Microcontroller Programming

How to make something almost do something else

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What's wrong with a P4?

Pentiums

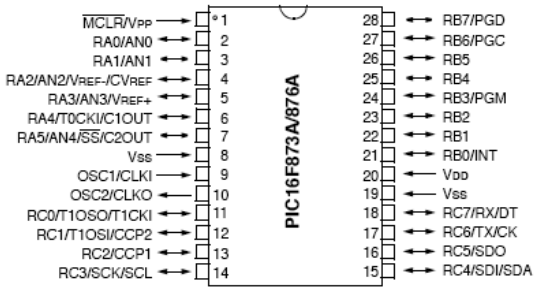
- 50 million transistors
- $200
- Watts @ idle
- Complicated instruction set and usage model

Microcontrollers

- < 150,000 transistors
- $0.50 - $5.00
- 0.01s Watts while active
- "Simple" programming model

PIC16F876A

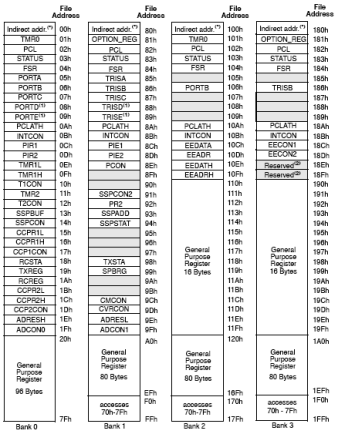
28-Pin PDIP, SOIC, SSOP



What is it?

- 8-bit processor that can be clocked from 50 kHz - 20 MHz
- 8K Flash program memory and 368 bytes SRAM
- 22 I/O pins (5 of which could be ADCs)
- 35 Instructions
- Hardware USART
- 2 Comparators

Memory



- Flash memory is where your “program” is stored
- SRAM is general purpose memory
- Registers can be memory mapped

Instructions

- Processors work with instructions
  - Move, Add, Jump, etc.
- Programs are just a series of instructions that the processor “steps” through

TABLE 15-2: PIC16F87XA INSTRUCTION SET

Mnemonic, Operands		Description	Cycles	14-Bit Opcode MSb LSb	Status Affected	Notes
BYTE-ORIENTED FILE REGISTER OPERATIONS						
ADDWF	f, d	Add W and f	1	00 0111 dfff ffff	C,DC,Z	1,2
ANDWF	f, d	AND W with f	1	00 0101 dfff ffff	Z	1,2
CLRF	f	Clear f	1	00 0001 lfff ffff	Z	2
CLRW	-	Clear W	1	00 0001 0xxx xxxx	Z	
COMF	f, d	Complement f	1	00 1001 dfff ffff	Z	1,2
DECF	f, d	Decrement f	1	00 0011 dfff ffff	Z	1,2
DECFSZ	f, d	Decrement f, Skip if 0	1(2)	00 1011 dfff ffff		1,2,3
INCF	f, d	Increment f	1	00 1010 dfff ffff	Z	1,2
INCFSZ	f, d	Increment f, Skip if 0	1(2)	00 1111 dfff ffff		1,2,3
IORWF	f, d	Inclusive OR W with f	1	00 0100 dfff ffff	Z	1,2
MOVF	f, d	Move f	1	00 1000 dfff ffff	Z	1,2
MOVWF	f	Move W to f	1	00 0000 lfff ffff		
NOP	-	No Operation	1	00 0000 0xx0 0000		
RLF	f, d	Rotate Left f through Carry	1	00 1101 dfff ffff	C	1,2
RRF	f, d	Rotate Right f through Carry	1	00 1100 dfff ffff	C	1,2
SUBWF	f, d	Subtract W from f	1	00 0010 dfff ffff	C,DC,Z	1,2
SWAPF	f, d	Swap nibbles in f	1	00 1110 dfff ffff		1,2
XORWF	f, d	Exclusive OR W with f	1	00 0110 dfff ffff	Z	1,2
BIT-ORIENTED FILE REGISTER OPERATIONS						
BCF	f, b	Bit Clear f	1	01 00bb bfff ffff		1,2
BSF	f, b	Bit Set f	1	01 01bb bfff ffff		1,2
BTFSC	f, b	Bit Test f, Skip if Clear	1 (2)	01 10bb bfff ffff		3
BTFSS	f, b	Bit Test f, Skip if Set	1 (2)	01 11bb bfff ffff		3
LITERAL AND CONTROL OPERATIONS						
ADDLW	k	Add Literal and W	1	11 111x kkkk kkkk	C,DC,Z	
ANDLW	k	AND Literal with W	1	11 1001 kkkk kkkk	Z	
CALL	k	Call Subroutine	2	10 0kkk kkkk kkkk		
CLRWDT	-	Clear Watchdog Timer	1	00 0000 0110 0100	$\overline{TO}$,$\overline{PD}$	
GOTO	k	Go to Address	2	10 1kkk kkkk kkkk		
IORLW	k	Inclusive OR Literal with W	1	11 1000 kkkk kkkk	Z	
MOVLW	k	Move Literal to W	1	11 00xx kkkk kkkk		
RETFIE	-	Return from Interrupt	2	00 0000 0000 1001		
RETLW	k	Return with Literal in W	2	11 01xx kkkk kkkk		
RETURN	-	Return from Subroutine	2	00 0000 0000 1000		
SLEEP	-	Go into Standby mode	1	00 0000 0110 0011	$\overline{TO}$,$\overline{PD}$	
SUBLW	k	Subtract W from Literal	1	11 110x kkkk kkkk	C,DC,Z	
XORLW	k	Exclusive OR Literal with W	1	11 1010 kkkk kkkk	Z	

