core. The OpenSDAv2 circuit includes a status LED (D2) and a pushbutton (SW1). The pushbutton asserts the Reset signal to the K64 target MCU. It can also be used to place the OpenSDAv2 circuit into bootloader mode. SPI and GPIO signals provide an interface to either the SWD debug port or the K20. Additionally, signal connections are available to implement a UART serial channel. The OpenSDAv2 circuit receives power when the USB connector J26 is plugged into a USB host.

#### Debug interface

Signals with SPI and GPIO capability are used to connect directly to the SWD of K64. These signals are also brought out to a standard 10-pin (0.05") Cortex debug connector (J9). It is possible to isolate the K64 MCU from the OpenSDAv2 circuit and use J9 to connect to an offboard MCU. To accomplish this, cut the trace on the bottom side of the PCB that connects J11 pin 2 to J9 pin 4. This will disconnect the SWD\_CLK pin to the K64 so that it will not interfere with the communications to an offboard MCU connected to J11.



**Figure 5. SWD debug connector**

J9 is populated by default. A mating cable, such as a Samtec FFSD IDC cable, can then be used to connect from the OpenSDAv2 of the FRDM-K64F to an offboard SWD connector.

### Virtual serial port

A serial port connection is available between the OpenSDAv2 MCU and pins PTB16 and PTB17 of the K64.

## 4. Microcontroller

The FRDM-K64F features the MK64FN1M0VLL12 MCU. This 120 MHz microcontroller is part of the Kinetis K6x family and is implemented in a 100 LQFP package. The following table describes some of the features of the MK64FN1M0VLL12 MCU.

**Table 3. Features of MK64FN1M0VLL12**

| Feature         | Description  |
|-----------------|--|
| Ultra low-power | <ul style="list-style-type: none"> <li>11 low-power modes with power and clock gating for optimal peripheral activity and recovery times.</li> <li>Full memory and analog operation down to 1.71 V for extended battery life</li> <li>Low-leakage wake-up unit with up to six internal modules and sixteen pins as wake-up sources in low-leakage stop (LLS)/very low-leakage stop (VLLS) modes</li> <li>Low-power timer for continual system operation in reduced power states</li> </ul> |
| Flash and SRAM  | <ul style="list-style-type: none"> <li>1024-KB flash featuring fast access times, high reliability, and four levels of security protection</li> <li>256 KB of SRAM</li> <li>No user or system intervention to complete programming and erase functions and full operation down to 1.71 V</li> </ul>  |

**Table 3. Features of MK64FN1M0VLL12**

| Feature                         | Description   |
|---------------------------------|---|
| Mixed-signal capability         | <ul style="list-style-type: none"> <li>High-speed 16-bit ADC with configurable resolution</li> <li>Single or differential output modes for improved noise rejection</li> <li>500 ns conversion time achievable with programmable delay block triggering</li> <li>Two high-speed comparators providing fast and accurate motor overcurrent protection by driving PWMs to a safe state</li> <li>Optional analog voltage reference provides an accurate reference to analog blocks</li> <li>One 12-bit DACs</li> </ul>   |
| Performance                     | <ul style="list-style-type: none"> <li>120 MHz ARM Cortex-M4 core with DSP instruction set, single precision floating point unit, single cycle MAC, and single instruction multiple data (SIMD) extensions</li> <li>Up to four channel DMA for peripheral and memory servicing with reduced CPU loading and faster system throughput</li> <li>Cross bar switch enables concurrent multimaster bus accesses, increasing bus bandwidth</li> <li>Independent flash banks allowing concurrent code execution and firmware updating with no performance degradation or complex coding routines</li> </ul>  |
| Timing and control              | <ul style="list-style-type: none"> <li>Four Flex Timers with a total of 20 channels</li> <li>Hardware dead-time insertion and quadrature decoding for motor control</li> <li>Carrier modulator timer for infrared waveform generation in remote control applications</li> <li>Four-channel 32-bit periodic interrupt timer provides time base for RTOS task scheduler or trigger source for ADC conversion and programmable delay block</li> <li>One low-power timer</li> <li>One independent real-time clock</li> </ul>  |
| Connectivity and communications | <ul style="list-style-type: none"> <li>Full-Speed USB device/host/on-the-go with device charge detect capability</li> <li>Optimized charging current/time for portable USB devices, enabling longer battery life</li> <li>USB low-voltage regulator supplies up to 120 mA off-chip at 3.3 volts to power external components from 5-volt input</li> <li>Five UARTs: <ul style="list-style-type: none"> <li>One UART supports RS232 with flow control, RS485, and ISO7816</li> <li>Four UARTs support RS232 with flow control and RS485</li> </ul> </li> <li>One Inter-IC Sound (I2S) serial interface for audio system interfacing</li> <li>Three DSPI modules and three I2C modules</li> <li>Secured digital host controller (SDHC)</li> <li>One FlexCAN module</li> <li>One Ethernet module with 1588</li> <li>A multifunction external bus interface (FlexBUS) controller capable of interfacing to slave-only devices.</li> </ul> |

