AVR ATmega16/32 Fuse Bits

Summary

Updating with the era of technology, the new microcontrollers are coming with lots of inbuilt peripherals and features. These inbuilt peripherals and features not only reduce the cost of additional circuits to be used with the controller but also provide an ease to interface additional devices (such as Modems etc) directly with the microcontroller.

The new generations of microcontrollers are capable of working on internal as well as on external clock option. But then the question comes as to how do we make them work on a desired clock option? How to disable/enable a particular peripheral? As a beginner when you get a new chip (ATmega16/32) you may complain that 'PORTC of the chip is not working!' or 'when the reset pin and 6th pin of PORTC (in ATmega8) are common how shall I select them/distinguish between them?'. These questions may taste bitter when you try to skip them and go ahead, but all these issues can be solved by properly setting the **FUSE BITS** of your device.

There are few parameters in the chip which are used to configure it before it can be used for external environment. These parameters are set with the use of Fuse Bits. In other words, the fuse bit determines the behavior of the chip, whether it has a boot loader, what is the speed and voltage it runs at, theWatchdog Timer conditions, etc. The main advantage of fuse bits is that the microcontroller can be configured as per the requirement.

Once the **fuse bits** are set for a particular configuration, the controller can be used again and again (program can be burned again and again). You don't have to set the fuse bits every time you are using the controller till the time you want to use it under the same configuration. **Fuse bits** need to be changed only in case you want to change the initial configuration of the controller. The fuse bits are very confusing for the beginners. This tutorial will ***explore the fuse bits***and also give a clear understanding of what fuses you need to set for your device.

Description

Before configuring the fuse bits for your device, one must have thorough knowledge of fuse bits, when exactly and how would you configure them and what all are the factors which may affect the working of the device. It is important to note that the fuse bit settings are not affected by the chip erase operation. They are configured separately by using external programmer.

Another very important aspect to note is that the desired fuse bits must be programmed before setting the lock bits of the device. You must be very careful while writing the fuse bits of the device. Suppose if you using an SPI programmer/burner to program your controller and by chance you disabled (unprogrammed) the SPIEN bit, then the chip cannot be further programmed. The SPIEN bit can again be enabled (programmed) by using a parallel burner. If the bit reads as logic 0, it means the bit is programmed or else it is called as unprogrammed bit.

The AVR microcontroller (ATmega16) consists of sixteen fuse bits which are classified as low fuse and high fuse. These Fuse bits can be configured to select the microcontroller clock options or to control some in-built peripherals like JTAG, SPI etc.

A new or virgin microcontroller has a default value of fuse bytes which is equal to 0x99E1 in hexadecimal. To understand the meaning of this default value, each fuse bit must be understood.

High Fuse bits:

Fuse Bit	OCDEN	JTAGEN	SPIEN	CKOPT	EESAVE	BOOTSZ1	BOOTSZ0	BOOTRST
Bit No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Default values	**1**	**0**	**0**	**1**	**1**	**0**	**0**	**1**

Low Fuse bits:

Fuse Bit	BODLEVEL	BODEN	SUT1	SUT0	CKSEL3	CKSEL2	CKSEL1	CKSEL0
Bit No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Default values	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**1**

CKSEL [3:0] (Clock Select)

These fuse bits are used to select different clock source option for microcontroller. The table below shows the different device clock sources and their corresponding fuse bits.

Device Clocking Option	CKSEL[3:0]
External Crystal/Ceramic Resonator	1111 - 1010
External Low-frequency Crystal	1001
External RC Oscillator	1000 - 0101
Calibrated Internal RC Oscillator	0100 - 0001
External Clock	0000

The default clock setting for new controller is CKSEL = 0001 (internal RC oscillator 1MHz). Generally, external crystal is used as a clock option (so fuse bit is set between the range 1111-1010).

CKOPT (Clock Option)

There are two oscillation modes in ATmega16 microcontroller; the CKOPT bit selects one of these modes. If CKOPT bit is programmed (0), the oscillator generates full rail-to-rail output swing. This mode has wide frequency range. If CKOPT is unprogrammed (1), the oscillation has smaller output swing (this mode has limited frequency).

Atmega16 can be operated on a maximum clock frequency of 16 MHz (16PU or 16PI), thus the CKOPT is programmed. The CKOPT bit is combined with CKSEL [3:1] bits to select operating frequency and its mode. *Table2* shows the CKSEL[3:1] and CKOPT bit combination used to select frequency of crystal for ATmega16. The table below also recommends the capacitors' ranges which are connected across the crystal.

CKOP	CKSEL[3:1]	Frequency Range (MHz	Recommended Range for Capacitors (pF)
1	101*	0.4 - 0.9	–
1	110	0.9 - 3.0	12 - 22
1	111	3.0 - 8.0	12 - 22
0	101, 110, 111	1.0 -16.0	12 - 22

* This mode is only used for ceramic resonator.

For CKOPT=0, the CKSEL [3:1] bits are selected as follows:

- 101 = low frequency external crystal
- 110 = medium frequency external crystal
- 111 = high frequency external crystal

For 12 MHz frequency of external crystal, CKSEL [3:1] is set to 111.

SUT [1:0] (Start Up Time)

This bit is used to set start up time of ATmega16. The combination of SUT [1:0] and CKSEL0 bits are used to select the start-up time of controller. The table below shows the bit combinations to select the start-up time.

