freescale semiconductor

# FRDM-KE02Z

## User's Manual

Rev. 0

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# Revision History

| Revision | Date | Changes |
|---|---|---|
| 0 | 4/17/2014 | Initial version |
| | | |

# 1 Overview

The Freescale Freedom development platform is an evaluation and development tool ideal for rapid prototyping of microcontroller-based applications. The hardware design is form-factor compatible with popular third-party hardware designed to work with Arduino™ and Arduino-compatible boards.

The Freescale KE02Z freedom board (FRDM-KE02Z) is a simple, yet sophisticated design featuring a Kinetis E Series microcontroller KE02Z64VQH2, the industry's first microcontroller built on the ARM® Cortex™-M0+ core with 0.18um process.
The Kinetis E series is the most scalable portfolio of low-power, high-robustness, mixed signal 32-bit ARM Cortex-M0+ MCUs running up to 20MHz in the industry based on .18um process. It supports power supply voltage range from 2.7V to 5.5V, ambient operating temperature ranges from -40C to 105C and includes up to 64KB flash.

The FRDM-KE02Z includes the Freescale open standard embedded serial and debug adapter known as OpenSDA. This circuit offers the user several options for serial communications, flash programming and run-control debugging.

There are also many software development tool options available to the user. Choices include CodeWarrior for Microcontrollers, IAR Embedded Workbench, Keil MDK featuring the µVision IDE, Red Suite from Code Red Technologies, Atollic TrueSTUDIO, Rowley Crossworks, and more.

All of these features combine to give the user the freedoms needed to rapidly prototype many embedded designs: a powerful microcontroller built on a very low-power core and SoC platform, easy-access to I/O with a large ecosystem of compatible hardware, a flexible programming and debug interface, and a large ecosystem of software development environments. Freedom!

# 2 Reference Documents

| | |
|---|---|
| OpenSDA User's Guide | – A guide for users of the OpenSDA embedded circuit. |
| KE02 Sub-Family Reference Manual | - A reference manual for KE02 sub-family devices |
| Arduino Overview | - A guide of Arduion platform |
| Arduino Uno | - A guide of Arduion Uno revision |

# 3 Getting Started

Refer to the *FRDM-KE02Z Quick Start Package* for step-by-step instructions for getting started with the FRDM-KE02Z. See the ***Jump Start Your Design*** section on http://www.freescale.com/FRDM-KE02Z for the Quick Start Package and software lab guides.

# 4 FRDM-KE02Z Hardware Overview

The FRDM-KE02Z hardware is a Freescale Freedom development platform microcontroller board assembled with the following features:

- Kinetis E Series KE02 family MCU in an 64 QFP package (14x14 document number: 98ASB42844B)
- On-board serial and debug adapter (OpenSDA)
- I/O headers for easy access to MCU I/O pins
- Freescale inertial sensor, MMA8451Q
- Capacitive touch slider
- Reset pushbutton
- RGB LED
- infrared communication
- 1 thermistor
- Motor control header for simple BLDC motor control on APMOTOR56F8000E

Figure 1 shows a block diagram of the FRDM-KE02Z board.