Table 3. Features of MK64FN1M0VLL12

| Feature                          | Description  |
|----------------------------------|--|
| Reliability, safety and security | <ul style="list-style-type: none"> <li>Hardware encryption coprocessor for secure data transfer and storage. Faster than software implementations and with minimal CPU loading. Supports a wide variety of algorithms - DES, 3DES, AES, MD5, SHA-1, SHA-256</li> <li>Memory protection unit provides memory protection for all masters on the cross bar switch, increasing software reliability</li> <li>Cyclic redundancy check (CRC) engine validates memory contents and communication data, increasing system reliability</li> <li>Independently-clocked COP guards against clock skew or code runaway for fail-safe applications, such as the IEC 60730 safety standard for household appliances</li> <li>External watchdog monitor drives output pin to safe state for external components in the event that a watchdog timeout occurs</li> <li>Included in NXP product longevity program, with assured supply for a minimum of 10 years after launch</li> </ul> |

## 5. Clocking

The Kinetis MCU startup from an internal digitally-controlled oscillator (DCO). Software can enable the main external oscillator (EXTAL0/XTAL0) if desired. The external oscillator/resonator can range from 32.768 KHz up to 50 MHz. The default external source for the MCG oscillator inputs (EXTAL) is 50 MHz clock source from Micrel Ethernet PHY.

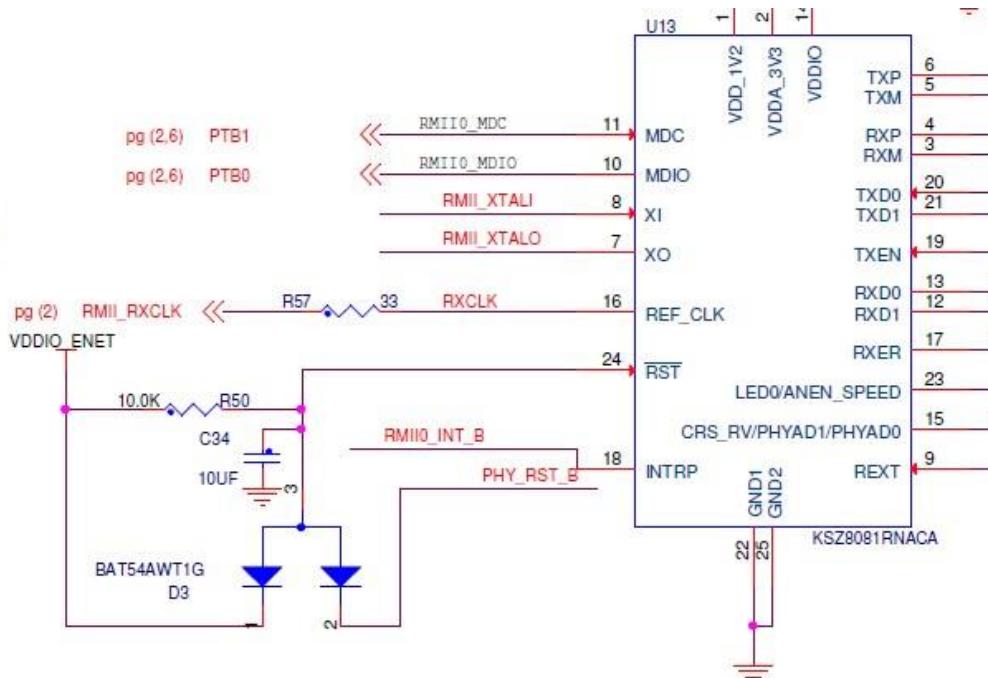


Figure 6. Micrel PHY provides 50 MHz for MCU

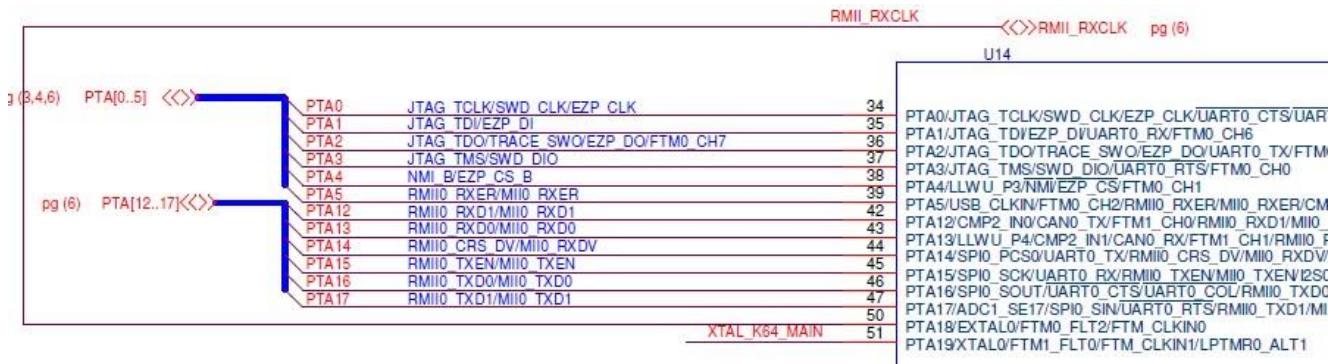


Figure 7. MCU receives RMII clock from Micrel Ethernet PHY

By default, the 32.768 KHz crystal is connected to the RTC oscillator inputs.

