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QFLEX 2 Embedded for QUBE-Servo 2

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Features

Control DC motor voltage
Read encoder feedback from DC motor
Read encoder value from secondary input
Read current sense feedback from PWM amplifier
Set encoder reference points
Control tri-colour LED output

System Overview

The QFLEX 2 Embedded provides a standard SPI interface for interacting with the QUBE-Servo 2. QFLEX 2 Embedded panel is powered via the 1.8V-5V and GND input pins and provides signal isolation between the external connector and the internal QUBE data bus. Data signals in the SPI interface will operate at the voltage provided on the 1.8V-5V pin. The QUBE-Servo 2 controller receives the data from the SPI interface and sets the motor PWM duty cycle, LED brightness, and encoder reference. The controller collects current sense and encoder read values and feeds this information back over the data bus, back to the SPI interface. The full system diagram is shown in Figure 1.

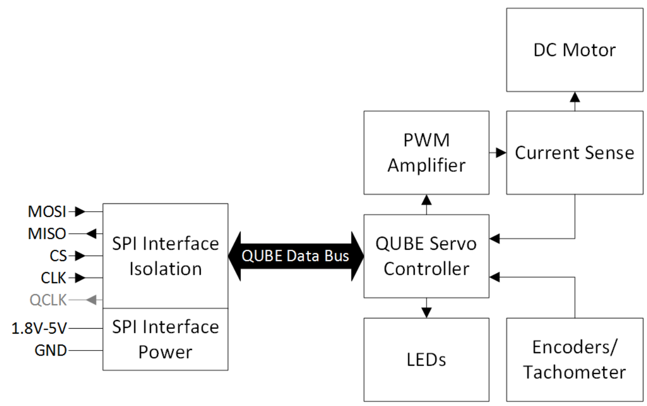

Figure 1: *System Diagram*

Table 1: *QFLEX 2 Embedded IO connections*

#	Pin Name	Description
1	1.8V-5V	Controller Vcc
2	MOSI	QUBE data IN
3	MISO	QUBE data OUT
4	CLK	SPI data clock IN
5	QCLK	QUBE controller clock OUT
6	CS	QUBE slave chip select
7	GND	Controller ground

Connections

The QFLEX 2 Embedded has a 7-pin connector (shown in Figure 2) which mates with a TE Connectivity 104257-6 rectangular connector. Table 1 outlines the IO connection pins

Communication

The QFLEX 2 Embedded operates as a standard SPI slave with SPI mode 2. When SPI communication is initiated by pulling the CS line low, the first byte of data received by the QFLEX 2 Embedded, referred to as the mode byte, will determine the communication mode to follow.

Mode = 0 Only read device ID (no settings changed)

Mode = 1 A full command packet is transmitted

Concurrently, as the mode byte is being received, the QUBE-Servo 2 will respond with the upper byte of the device ID. The next byte sent to the QFLEX 2 Embedded is a padding byte with a value of 0, the data returned during this transmission will be the lower byte of the de-

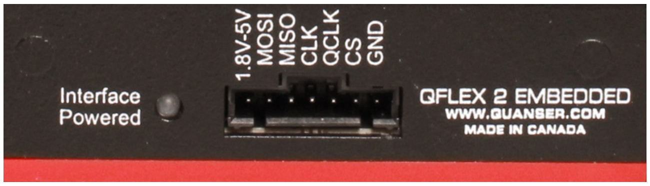

Figure 2: *QFLEX 2 Embedded Panel*

vice ID. At this point if Mode = 0, the communication is complete and the CS line can be set high. If Mode = 1, the command communication packet continues as outlined in Table 2

Table 2: *QFLEX 2 Embedded Command Packet Structure*

B	MOSI Data	MISO Data
0	Mode (0x01)	Device ID MSB
1	Padding byte (0x00)	Device ID LSB
2	Write Mask	Encoder 0 (23-16)
3	Red LED MSB	Encoder 0 (15-8)
4	Red LED LSB	Encoder 0 (7-0)
5	Green LED MSB	Encoder 1 (23-16)
6	Green LED LSB	Encoder 1 (15-8)
7	Blue LED MSB	Encoder 1 (7-0)
8	Blue LED LSB	Tachometer 0 (23-16)
9	Set Encoder 0 (23-16)	Tachometer 0 (15-8)
10	Set Encoder 0 (15-8)	Tachometer 0 (7-0)
11	Set Encoder 0 (7-0)	Status
12	Set Encoder 1 (23-16)	Current Sense (15-8)
13	Set Encoder 1 (15-8)	Current Sense (7-0)
14	Set Encoder 1 (7-0)	Null
15	Motor Command (15-8)	Null
16	Motor Command (7-0)	Null

Transmit/Receive Bytes

The expected values and description for each of the data bytes are as follows.