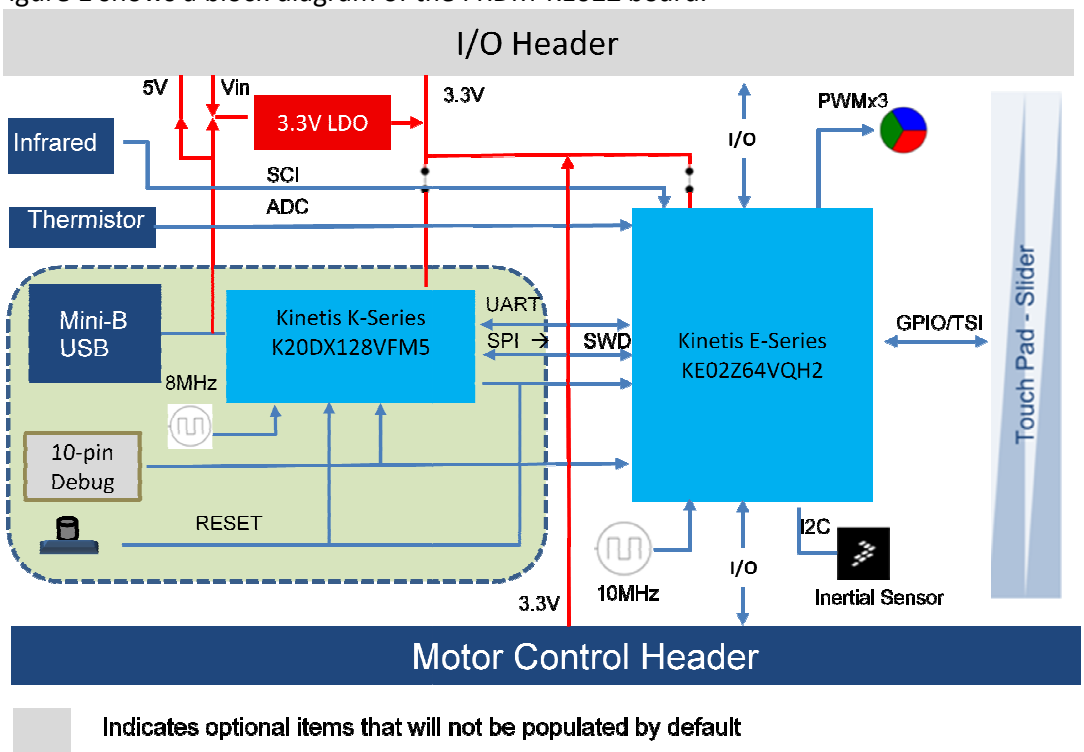



**Figure 1.** FRDM-KE02Z Block Diagram

The FRDM-KE02Z features two microcontrollers (MCUs): the target MCU and a serial and debug adapter (OpenSDA) MCU. The target MCU is a Kinetis E Series MA64 family device, the KE02Z64VQH2. The OpenSDA MCU is a Kinetis K Series K20 family device, the K20DX128VFM5.

Features of the KE02Z64 target MCU include:

- 32-bit ARM Cortex-M0+ core
  - up to 20 MHz operation
  - Single-cycle fast I/O access port
- Memories
  - 64 KB flash and 256B D-flash as EEPROM
  - 4 KB SRAM
- System integration
  - Power management and mode controllers
  - Low-leakage wakeup unit
  - Bit manipulation engine (BME) for read-modify-write peripheral operations
- Clocks
  - Clock generation module with FLL for system and CPU clock generation
  - 32 kHz internal reference clock
  - System oscillator supporting external crystal or resonator
  - Low-power 1kHz RC oscillator for RTC and watchdog
- Analog peripherals
  - 12-bit SAR ADC
  - Tow analog comparators
- Communication peripherals
  - Two 8-bit Serial Peripheral Interfaces (SPI)
  - one $I^2C$ modules
  - Three  UART modules
- Timers
  - One 6-channel FlexTimer module
  - Two 2-channel Timer/PWM modules
  - 2-channel Periodic Interrupt Timer (PIT)
  - Real time clock (RTC)
  - System tick timer
  - One watchdog module
- Security
  - One CRC
- Human-Machine Interfaces (HMI)
  - General purpose input/output controller
  - IRQ

# 5 FRDM-KE02Z Hardware Description

## 5.1 Power Supply

The FRDM-KE02Z offers a design with multiple power supply options. It can be powered from the USB connector, the $V_{IN}$ pin on the I/O header,  an off-board 1.71-3.6V supply from the 3.3V pin on the I/O header or 3.3V from motor control header .  The USB and $V_{IN}$ supplies are regulated on-board using a 3.3V linear regulator to produce the main power supply. The other two sources are not regulated on-board.  The following figure shows the schematic drawing for the power supply inputs and the on-board voltage regulator.