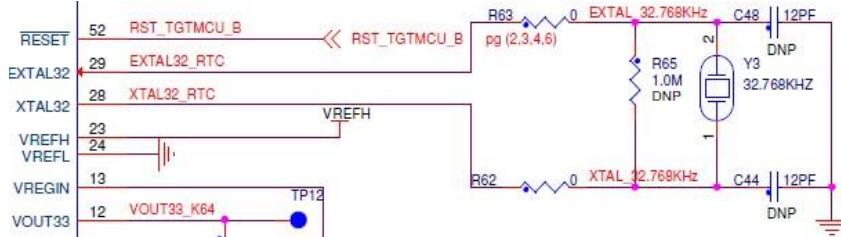


Figure 8. 32.768 KHz crystal for RTC

## 6. USB

The MK64FN1M0VLL12 MCU features a full-speed/low-speed USB module with on-the-go/host/device capability and built-in transceiver. The FRDM-K64F board routes the USB D+ and D- signals from the MK64FN1M0VLL12 MCU directly to the onboard micro USB connector (J22).

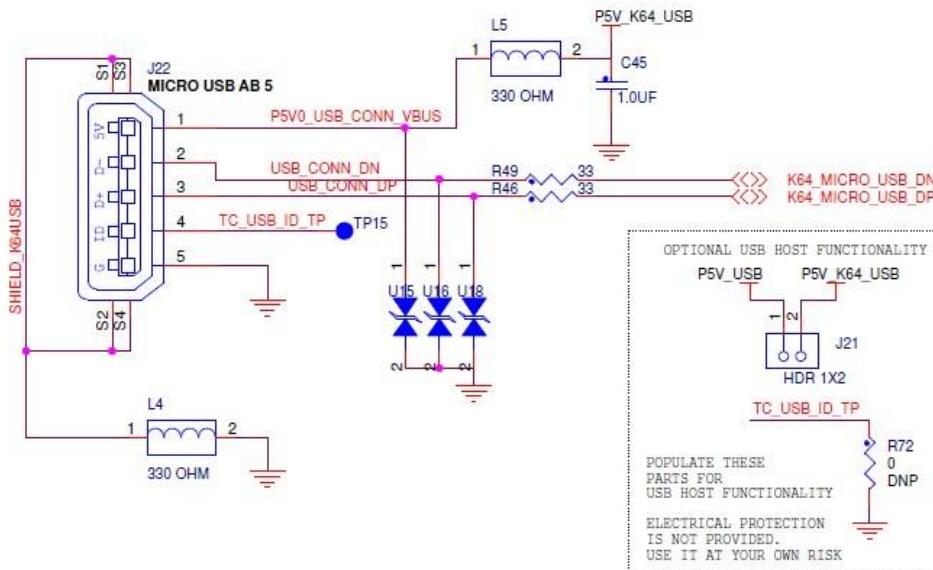


Figure 9. K64 USB port

When the FRDM-K64F board is operating in USB host mode, J21 must be shunt to supply 5 V power from VBUS (J22). The source of 5 V power can be OpenSDAv2 USB port (J26), pin 10 of J3 I/O header, and P5-9V\_VIN DC-DC converter of J27.

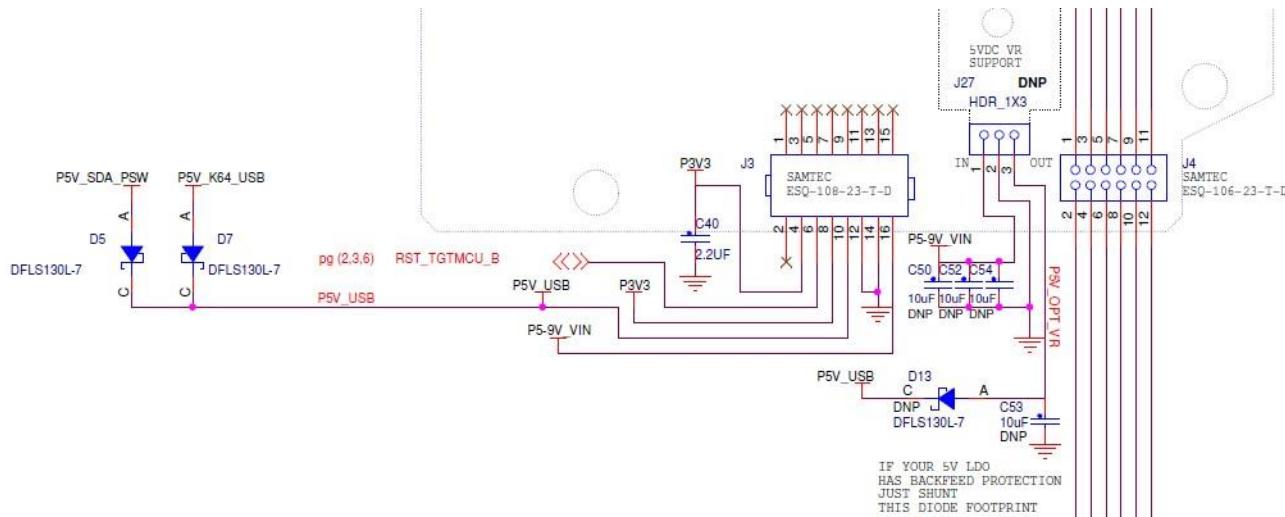


Figure 10. K64 USB power input for host mode

## 7. Secure Digital Card

A micro Secure Digital (SD) card slot is available on the FRDM-K64F connected to the SD Host Controller (SDHC) signals of the MCU. This slot will accept micro format SD memory cards. The SD card detect pin is an open switch that shorts with V<sub>DD</sub> when card is inserted. [Table 4](#) describes the SDHC signal connection details of micro SD card.