Mode (Transmit byte 0)

Expected value 0x00-0x01. A value of 0 will result in only the device ID being returned. A value of 1 will initiate the transmission of a full command packet.

Write Mask (Transmit byte 2)

Expected value 0x00-0x7F. This byte controls what values will be overwritten on the QUBE-Servo 2. The mapping of the bits in the mask to written values is shown in Table 3 To zero the encoders, the write mask must be 0b011xxxxx. To set the LED values, the mask must be 0b0xx111xx. To enable the motor and set the voltage, the mask must be 0b0xxxxx11.

Table 3: *Write Mask Bit Mapping*

b	Action Enabled
7	-
6	Set Encoder 1
5	Set Encoder 0
4	Write Blue LED
3	Write Green LED
2	Write Red LED
1	Write Motor Enable
0	Write Motor

LED Values (Transmit bytes 3-8)

Expected value 0x0000-0x03E7. The brightness of the LEDs is controlled on a scale from 0 to 999 (decimal) this value is transmitted over two bytes for each LED with the MSB preceding the LSB.

Set Encoder Values (Transmit bytes 9-14)

These bytes allow for the encoder counts value to be set as desired. The most likely application for these bytes is to send 0x00 for all bytes to zero the encoder counts.

Motor Command (Transmit bytes 15-16)

Bit 15 of the motor command controls whether the PWM amplifier in the QUBE-Servo 2 is activated. Thus the upper byte of the motor command must be 0b1xxxxxxx in order for the motor to be enabled. The expected value of the bits 14-0 of the motor command is a value between -999 and 999 (decimal) formatted in 2's complement and represents a value equal to 10 times the desired percentage duty cycle of the PWM amplifier. For example, writing the motor command value 0x81F4 would activate the PWM amplifier and apply a 50% duty cycle, equivalent to approximately 12VDC.

Device ID (Receive bytes 0-1)

Expected Value of these bytes for the QUBE-Servo 2 is always 0x309 or 777 decimal. Any other value indicates a fault in communication between the QFLEX 2 Embedded and the QUBE.

Read Encoder Values (Receive bytes 2-7)

These bytes represent the current value of the encoder counts, represented in 2's complement. Each value consists of three bytes and begins with the most significant byte. Encoder 0 is the encoder internal to the QUBE-Servo 2 and indicating the position of the DC motor. Encoder 1 is the encoder connected to the external "Encoder 1" connector on the top of the QUBE-Servo 2 and will usually indicate the position of the pendulum attachment.

Tachometer Value (Receive bytes 8-10)

These bytes represent the current value read from the QUBE-Servo 2 internal tachometer, consisting of three bytes and beginning with the most significant byte. The most significant bit represents the direction of rotation with a value of zero indicating counter-clockwise rotation. Bits 23-0 represent the number of clock cycles (at 40MHz) between rising edges of the encoder 0 *A* signal line. The encoder value can be converted to encoder counts per second with the following equation:

$$\text{Counts/Sec} = \frac{4}{Tach \cdot (25 \cdot 10^{-9})} \qquad (1)$$

Note that when the motor velocity is 0 the tachometer value will indicate the maximum value of 0x7FFFFF indicating a reading of approximately 20 counts/s.

Status (Receive byte 11)

The three least significant bits of this byte represent various warning or error states as outlined in Table 4. A status byte value of 0x00 indicates normal operation.

Table 4: *Status Bits*

b	Indicated Status
7-3	-
2	Stall Error
1	Stall Detected
0	Amplifier Fault

Current Sense (Receive bytes 12-13)

These bytes represent the measured current draw of the DC motor, represented in two's complement. The current can be calculated using the equation:

$$\text{Current (mA)} = \frac{I_{sense} - 8190}{9828} \qquad (2)$$

Quanser Inc.
119 Spy Court
Markham, ON
L3R 5H6
Canada
info@quanser.com
Phone: 1-905-940-3575
Fax: 1-905-940-3576

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