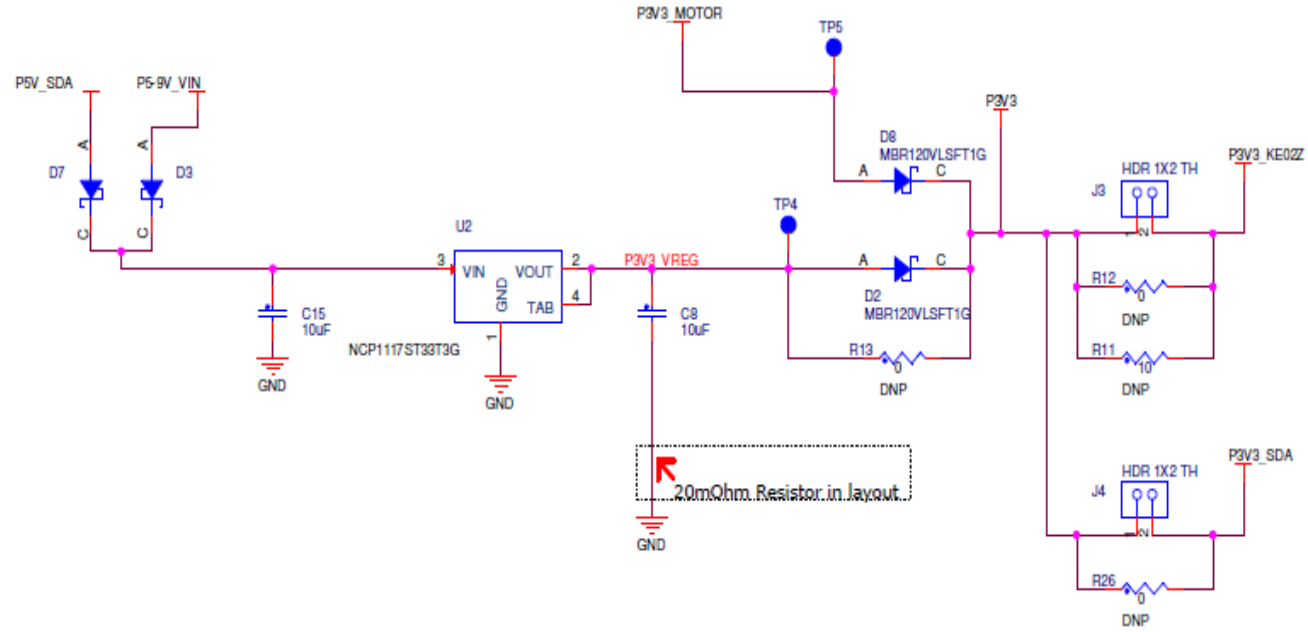



**Figure 2.** FRDM-KE02Z Power Supply

Table 1 provides the operational details and requirements for the power supplies.

**Table 1.** Power Supply Requirements

| Supply Source | Valid Range | OpenSDA Operational? | Regulated on-board? |
|---|---|---|---|
| OpenSDA USB (J7) | 5V | Yes | Yes |
| $V_{IN}$ Pin on I/O header | 4.3-9V | No | Yes |
| 3.3V Pin on I/O header | 1.71-3.6V | No | No |
| 3.3V Pin on motor control header | 3.3V | Yes | No |

Note that the OpenSDA circuit is only operational when a USB cable is connected and supplying power to J6. However, the protection circuitry is in place to allow multiple sources to be powered at once.

**Table 2.** FRDM-KE02Z Power Supplies

| Power Supply Name | Description |
|---|---|
| P5-9V_VIN | Power supplied from the **$V_{IN}$ pin of the I/O headers** (J9 pin 16). |
| P5V_SDA | Power supplied from the **OpenSDA USB** connector (J6). |
| P3V3_VREG | **Regulated 3.3V supply**. Sources power to the P3V3 supply rail through a back drive protection Schottky diode. |
| P3V3 | **Main supply rail** for the FRDM-KE02Z. can be sourced from P3V3_VREG, or directly from the I/O headers (J9 pin 8), or from P3V3_MOTOR. |

| | |
|---|---|
| P3V3_KE02Z | **KE02Z MCU power supply.** Header J3 provides a convenient means for KE02Z energy consumption measurements. |
| P3V3_SDA | **OpenSDA circuit power supply.** Header J4 provides a convenient means for K20 energy consumption measurements. |
| P5V_USB | Nominal **5V supplied to the I/O headers** (J9 pin 10). Sourced from P5V_SDA supply through a back drive protection Schottky diode. |
| P3V3_MOTOR | 3.3V supply from motor control header |

Notes:

1) J3 and J4 are not populated by default on the production version. The two pins of these headers are shorted together by 0 ohm resistor R11 and R26 on the PCB. To measure the energy consumption of either the KE02Z64 or the OpenSDA MCU, the 0 ohm resistor between these pins must first be cut. A current probe or a shunt resistor and voltage meter can then be applied to measure the energy consumption on these rails. When the MCU current measurement is done with no further need, this 0 ohm resistor can be soldered on again.
2) To better get ADC accuracy on KE02Z64, it is recommended that a 0 ohm resistor R13 be soldered on and ensure there is no power supply from P3V3_MOTOR and P3V3 sourced from I/O headers.

## 5.2 Serial and Debug Adapter (OpenSDA)

OpenSDA is an open-standard serial and debug adapter. It bridges serial and debug communications between a USB host and an embedded target processor as shown in Figure 3. The hardware circuit is based on a Freescale Kinetis K20 family microcontroller (MCU) with 128 KB of embedded flash and an integrated USB controller. OpenSDA features a mass storage device (MSD) bootloader, which provides a quick and easy mechanism for loading different OpenSDA Applications such as flash programmers, run-control debug interfaces, serial-to-USB converters, and more. Two or more OpenSDA applications can run simultaneously. For example, run-control debug application and serial-to-USB converter runs in parallel to provide a virtual COM communication interface while allowing code debugging via OpenSDA with just single USB connection. These two applications are provided in a single code package.
Refer to the *OpenSDA User's Guide* for more details.