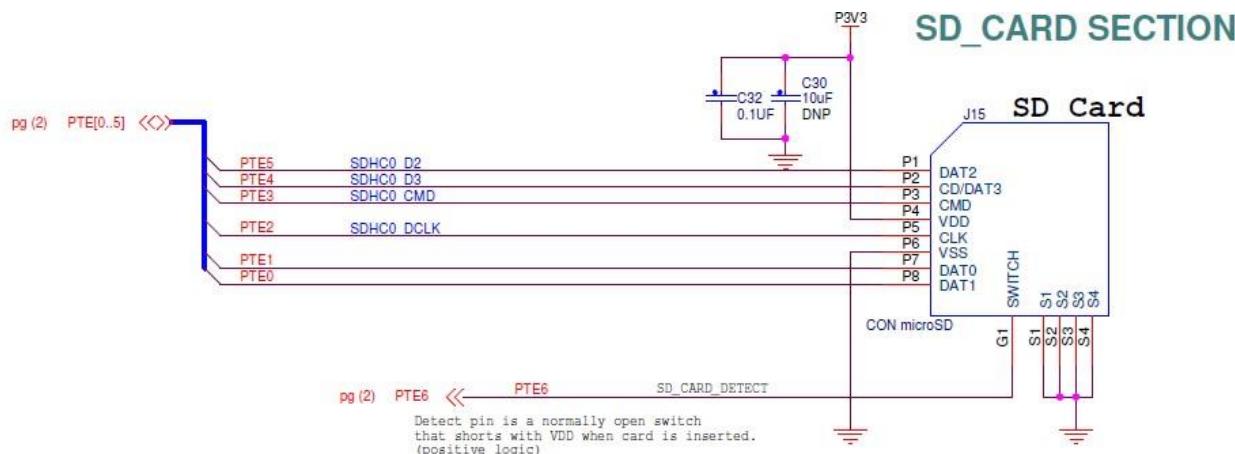


Figure 11. Micro SD interface

Table 4. Micro SD card socket connection

| Pin | Function | TWR-K64120M connection   |
|-----|----------|--|
| 1   | DAT2     | PTE5/SPI1_PCS2/UART3_RX/ <b>SDHC0_D2</b> /FTM3_CH0                               |
| 2   | CD/DAT3  | PTE4/LLWU_P2/SPI1_PCS0/UART3_TX/ <b>SDHC0_D3</b> /TRACE_D0                       |
| 3   | CMD      | PTE3/ADC0_DM2/ADC1_SE7A/SPI1_SIN/UART1_RTS/ <b>SDHC0_CMD</b> /TRACE_D1/SPI1_SOUT |

Table 4. Micro SD card socket connection

| Pin   | Function       | TWR-K64120M connection  |
|-------|----------------|---|
| 4     | VDD            | 3.3 V board supply (V_BRD)  |
| 5     | CLK            | PTE2/LLWU_P1/ADC0_DP2/ADC1_SE6A/SPI1_SCK/UART1_CTS/SDHC0_DCLK/TRACE_D2        |
| 6     | VSS            | Ground  |
| 7     | DAT0           | PTE1/LLWU_P0/ADC1_SE5A/SPI1_SOUT/UART1_RX/SDHC0_D0/TRACE_D3/I2C1_SCL/SPI1_SIN |
| 8     | DAT1           | PTE0/ADC1_SE4A/SPI1_PCS1/UART1_TX/SDHC0_D1/TRACE_CLKOUT/I2C1_SDA/RT_C_CLKOUT  |
| G1    | SWITCH         | PTE6/SPI1_PCS3/UART3_CTS_b/I2S0_MCLK/FTM3_CH1/USB0_SOF_OUT                    |
| S1-S4 | S1, S2, S3, S4 | Shield ground   |

## 8. Ethernet

The MK64FN1M0VLL12 MCU features a 10/100 MB/s Ethernet MAC with MII and RMII interfaces. The FRDM-K64F board routes RMII interface signals from the K64 MCU to the onboard Micrel 32-pin Ethernet PHY.

When the K64 Ethernet MAC is operating in RMII mode, synchronization of MCU clock and 50 MHz RMII transfer clock is important. The MCU input clock must be kept in phase with external PHY. The 32-pin Micrel Ethernet PHY has the ability to provide 50 MHz clock to MK64FN1M0VLL12 MCU EXTAL0 and Ethernet PHY itself.

