TI TechNotes

Servo Motor Controller Using MSP430™ MCUs

TEXAS INSTRUMENTS

Introduction

Used in several industrial applications such as robotics, factory automation, and device positioning, servo motors allow for precise control of either angular or linear positioning and as such have become necessary components of several sophisticated systems. By integrating a motor, driver, encoder, and electronics into a single unit, the motor can be controlled by a microcontroller (MCU) using Pulse Width Modulation (PWM) signals. This modulation technique varies the duty cycle of a known frequency which correlates with the motors position. Typically, this is provided in the form of 1- to 2-ms pulses of a 20-ms waveform (or 50 Hz at 5% to 10% duty cycle) for a total 180˚ of motor movement. See Figure 1 for further signal conditioning and device connection details, but note that these can differ based on the motor used and, as such, always consult the data sheet of the servo.

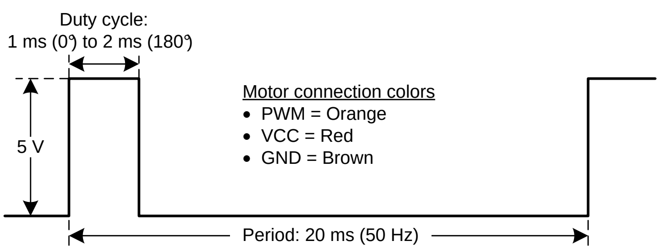

Figure 1. Servo Motor Connections and Waveform

The example code included with this documentation provides basic control of a servo motor though UART hexadecimal commands to a MSP430FR2000 device. This MCU provides a cost-effective solution, which is achieved while keeping the code size below the available 512 bytes of main memory. To get started, download project files and a code example demonstrating this functionality.

Implementation

MSP430™ device GPIO pins allow for a maximum output of 3.6 V, depending on its V_{CC} level. However, most servo motors operate on a 5-V rail and therefore require some form of voltage level translation to be driven by the microcontroller. It is possible to use an N-channel MOSFET as a logic switch, as shown in Figure 2 with the CSD18537NKCS, or a unidirectional voltage translation device (such as from the SN74LV1Txx family) to accomplish this task.

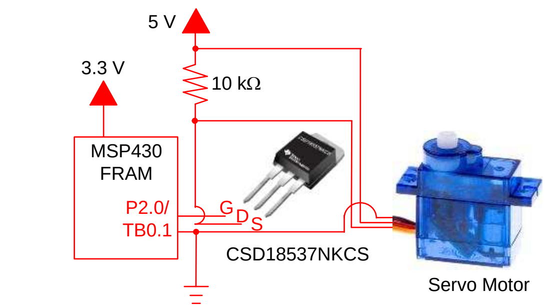

Figure 2. Servo Motor Circuit Diagram

PWM signals can be generated through the use of a timer peripheral, in this case Timer_B0. The default ACLK supply from internal trimmed low-frequency reference oscillator (REFO) (approximately 32 kHz) is used to source the timer, which operates in up mode. The TB0CCR0 register is set to produce a 20-ms period. Likewise, the TB0CCR1 register establishes the duty cycle, or amount of time during the period for which a signal is driven high, and controls the output to the P2.0/CCR1 pin of the MSP430FR2000 MCU. The duty cycle should remain between 1 and 2 ms to effectively control the servo motor.

In this example, a terminal program is used to provide a straightforward method for controlling servo motor position. The eUSCI_A0 peripheral is used in UART mode, enabling commands to be received on P1.6/UCA0RXD. An MSP-FET programmer and debugger and a MSP-TS430PW20 target development board is used for evaluation. A baud rate of 4800 must be selected with one stop bit and no parity. A hexadecimal input from 0x00 to 0x0F selects the motor position, from its starting position to the maximum rotation allowed, in incremental steps. CCR1 register values are determined through the use of a lookup table (see Table 1), which provides the predefined duty cycle value.

Table 1. Hex to Duty Cycle Lookup

Received Byte	TB0CCR1 Value	Output Duty cycle
0x00	33	1.00 ms (5.0%)
0x01	36	1.10 ms (5.5%)
0x02	38	1.16 ms (5.8%)
0x03	40	1.22 ms (6.1%)
0x04	42	1.28 ms (6.4%)
0x05	44	1.34 ms (6.7%)
0x06	46	1.41 ms (7.1%)

Table 1. Hex to Duty Cycle Lookup (continued)

Received Byte	TB0CCR1 Value	Output Duty cycle
0x07	48	1.46 ms (7.3%)
0x08	50	1.53 ms (7.7%)
0x09	52	1.59 ms (8.0%)
0x0A	54	1.65 ms (8.3%)
0x0B	56	1.71 ms (8.6%)
0x0C	58	1.77 ms (8.9%)
0x0D	60	1.83 ms (9.2%)
0x0E	62	1.89 ms (9.5%)
0x0F	65	1.98 ms (9.9%)

Performance

Figure 3 shows three examples of PWM waveforms generated from hexadecimal terminal entries (in red). The 1-ms pulse refers to 0° rotation of the servo motor, whereas a 2-ms pulse turns the motor to 180°. 1.5 ms therefore sets the position near 90°, and so forth.

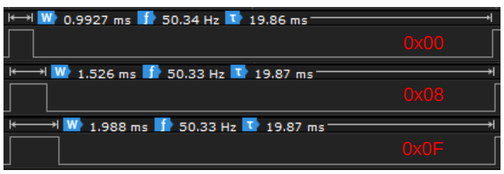

Figure 3. Duty Cycle Modulation

The code example uses approximately 200 bytes of main memory. This leaves more space for additional application code, detailed position sequences, or dual servo motor control by employing the TB0CCR2 register on P2.1. MSP430 MCUs with larger memory footprints can be substituted to further increase functionality. If the eUSCI peripheral is not required then PWM outputs can also be accessed through the P1.6 and P1.7 pins.

A FRAM variable is used to save the position of the servo motor. In instances where the device is reset, for example by pulling the $\overline{\text{RST}}$ line low or through an unintentional power cycle, then CCR1 retains the duty cycle output necessary to keep the servo motor in its former position. This functionality can be removed or disabled if the application does not require the motor to reposition itself any time a reset occurs.

Although REFO supplies a 32-kHz frequency to ACLK for the UART baud-rate source, an external crystal can be substituted as it is more stable over temperature changes. During inactivity, the code utilizes low-power mode 3 (LPM3) to achieve power consumption currents of 17 µA as realized through LPM3, but using a LFXT instead reduces this power consumption to 1 µA.

Device Recommendations

The device used in this example is part of the MSP430 Value Line Sensing portfolio of low-cost MCUs, designed for sensing and measurement applications. This example can be used with the devices shown in Table 2 with minimal code changes. For more information on the entire Value Line Sensing MCU portfolio, visit www.ti.com/MSP430ValueLine.

Table 2. Device Recommendations

Part Number	Key Features
MSP430FR2000	0.5KB FRAM, 0.5KB RAM, eComp
MSP430FR2100	1KB FRAM, 0.5KB RAM, 10-bit ADC, eComp
MSP430FR2110	2KB FRAM, 1KB of RAM, 10-bit ADC, eComp
MSP430FR2111	3.75KB FRAM, 1KB RAM, 10-bit ADC, eComp

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