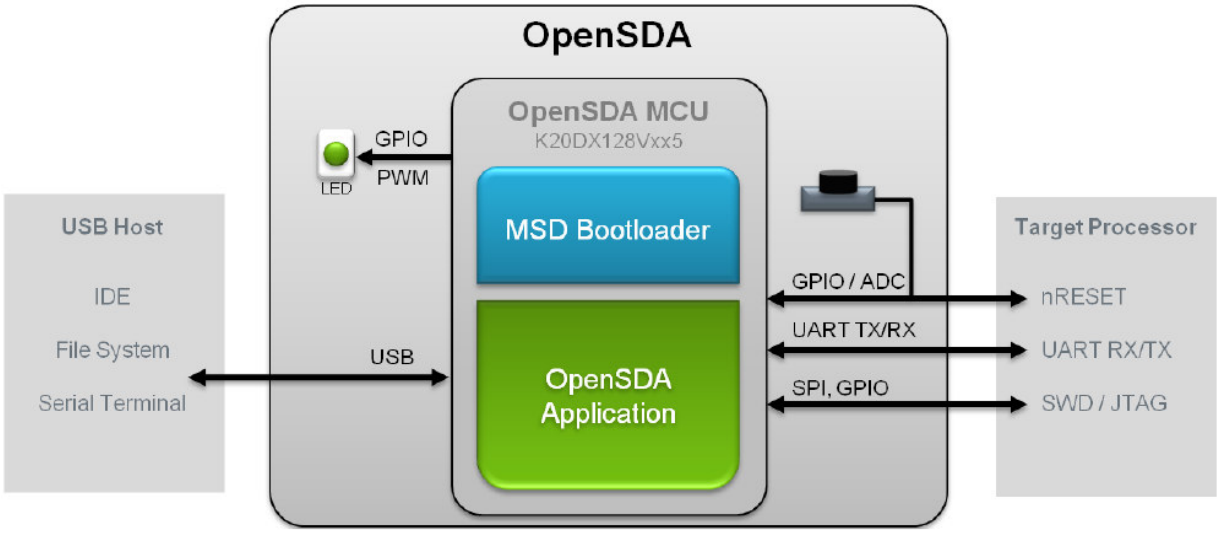


**Figure 3.** OpenSDA Block Diagram

OpenSDA is managed by a Kinetis K20 MCU built on the ARM® Cortex™-M4 core. The OpenSDA circuit includes a status LED (D4) and a RESET pushbutton (SW1). The pushbutton asserts the Reset signal to the KE02Z target MCU. It can also be used to place the OpenSDA circuit into Bootloader mode by holding down the RESET pushbutton while plugging the USB cable to USB connector J6. Once the OpenSDA enters bootloader mode, other OpenSDA applications such as debug app can be programmed.
SPI and GPIO signals provide an interface to the SWD debug port of the KE02Z. Additionally, signal connections are available to implement a UART serial channel. The OpenSDA circuit receives power when the USB connector J6 is plugged into a USB host.

### 5.2.1 Debugging Interface

Signals with SPI and GPIO capability are used to connect directly to the SWD of the KE02Z. These signals are also brought out to a standard 10-pin (0.05”) Cortex Debug connector (J7) as shown in Figure 4. It is possible to isolate the KE02Z MCU from the OpenSDA circuit and use J7 to connect to an off-board MCU. To accomplish this, cut the 0 ohm resistor R58. This will disconnect the SWD_CLK pin to the KE02Z so that it will not interfere with the communications to an off-board MCU connected to J7.