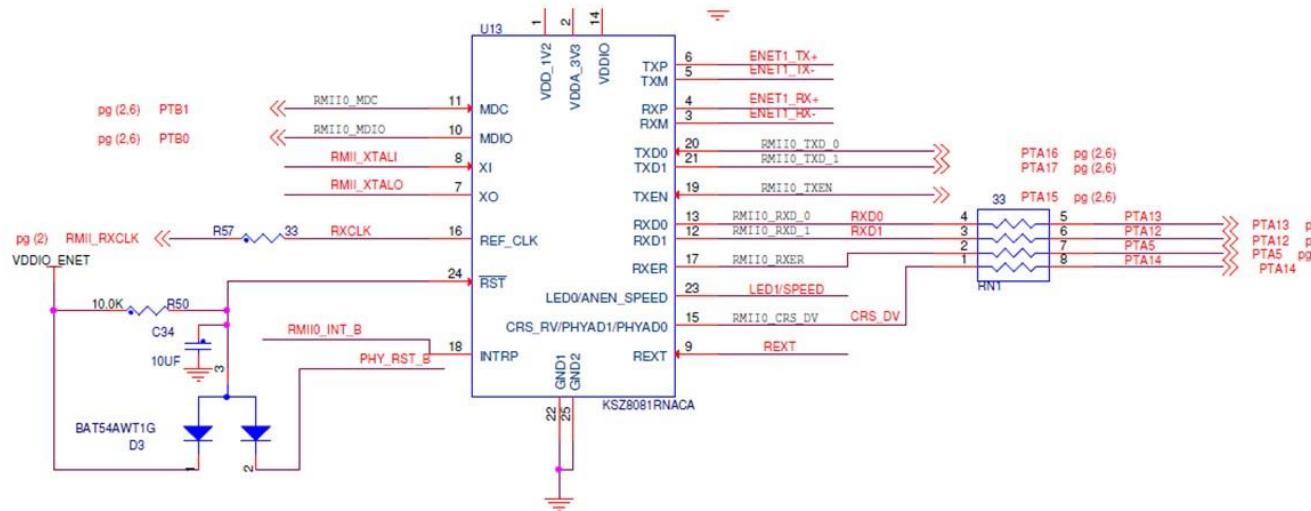


Figure 12. RMII to Ethernet PHY

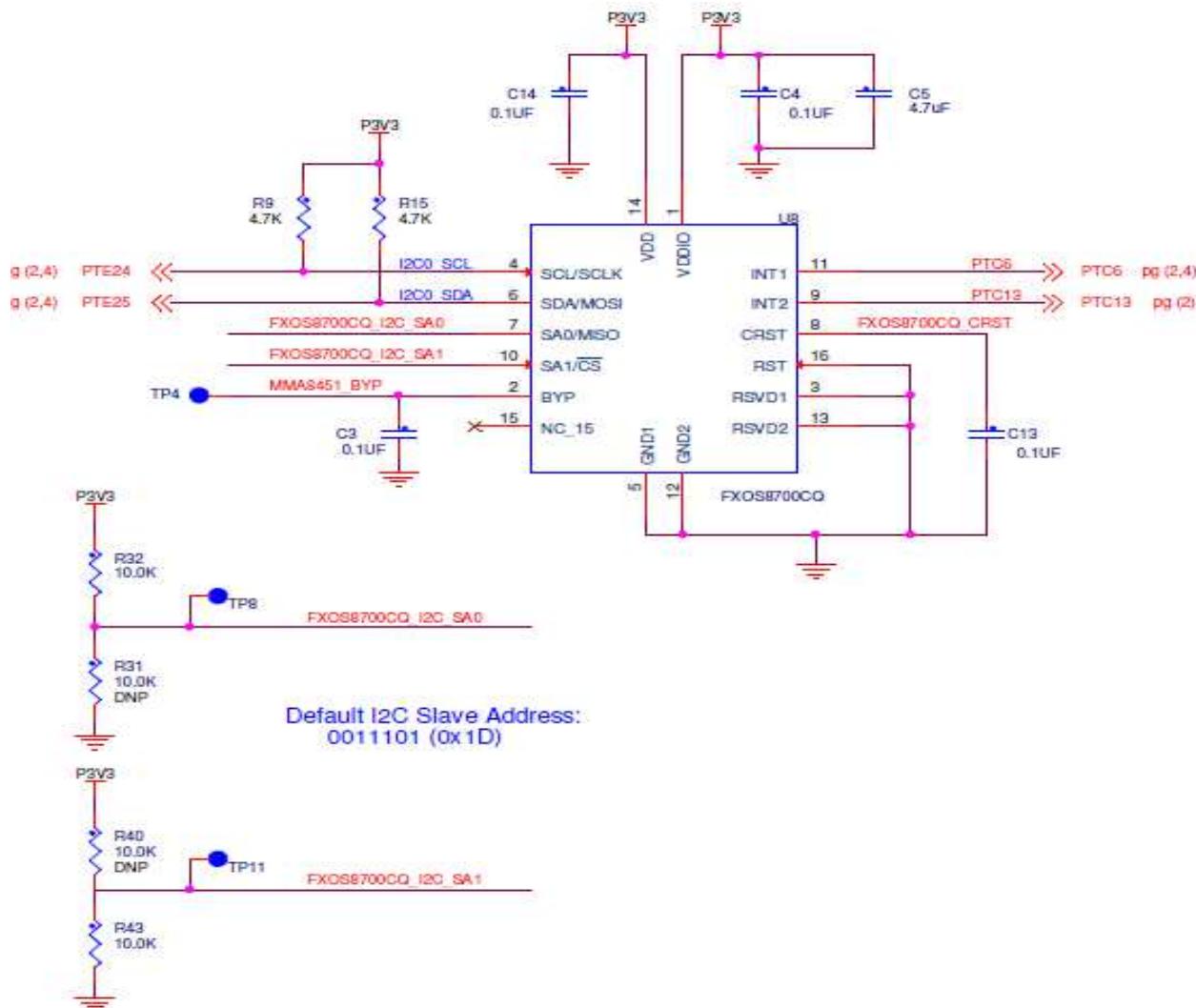
No external pullup is available on MDIO signal when MK64FN1M0VLL12 MCU is requests status of the Ethernet link connection. Internal pullup is required when port configuration for MDIO signal is enabled.

