Programmable Clock Source Using MSP430™ MCUs

TEXAS INSTRUMENTS

Introduction

The programmable clock source function uses the MSP430FR2000 microcontroller (MCU) to offer a simple way to generate multiple fixed frequencies with or without an external crystal oscillator. This design can achieve output frequencies of 1 MHz, 2 MHz, 4 MHz, 8 MHz, or 16 MHz using the internal digitally controlled oscillator (DCO) stabilized with an internal frequency locked loop (FLL). A fixed 32.768-kHz frequency is also output for use with real-time applications. The MSP430™ MCU can receive commands over a SPI or a 4800-baud UART interface, and the ferroelectric random access memory (FRAM) allows the device to recover to the last programmed frequency after reset. This type of functionality is useful for systems that need to generate multiple frequencies using a minimum number of components. To get started, download project files and a code example demonstrating this functionality.

Implementation

The clock system in the MSP430FR2000 device features an FLL that can be used to stabilize the internal DCO and achieve clock frequencies up to 16 MHz. The FLL requires a reference clock that can be sourced from either an internal 32.768-kHz reference oscillator (REFO) or an external crystal of the same frequency. However, TI recommends using a high-accuracy external 32.768-kHz crystal for best performance. Figure 1 shows the inputs and outputs of the programmable clock source.

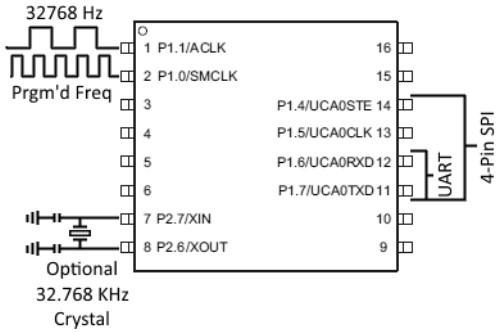

Figure 1. Programmable Clock Source Inputs/Outputs

After a device reset, the MSP430 MCU sources the subsystem master clock (SMCLK) from the DCO configured to run at 16 MHz. The device then executes a frequency command stored in FRAM that divides SMCLK to the last known frequency before device reset. This frequency is then output on P1.0, and the FLL reference is output on P1.1.

When the MSP430 MCU is first programmed, the default output frequency is 1 MHz. This default frequency can be altered by changing the initialization value of the *command* variable found in the accompanying software example. Then, as previously described, the MSP430 device will output the last known frequency upon device start-up.

The programmable clock source can receive commands from a host processor through a 4800-baud UART or a 4-wire SPI. The UART interface uses P1.6 and P1.7 as receive and transmit respectively. The SPI uses P1.4 to P1.7, and Table 1 lists the phase and polarity settings required for proper communication.

Table 1. 4-Wire SPI Settings

Slave or Master	CLK Phase	CLK Polarity	CS Polarity
Slave	Data changed on first clock edge and captured on second	Inactive state is low	Active low

Either interface allows a host processor to set the desired output frequency using any of the commands listed in Table 2. Each command is only one byte in length to maintain simplicity and reduce code size.

Table 2. Programmable Clock Source Command Set

Command Description	Hex Value
COMMAND_SET_1MHZ	0x00
COMMAND_SET_2MHZ	0x02
COMMAND_SET_4MHZ	0x04
COMMAND_SET_8MHZ	0x06
COMMAND_SET_16MHZ	0x08
COMMAND_GET_STATUS	0x0A

When using the UART interface, the MSP430 MCU will respond with a single byte when a command has completed execution. When using a SPI interface, the host processor must use COMMAND_GET_STATUS to query the execution status of the last command. Table 3 lists the three responses that can be issued from the programmable clock source.

Table 3. Programmable Clock Source Responses

Response Description	Hex Value
Command executed successfully	0x00
Incorrect command	0x01
Command is still being processed	0x02

Performance

The programmable clock source can achieve 1-MHz, 2-MHz, 4-MHz, 8-MHz, or 16-MHz frequency output at ±2% accuracy using the internal REFO or ±0.5% accuracy using an external crystal. More detailed performance specifications can be found in the clock specifications section of the MSP430FR2000 MCU data sheet. Overall, the accuracy and power consumption is improved when using an external crystal oscillator.

Several design decisions were made to ensure the code could fit into the limited 512-byte memory space of the MSP430FR2000 device. Of these decisions, the 4800 baud rate has the most affect.

In this application, the UART module receives its source clock from either REFO or the 32.678-kHz external crystal. This was done so the baud rate registers did not need to be altered when the user changed the device's frequency. Consequently, this greatly reduced the amount of code required to implement UART communication. Finally, a baud rate of 4800 was chosen because of the relatively low error when compared to a 9600-baud rate source from a 32.678-kHz clock. There are no such limitations when using SPI communication.

To ensure the clock source is always active, the deepest low-power mode (LPM) the MSP430 MCU can enter is LPM0. Therefore the programmable clock source typically consumes 402 µA of current at 3 V, regardless of the selected output frequency.

Finally, the code has two infinite loops that have the potential to keep the device from outputting the correct frequency at startup. The first is a loop checking for the external crystal stability. The second is a loop checking for the FLL locking to a frequency of 16 MHz. When the device is stuck in either loop, the response to sending a COMMAND_GET_STATUS is always 0x02, as described in Table 3. If this problem occurs, reset the MSP430 MCU.

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 4 with minimal code changes. For more information on the entire Value Line Sensing MCU portfolio, visit www.ti.com/MSP430ValueLine.

Table 4. 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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Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265