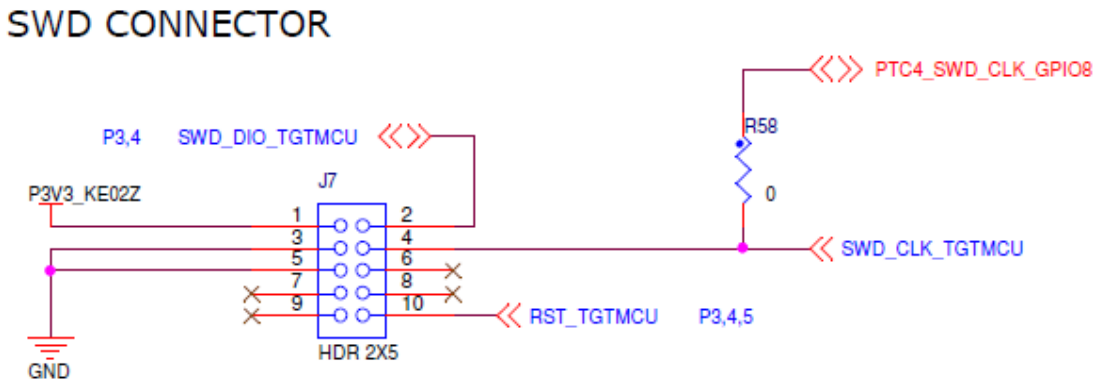



**Figure 4.** SWD debug connector to KE02Z

### 5.2.2 Virtual Serial Port

A serial port connection is available between the OpenSDA MCU and UART1 pin PTC7 (TXD1) and PTC6 (RXD1) of KE02Z. Several of the default OpenSDA Applications provided by Freescale, including the MSD Flash Programmer and the P&E Debug Application, provide a USB Communications Device Class (CDC) interface that bridges serial communications between the USB host and this serial interface on the KE02Z.

## 5.3 KE02Z Microcontroller

## 5.4 Clock Source

The Kinetis KE02 microcontrollers feature an on-chip oscillator compatible with two ranges of input crystal or resonator frequencies: 32 kHz (low frequency mode), 4-20 MHz (high frequency mode). The KE02Z64 on the FRDM-KE02Z is clocked from a 10 MHz crystal.

### 5.4.1 Serial Port

The serial port interface signals used with OpenSDA are UART1 pin PTC7 (TXD1) and PTC6 (RXD1). These signals are also connected to I/O header J1.

### 5.4.2 Reset

The PTA5/RESET signal on the KE02Z is connected externally to a pushbutton, SW1. The reset button can be used to force an external reset event in the target MCU. The reset button can also be used to force the OpenSDA circuit into bootloader mode when plugging the USB cable to J6. Please refer to the Serial and Debug Adapter (OpenSDA) section for more details.

### 5.4.3 Debug

The sole debug interface on all Kinetis E Series devices is a Serial Wire Debug (SWD) port. The primary controller of this interface on the FRDM-KE02Z is the onboard OpenSDA circuit. However, a 2x5-pin (0.05") Cortex Debug connector, J7, provides access to the SWD signals for the KE02Z MCU. The following table shows SWD connector signals description for KE02Z:

**Table 3.** ARM JTAG/SWD mini Connector Description

| Pin | Function | Connection to KE02Z |
|---|---|---|
| 1 | VTref | 3.3V system power supply (V_BRD) |
| 2 | SWDIO/TMS | PTA4/SWD_DIO |
| 3 | GND | GND |
| 4 | SWDCLK/TCK | PTC4/SWD_CLK |
| 5 | GND | GND |
| 6 | SWO/TDO | NC |
| 7 | NC | NC |
| 8 | TDI | NC |
| 9 | NC | NC |
| 10 | RESET | PTA5/RESET |

## 5.5 Thermistor

One thermistor (RT1) is connected to two ADC inputs (PTF4/ADP12, PTF5/ADP13) of KE02Z for evaluating the ADC module.

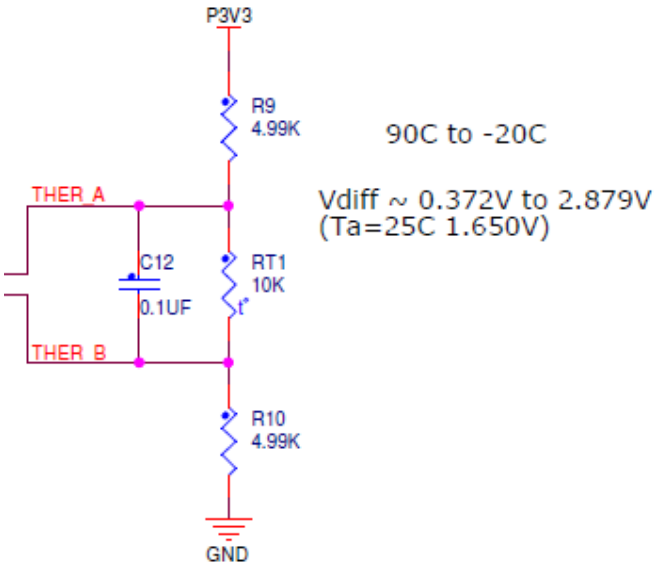



**Figure 5.** Thermistor connection

## 5.6 Infrared Port

One infrared Rx port and one tx port as shown in Figure 6 are connected to ACMP0 input pin (ACMP0_IN1) and SCI0 TXD0 pin of KE02Z to demonstrate the capability of SCI0 modulated by Flextimer for generating infrared signals and use ACMP0 as a filter to receive the SCI data via infrared signal.