## 9. Accelerometer and Magnetometer

An NXP FXOS8700CQ low-power, six-axis Xtrinsic sensor is interfaced through an I<sup>2</sup>C bus and two GPIO signals, as shown in [Table 5](#). By default, the I<sup>2</sup>C address is 0x1D (SA0 pullup and SA1 pulldown).

**Table 5. Accelerometer and magnetometer signals connection**

| FXOS8700CQ | K64  |
|------------|--|
| SCL        | PTE24/UART4_TX/I2C0_SCL/EWM_OUT_b                                |
| SDA        | PTE25/UART4_RX/I2C0_SDA/EWM_IN                                   |
| INT1       | PTC6/SPI0_SOUT/PDB0_EXTRG/I2S0_RX_BCLK/FB_AD9/I2S0_MCLK/LLWU_P10 |
| INT2       | PTC13/UART4_CTS_b/FB_AD26  |



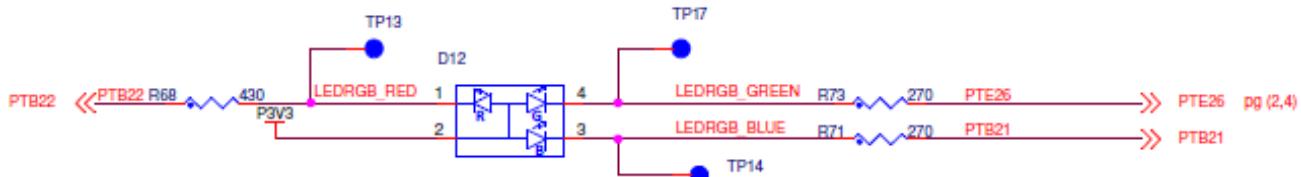
**Figure 13. Accelerometer and magnetometer**

## 10. RGB LED

RGB LED is connected through GPIO, signal connections are shown in *Table 6*.

**Table 6. LED signal connections**

| LED   | K64   |
|-------|---|
| RED   | PTB22/SPI2_SOUT/FB_AD29/CMP2_OUT                        |
| BLUE  | PTB21/SPI2_SCK/FB_AD30/CMP1_OUT                         |
| GREEN | PTE26/ENET_1588_CLKIN/UART4_CTS_b/RTC_CLKOUT/USB0_CLKIN |



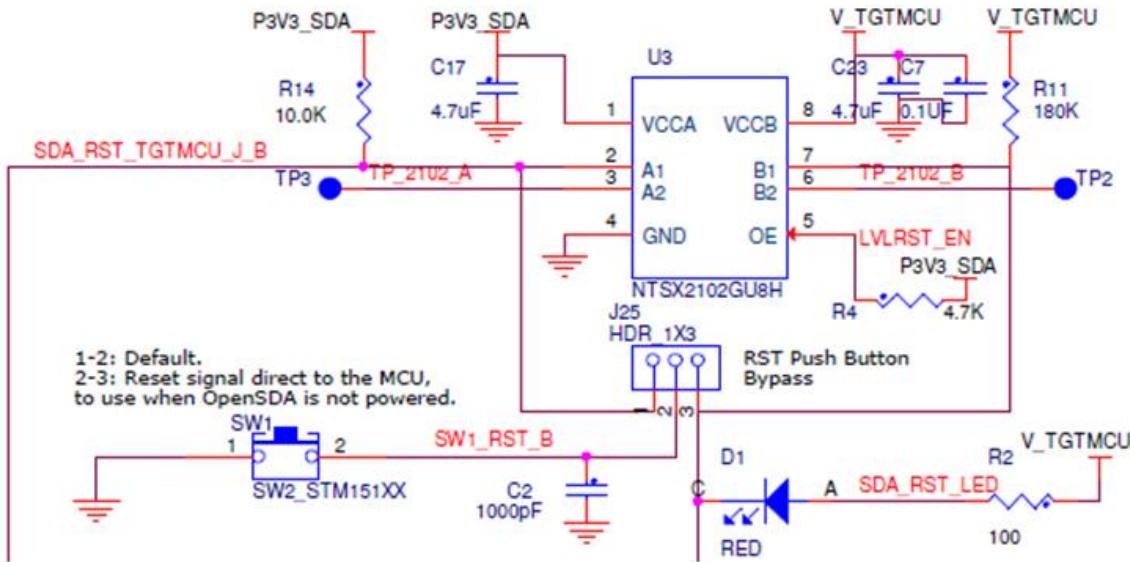
**Figure 14. Tricolor LED**

## 11. Serial Port

The primary serial port interface signals are PTB16 UART1\_RX and PTB17 UART1\_TX. These signals are connected to the OpenSDAv2 circuit.