Adding two numbers

- Numbers are defined in locations in memory
- Move NUMBER1 to the W registers (working register)
- Add NUMBER2 to W and store the result back in W
- Move the value in W to the NUMBER3's memory location

```
// NUMBER3 =
// NUMBER1 + NUMBER2

NUMBER1 EQU 0x20
NUMBER2 EQU 0x21
NUMBER3 EQU 0x22

 MOVF  NUMBER1, W
 ADDWF NUMBER2, W
 MOVWF NUMBER3
```

Counting `down v1.0`

- W <- 10
- COUNT <- W
- Do some stuff
- If the Z bit is set in STATUS (the last operation == 0), then skip the next line
- If the GOTO is not skipped, then jump back to the do_loop

```
COUNT EQU 0x20

 MOVLW  d'10'
 MOVWF  COUNT
do_loop:
 // do stuff
 DECF   COUNT, F
 BTFSS  STATUS, Z
 GOTO   do_loop
```

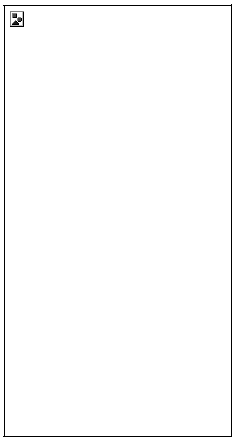
Counting `down v2.0`

- There are optimizations for common operations
- DECFSZ decrements the value in COUNT, stores it into COUNT, *and* if COUNT == 0 (if the Z bit is set), it skips the next instruction

```
COUNT EQU 0x20

 MOVLW d'10'
 MOVWF COUNT
do_loop:
 // do stuff
 DECFSZ COUNT, F
 GOTO  do_loop
```

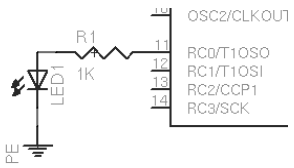
Labels



- Labels allow you to mark a place in the code to GOTO or CALL
- GOTO jumps to a label
- CALL saves the current position, then jumps to a label
  - Allows for a RETURN to the current position

Simple Output

- Setup PORTC pin 0 (RC0) to be an output
- Turn PORTC pin 0 on
- Turn PORTC pin 0 off

