UNIVERSITY OF MICROCHIP
U OF M
MASTERs 2007

11028 CCS

A Comprehension of CCS C Compiler Advanced Techniques

Class Objectives

- **When you finish this class you will:**
  - Learn about the newest features added to the CCS C Compiler
  - Be able to use compiler output to diagnose problems
  - Know how to force ROM/RAM placement.
  - Get an overview of some of CCS's power features

Agenda

- **New Features**
- **Output Files and Messages**
- **Memory Control**
  - RAM
  - ROM
  - Bootloader Example
- **addressmod**
- **RTOS**

New Features

SPI

- **Configurable SPI library**
- **#use spi(parameters)**
  - HW or SW pins
  - Multiple streams
  - Clock rate and clock mode configurable
- **in = spi_xfer(STREAM_SPI, out)**

Bit Arrays

- **Array of bits:**
  - int1 flags[30]={FALSE};
  - flags[i] = TRUE;
  - if (flags[10]) { /* some code */ }
- **Bits are packed**
- **Pointers not supported!**

Fixed Point Decimal

- **Represent decimal numbers with integers, instead of floats**
  - Faster, Smaller
  - 100% precision
- **Example Declaration:**

```
[type] _fixed(y) [declarator]
int16 _fixed(2) money;
```

- **Supported by printf()**

Fixed Point Decimal Examples

- `int16 _fixed(2) cash;`
  - Range: 0.00 to 655.35
- `cash = 20.50;`
- `cash += 5;      //adds 5.00`
- `cash += value;`
- `printf(“%w”, cash);`

String Parameters

- String can be function parameter
- `LCDPuts(“Hello”);`
- Example (RAM):

```
#device PASS_STRINGS=IN_RAM
void LCDPuts(char *str);
```

- Example (Const RAM):

```
#device PASS_STRINGS=IN_RAM
#device CONST=ROM
void LCDPuts(const char *str);
```

- Example (ROM):

```
void LCDPuts(rom char *str);
```

#import()

- **Import various files into project.**
- **#import(File=name, Type)**
- **Type = Relocatable (.o, .cof)**
  - ‘only’ and ‘except’ specifies what C symbols
- **Type = HEX (.hex)**
  - ‘range’ parameter specifies range
- **Type = RAW**
  - ‘location’ gets or sets location
  - ‘size’ parameter gets size

Examples / Libraries

- **Variable number of parameters (…)**
- **Borrowed from C++:**
  - Default parameters
  - Function Overloading
- **New examples / libraries:**
  - FAT
  - XTEA Cipher
  - Modbus

Output Messages and Output Files

Output Files

- HEX – Compiled Application
- COF – Debug Application
- ERR – Compile output messages
- LST – C to Assembly comparison
- SYM – Memory Map
- STA – Statistics
- TRE – Call Tree

SYM – Memory Map

- **First section is RAM memory map**

```
005-014     main.buffer
na      main.index
```

- **‘na’ indicates no RAM**
- **Following sections include:**
  - Other Input files
  - ROM memory map
  - PIC® MCU / Compiler Settings

STA Statistics

- Review ROM/RAM/Stack used
- Statistics for each function:

```
Page ROM  %  RAM  Functions:
---- --- --- ---  ----------
0     26  0    1  @delay_ms1
0    284  1    3  ee_reset
```

STA Statistics

- **Statistics for each segment:**

```
Segment        Used   Free
---------     -----   ----
00000-00006       4      4
00008-000B2     172      0
000B4-03FFE   15826    378
```

TRE Statistics

- **Review call tree**
  - Function Name - Segment/ROM – RAM

```
project
  main  0/84  Ram=0
   init  0/194  Ram=1
      RELAY_INIT  0/16  Ram=0
          RELAY1_OFF  (Inline)  Ram=0
          @delay_ms1  0/26  Ram=1
```

- **Segment will be ? if it won’t fit**

Out of ROM

- **Full output:**

  ```
  Out of ROM, A segment or the program is too
  large: XXXXXX
  Seg w-x, y left, need z
  Seg 0-3ff, 12C left, need 12F
  ```

- **Tips:**
  - Be aware of processor segment size

    ```
    Seg 0-3FF, 3FF left, need 412
    ```

  - Optimize code
  - Split large functions
  - Reduce stack space

How Can I Reduce Code Space?

- Use int1 or bit fields for flags
- Use fixed point decimal, not float
- Divide large functions
- Avoid ->, move structure to local
- Use access bank mode
  - #device *=8
  - read_bank(b,o), write_bank(b,o,v)

Out of RAM

- **Full error message:**

  `Not enough RAM for all variables`

- **Review SYM file**
- **Tips:**
  - Be aware of PIC® MCU bank size
  - Use bit flags
  - Remove unused variables

Memory Management

#locate

- **Force location of variable**
- **#locate ident=X**
  - Assigns the C variable ident to location X
  - X can be a literal, or variable identifier
  - If not specified, ident is treated as a byte
  - Compiler allocates X
  - Can be any structure or type (not const)

#locate examples

- Overlaying variable onto SFR:

```
#locate STATUS=5
```

- Repeat, but using get_env():

```
#locate STATUS=get_env(“SFR:STATUS”)
```

- Overlaying two variables:

```
char buffer[512];
struct { /*protocol */} header;
#locate header=buffer+2
```