## 12. Reset

The RESET signal on the K20 is connected externally to a pushbutton, named SW1, and also to the OpenSDAv2 circuit. The reset button can be used to force an external reset event on the target MCU. The reset button can also be used to force the OpenSDAv2 circuit into boot loader mode. For more details, see [Serial and debug adapter \(OpenSDAv2\)](#).



**Figure 15.** Reset circuit

## 13. Push Button Switches

Two push buttons, SW2 and SW3, are available on FRDM-K64F board, where SW2 is connected to PTC6 and SW3 is connected to PTA4. Besides the general purpose input/output functions, SW2 and SW3 can be low-power wake up signal. Also, only SW3 can be a non-maskable interrupt.

Table 7. Push button GPIO function

| Switch | GPIO Function   |
|--------|---|
| SW2    | PTC6/SPI0_SOUT/PD0_EXTRG/I2S0_RX_BCLK/FB_AD9/I2S0_MCLK/LLWU_P10 |
| SW3    | PTA4/FTM0_CH1/NMI_b/LLWU_P3                                     |

## 14. Debug

The debug interface on MK64FN1M0VLL12 MCU is a Serial Wire Debug (SWD) port with trace output capability. There are two debug interfaces on the FRDM-K64F: onboard OpenSDAv2 circuit (J26) and K64 direct SWD connection (J9).

### NOTE

To use an external debugger, such as J-Link, you may need to disconnect the OpenSDA SWD from the K64. To do this on the FRDM-K64F board, cut the shorting trace which connects the pins of jumper holes on connectors J8 and J12.

## 15. Add-on modules

### 15.1. RF module

The Add-on 2.4GHz interface on FRDM-K64F board is using SPI to interface with nRF24L01+ Nordic 2.4G Radio module. Alternatively, any SPI based device or module could be used with this connector.

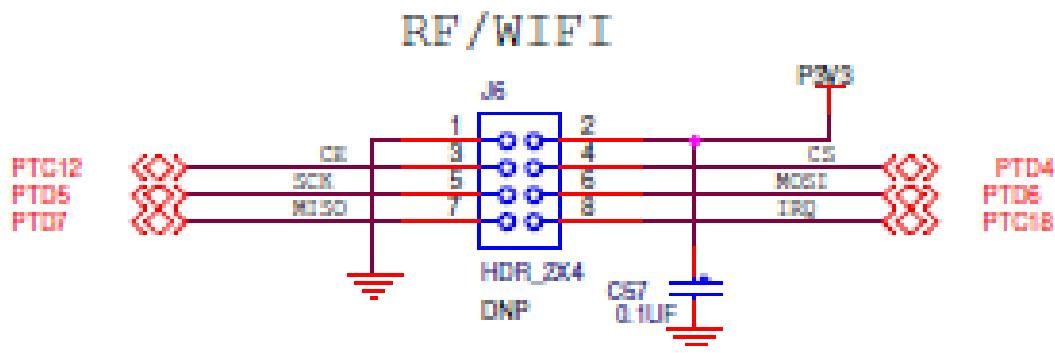


Figure 16. Add-on 2.4GHz ISM module

## 15.2. Bluetooth module

The Add-on Bluetooth interface on FRDM-K64F board is using UART to interface with JY-MCU BT board V1.05 BT. Alternatively any serial (SCI) module can be used with this connector. Consider that the signals are not conforming to the RS-232 logic levels, and are 0–3.3 V only. A level shifter, like Maxim DS3232, should be used with RS-232 devices through proper RS-232 logic levels.

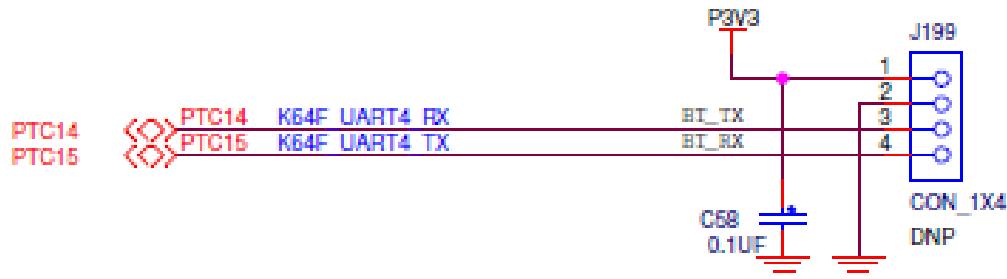


Figure 17. Add-on Bluetooth module

## 16. Input/output connectors

The MK64FN1M0VLL12 microcontroller is packaged in a 100-pin LQFP. Some pins are utilized in onboard circuitry, but some are directly connected to one of the four I/O headers.