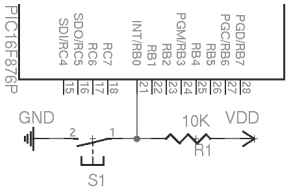



```
BSF STATUS, RP0
BCF TRISC, 0
BCF STATUS, RP0

BSF PORTC, 0
BCF PORTC, 0
```

Simple Input

- Setup PORTB pin 0 (RB0) to be an input
- If RB0 is “low” (reads 0), then skip
  - this is the button press
- If RB0 is “high”, then do next instruction
  - Keeps us looping until the button press




```
BCF  STATUS, RP0
BSF  TRISB, 0
BSF  STATUS, RP0

button_test:
BTFSC PORTB, 0
GOTO  button_test
// button pressed
```

Using the USART

- USART RX on RC7, TX on RC6
  - Make sure that RC7 is an input, and RC6 is an output in your code
- Load baud rate into SPBRG
- Receiver enable with CREN bit in RCSTA, transmitter enable with TXEN bit in TXSTA
- Put value you want to transmit into TXREG
- Loop on PIR1 bit RCIF to wait for bytes
- See sample code!

Assembler is fast! But…

- Large programs are hard to manage
- Allocating memory locations in your head is a pain
- Remembering the nuances of all the instructions can get annoying
- “Porting” your code to a different processor is almost impossible

Higher level languages

- C, Basic, Java, Lisp
- All “abstract” out the processor and let you focus on code
  - The compiler handles the conversion from the high level language to the assembly instructions
- There is a penalty, however…
  - Size of code
  - Execution speed

C vs. Assembler

Assembler

```
 MOVLW  d'10'
 MOVWF  COUNT
flash:
 BSF   PORTC, 0
 BCF   PORTC, 0
 DECFSZ COUNT, F
 GOTO  flash
```

C

```
count = 10;
while( count-- > 0 ) {
  port_c = 1;
  port_c = 0;

}
```

Raffi vs. CCS compiled

Raffi-written ASM

```
MOVLW d'10'
MOVWF COUNT
flash:
BSF   PORTC, 0
BCF   PORTC, 0
DECFSZ COUNT, F
GOTO  flash
```

CCS generated ASM

```
MOVLW d'10'
MOVWF COUNT
flash:
MOVF  COUNT, W
DECF  COUNT, F
XORLW d'0'
BTFSC STATUS, Z
GOTO  flash_done
MOVLW d'1'
MOVWF PORTC
CLRF  PORTC
GOTO  flash
flash_done:
```

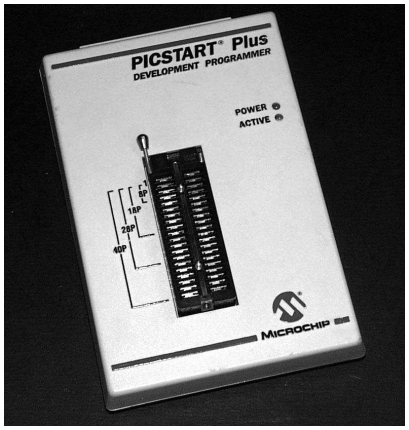
Getting the job done

Software

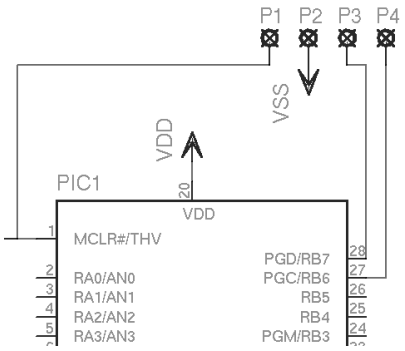
- MPLAB IDE : Microchip's integrated development environment
- PICC : CCS C compiler for PICs
  - Integrates into MPLAB
- gpasm : open source assembler

Hardware

- PICSTART Plus or equivalent programmer
- Project ideas
  - Program a "bootloader" into the software and then load code over the serial port
  - Build a PIC programmer (you can easily do it with another PIC and some simple circuitry)