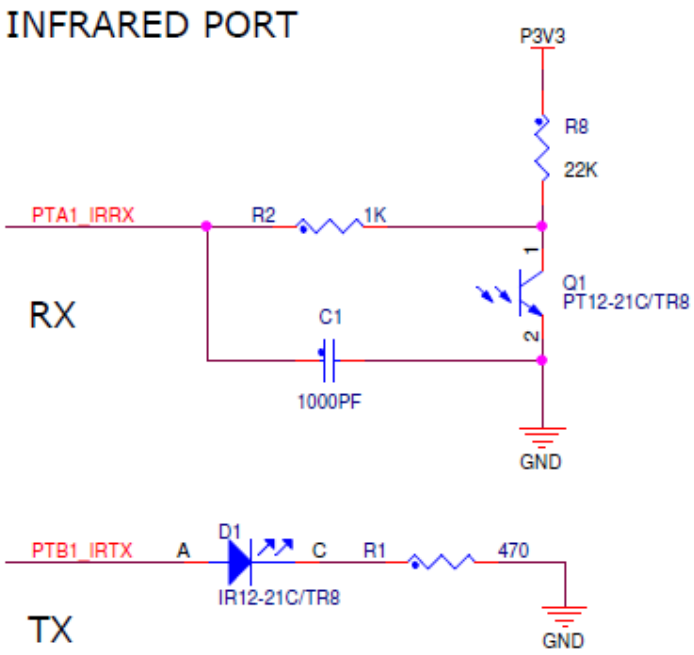



**Figure 6.** Infrared connection

## 5.7 Capacitive Touch Slider

Two GPIO pins functioning as Touch Sense Input (TSI) signals, are connected to capacitive electrodes configured as a touch slider as shown in Figure 7 below:

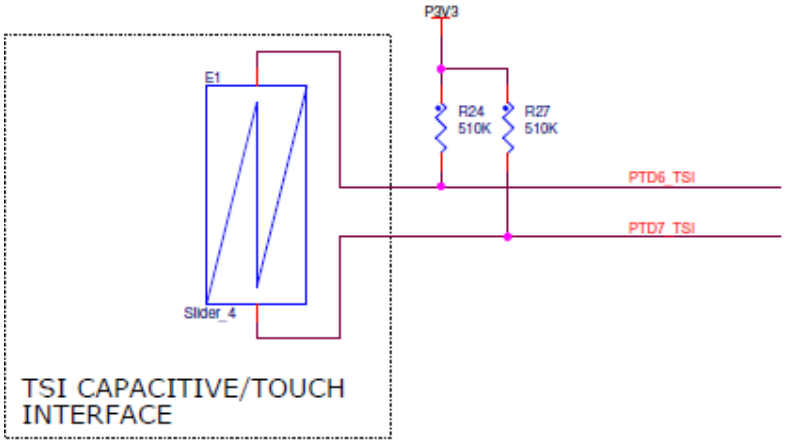



**Figure 7.** Touch Slider connection

## 5.8 3-axis Accelerometer

A Freescale MMA8451Q low-power, three-axis accelerometer is interfaced through an $I^2C$ bus and two GPIO signals as shown in Table 4 below. By default, the $I^2C$ address is 0x1D (SA0 pulled high).