The pins on the K64 microcontroller are named for their general purpose input/output port pin function. For example, the first pin on Port A is referred as PTA1. The name assigned to the I/O connector pin is same as of the K64 pin connected to it, if applicable.

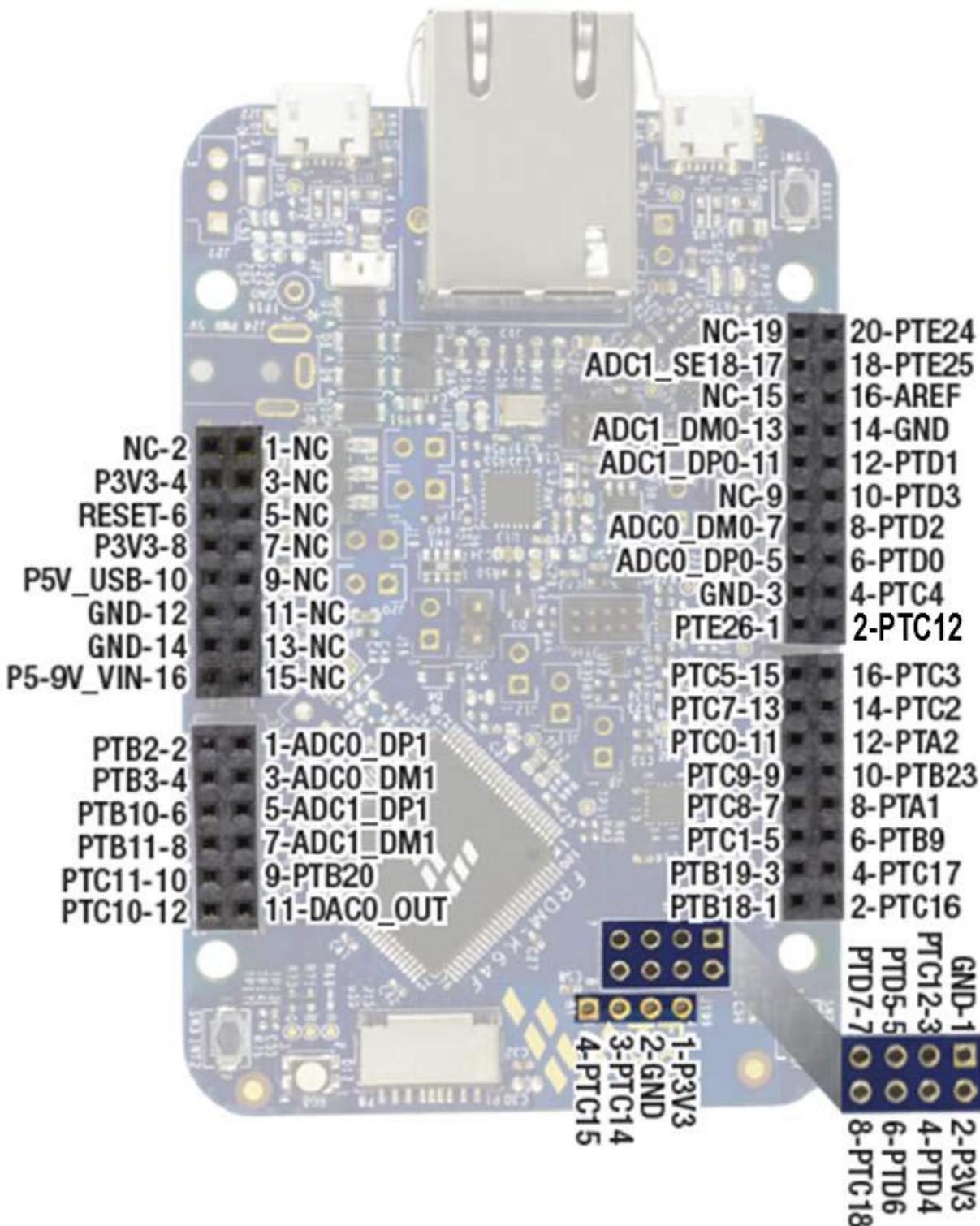


Figure 18. FRDM-K64F pinout

## 17. Arduino Compatibility

The I/O headers on the FRDM-K64F board are arranged to enable compatibility with peripheral boards (known as shields) that connect to Arduino and Arduino-compatible microcontroller boards. The outer rows of pins (even numbered pins) on the headers, share the same mechanical spacing and placement with the I/O headers on the Arduino Revision 3 (R3) standard.

## 18. References

The following references are available on [nxp.com](http://nxp.com):

- FRDMK64FQSG, FRDM-K64F Quick Start Guide
- FRDM-K64F Pinouts
- FRDM-K64F-SCH, FRDM-K64F Schematic
- FRDM-K64F Design Package

## 19. Revision History

**Table 8. Revision history**

| Revision number | Date    | Substantive changes   |
|-----------------|---------|---|
| 0               | 06/2015 | Initial release   |
| 1               | 08/2016 | <ul style="list-style-type: none"> <li>• Update <a href="#">Table 6</a></li> <li>• Add a note in <a href="#">Debug</a></li> </ul> |



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