CKSEL0	SUT[1:0]	No. of Start-up clocks	Additional Delay from Reset	Recommended Usage
0	00	258 CK	4.1 ms	Ceramic resonator, fast rising power
0	01	258 CK	65 ms	Ceramic resonator, slowly rising power
0	10	1K CK	–	Ceramic resonator, BOD enabled
0	11	1K CK	4.1 ms	Ceramic resonator, fast rising power
1	00	1K CK	65 ms	Ceramic resonator, slowly rising power
1	01	16K CK	–	Crystal Oscillator, BOD enabled
1	10	16K CK	4.1 ms	Crystal Oscillator, fast rising power
1	11	16K CK	65 ms	Crystal Oscillator, slowly rising power

BODEN (Brown-Out Detection Enable)

ATmega16 has a brown-out detection unit which continuously monitors Vcc level with fixed trigger level. This fuse bit is used to enable/disable the brown-out detection unit. To enable the BOD unit, BODEN bit is programmed (0).

BODLEVEL (Brown-Out Detection Level)

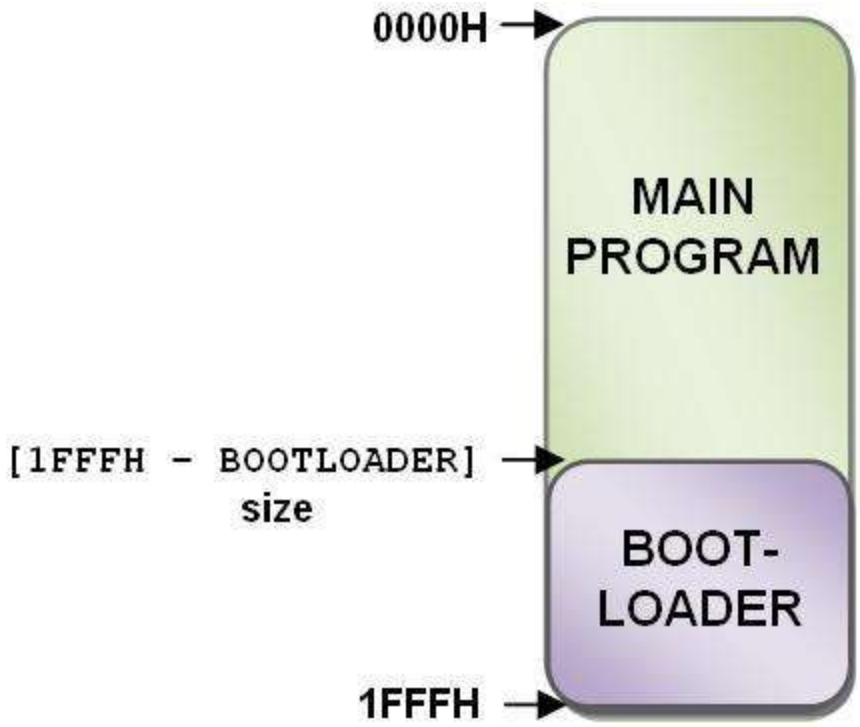
This fuse bit is used to set trigger level for BOD unit. The trigger voltage is set as 2.7 volts, if the BODLEVEL bit is unprogrammed (1). If this fuse bit is programmed (0), the trigger level is set to 4.0 volts.

BOOTRST [BootLoader Reset]

BootLoader is a small program which is written on a specific area of the flash memory. This program executes at the boot time of the controller. If BOOTRST bit is programmed (0), the device will jump on first address bootloader block.

BOOTSZ [1:0]

This fuse bit is used to set the bootloader size. The default value of these bits is '00' which sets the boot size to 1024 words. This size is allocated from flash memory. Bootloader always resides at the bottom of flash.



EESAVE (EEPROM Save)

This bit is used to preserve the EEPROM content during chip erase. If the fuse is programmed (0), the EEPROM preserves its content else it is not preserved duringchip erase.

SPIEN (SPI Serial Programming Enable)

If this bit is programmed (0), the SPI serial programming of the controller is enabled. To disable the serial programming, this bit is left unprogrammed (1).

JTAGEN (JTAG Enable)

There is an in-built JTAG unit in ATmega16, which is pre-activated in virgin microcontroller. To disable the JTAG, JTAGEN bit should be unprogrammed (1). (Refer How to disable JTAG)

OCDEN (On-Chip Debugging Enable)

The on-chip debugging is used to run the program step-by-step on hardware to study the internal signal which provides the information about state of the processor. This bit is used to enable/disable the on-chip debugging. If this bit is programmed (0), then the on-chip debugging is enabled.

There are few more bits which are not present in ATmega16 but they are important while using other ICs of AVR series like ATmega8. The RSTDISBL bit is very important (specially in the case of ATmega8). By programming this bit, the reset bit is converted into general I/O pin. It must be noted that while using SPI programmer, one should never program this bit. Programming this bit would disable the SPI programming since all the SPI programmers use RESET pin to program the microcontroller (AVR).

Configuring a new microcontroller

A virgin microcontroller controller is configured at 1MHz internal RC oscillator with longest start-up and the JTAG pre-enabled. So the fuse bytes are as follows:

High Fuse bit = 1001 1001 = $99
Low Fuse bit = 1110 0001 = $E1

To set the microcontroller for high external frequency with longest start-up and JTAG disabled, the fuse settings are changed as following.

- CKSEL [3:0] = 1111
- SUT [1:0] = 11
- CKOPT = 0
- JTAGEN = 1

So,

High Fuse bit = 1100 1001 = $C9
Low Fuse bit = 1111 1111 = $FF

Refer to JTAG disabling in AVR to learn the read/write operation of fuse bytes using AVRDUDE.