**Table 4.** Accelerometer Signal Connections

| MMA8451Q | KE02Z |
|---|---|
| SCL | PTA3 |
| SDA | PTA2 |
| INT1 | PTD4 |
| INT2 | PTD3 |

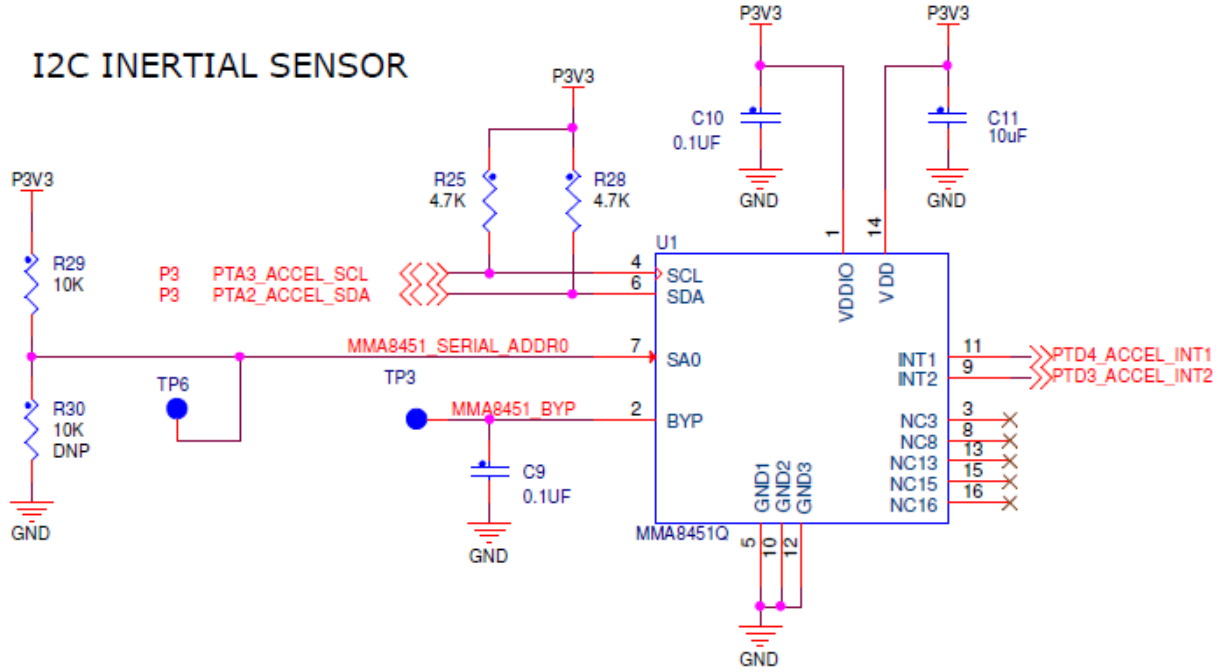



**Figure 8.** Accelerometer connection

## 5.9 RGB LED

Three PWM-capable KE02Z signals are connected to a red, green, blue LED. The signal connections are shown in Table 5 below.

**Table 5.** RGB LED Signal Connections

| RGB LED | KE02Z |
|---|---|
| Red Cathode | PTH1/FTM2CH1 |
| Green Cathode | PTH2/FTM1CH0 |
| Blue Cathode | PTE7/FTM1CH1 |

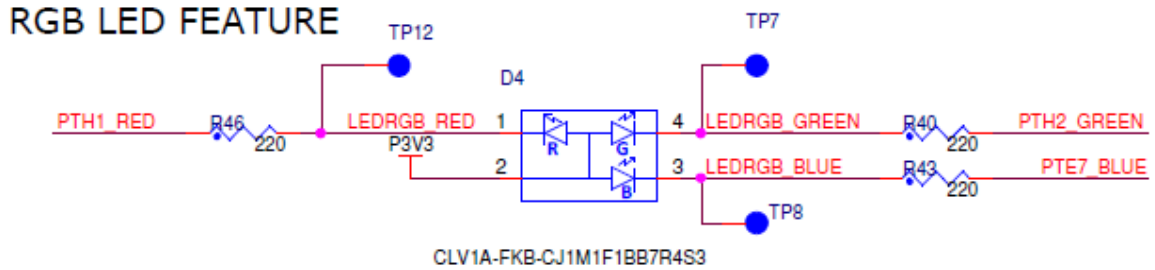
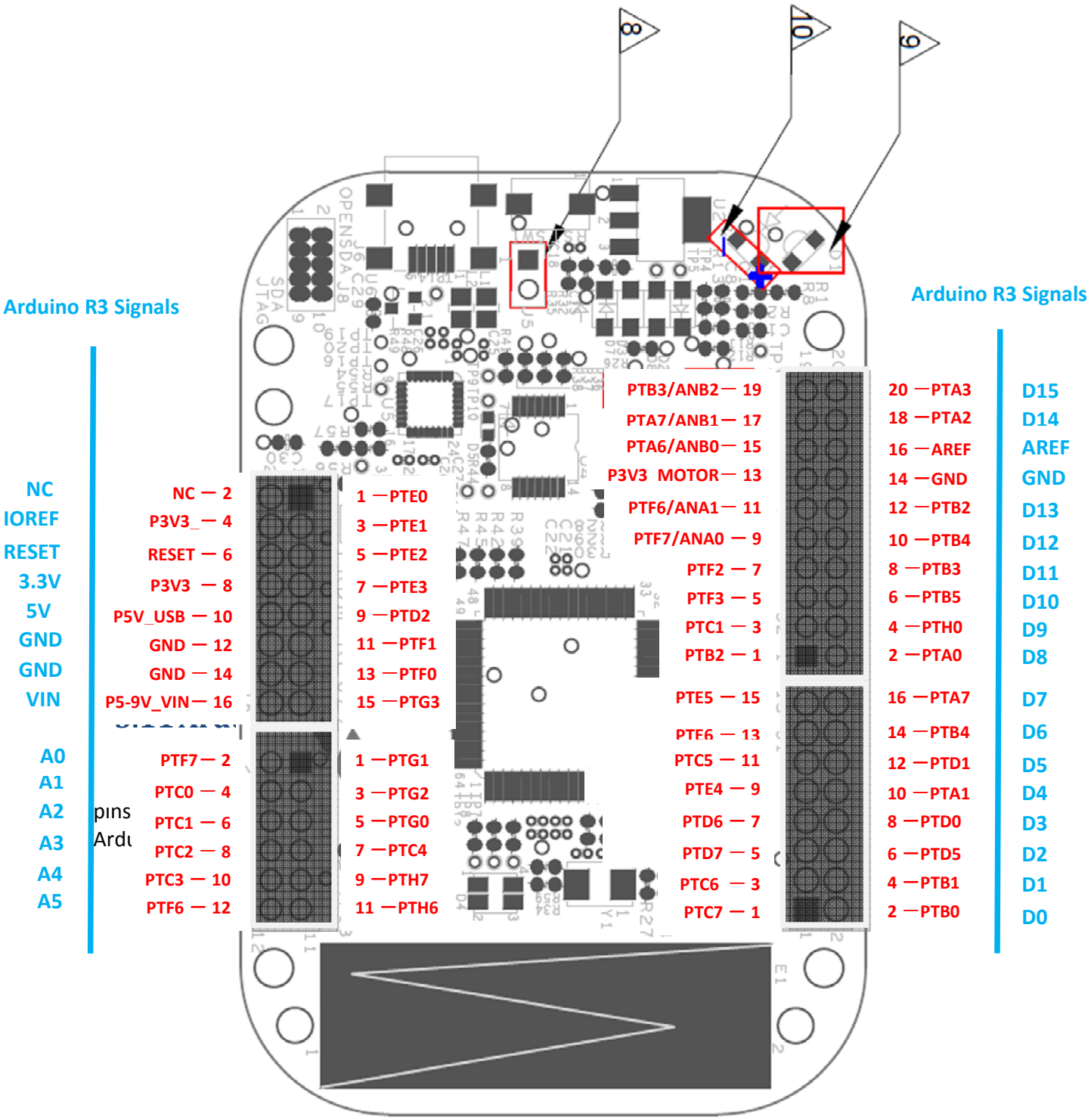