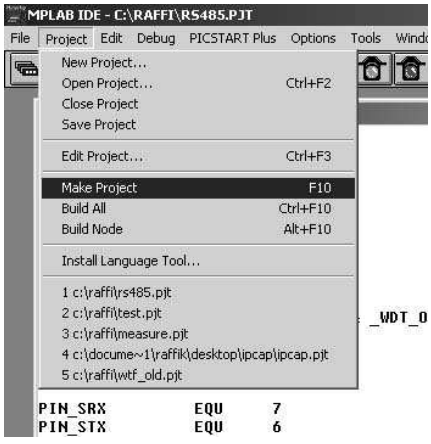


Attaching your board

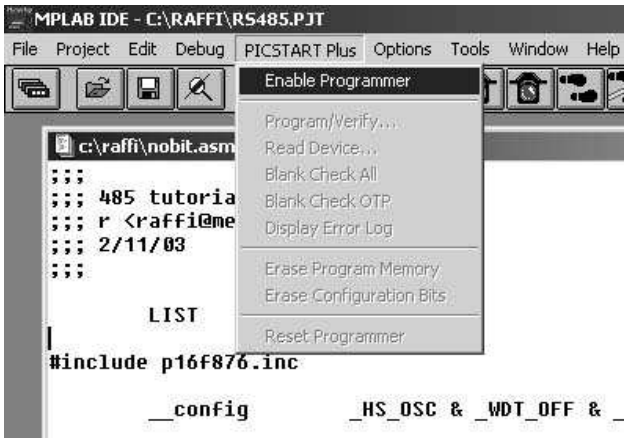


- Pin 1 goes to 15V when programming, pins 28 and 27 bidirectionally talk to programmer
- Attach a header and connect that to the programmer
- Also connect power (5V) and ground

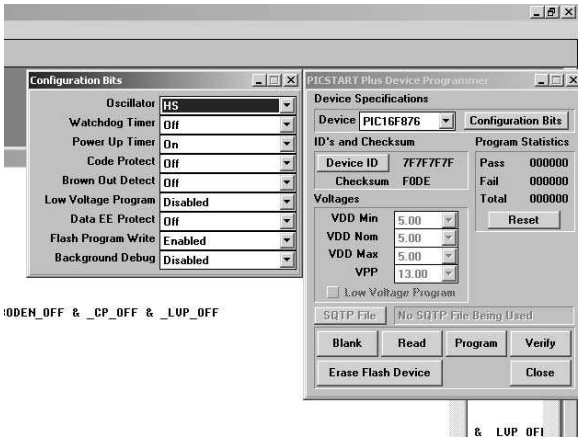
Compiling your code (MPLAB)



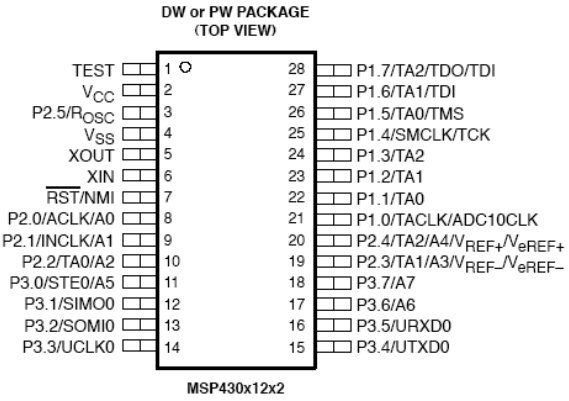
Getting ready to program (MPLAB)



Burn baby, burn (MPLAB)



MSP430F1232



What is it?

- 16-bit processor that can be clocked from 30 kHz - 8 MHz
- 8K Flash program memory and 256 bytes RAM
- 22 I/O pins (8 of which could be ADCs)
- Hardware USART

Why would you want to use it?

- This is where we're going
- GCC as the compiler/toolchain
- JTAG programming/debugging port
- 350 uA max current draw (PIC on avg. draws 6 mA)
- Easy to bridge into much more powerful micros