**Figure 9.** RGB LED connection

## 5.10 Input/Output Headers

The KE02Z64 microcontroller is packaged in an 64-pin QFP. Some pins are utilized in on-board circuitry, but many are directly connected to one of four I/O headers (J1, J2, J9 and J10). J1 and J2 also function as motor control headers to provide access to a motor control board such as simple BLDC motor driving board APMOTOR56F8000E.


8
10
6
Arduino R3 Signals
Arduino R3 Signals
NC
IOREF
RESET
3.3V
5V
GND
GND
VIN
A0
A1
A2
A3
A4
A5
NC — 2
P3V3_— 4
RESET — 6
P3V3 — 8
P5V_USB — 10
GND — 12
GND — 14
P5-9V_VIN— 16
PTF7— 2
PTC0 — 4
PTC1 — 6
PTC2 — 8
PTC3 — 10
PTF6 — 12
1 —PTE0
3 —PTE1
5 —PTE2
7 —PTE3
9 —PTD2
11 —PTF1
13 —PTF0
15 —PTG3
1 —PTG1
3 —PTG2
5 —PTG0
7 —PTC4
9 —PTH7
11 —PTH6
PTB3/ANB2— 19
PTA7/ANB1— 17
PTA6/ANB0— 15
P3V3 MOTOR— 13
PTF6/ANA1— 11
PTF7/ANA0 — 9
PTF2 — 7
PTF3 — 5
PTC1 — 3
PTB2 — 1
PTE5 — 15
PTF6 — 13
PTC5 — 11
PTE4 — 9
PTD6 — 7
PTD7 — 5
PTC6 — 3
PTC7 — 1
20 —PTA3
18 —PTA2
16 —AREF
14 —GND
12 —PTB2
10 —PTB4
8 —PTB3
6 —PTB5
4 —PTH0
2 —PTA0
16 —PTA7
14 —PTB4
12 —PTD1
10 —PTA1
8 —PTD0
6 —PTD5
4 —PTB1
2 —PTB0
D15
D14
AREF
GND
D13
D12
D11
D10
D9
D8
D7
D6
D5
D4
D3
D2
D1
D0