#byte and #bit

- **#byte ident=X**
  - Same as #locate, but no allocation
- **#bit ident=X.b**
  - Declares boolean at address X, bit b
  - Examples:
    - **`#bit CARRY=STATUS.0`**
    - **`#bit CARRY=get_env(“BIT:C”)`**

#rom

- **Place raw data into program memory**
- **#rom address={data….data}**
- **Application Ideas:**
  - Place strings into ROM
  - Initialize the internal data EEPROM
  - Manually set configuration bits
  - Manually set ID location

#inline and #separate

- **#inline**
  - Makes following function inline
- **#separate**
  - Makes following function separate (called)
  - Disables stack overflow check
- **Generally you should let the optimizer determine if a function should be separate or inline**

#org

- **Create segment, force code into segment**
- **#org start, end**
  - Place following function/constant in this segment
- **#org start**
  - Continue previous segment

#org Example

- Force following code into 0x100-0x1FF

```
#org 0x100, 0x1FF
void func1(void) {/*code*/}

#org 0x100
const cstring[]=“Hello”;

#org 0x100
void func2(void) {/*code*/}

//Valid Protoype
#seperate void func1(void);
```

#org

- **#org start, end DEFAULT**
  - Forces all following function/constants into this segment.
- **#org DEFAULT**
  - Terminate previous DEFAULT
- **#org start, end { }**
  - Reserve ROM

#org Example 2

- Force following code into 0x100-0x1FF

```
#org 0x100, 0x1FF default
void func1(void) {/*code*/}

const cstring[]=“Hello”;

void func2(void) {/*code*/}

#org default
```

#org

- View .STA to view current segment usage:

```
Segment         Used   Free
0000-0003:      4      0
0004-00FF:      250    2
0100-01FF:      190    66
0200-07FF:      1337   199
```

#build

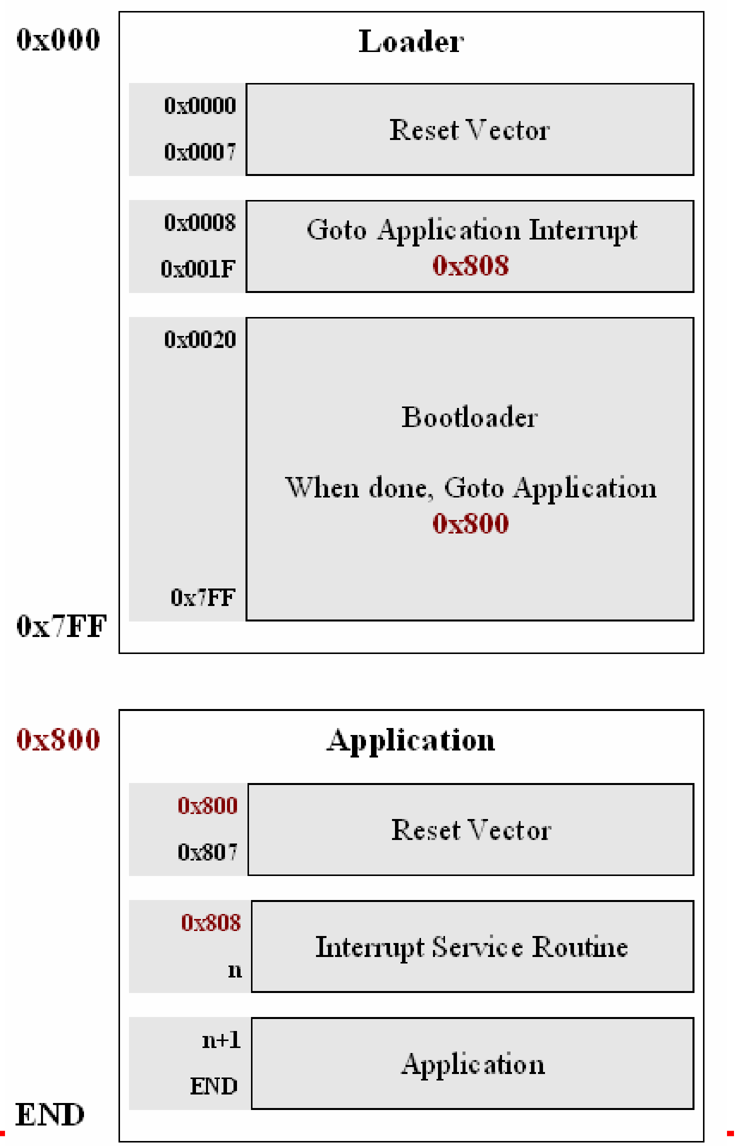
- **Can change reset and interrupt segment**
- **#build(segment=start:end)**
- **Valid segments:**
  - reset – the location of the reset vector
  - interrupt – the location of the interrupt vector
  - memory – external memory for CPU mode
- **Examples:**
  - #build(reset=0x800, interrupt=0x808)
  - #build(memory=0x10000:0x1FFFF)

Memory Management

Bootloader Example

Bootloader Overview

- Two programs:
  - Loader
  - Application
- Each program #org'd to their own space
  - Loader in low memory (0-7FF)
  - Application high memory (800-end)



0x000 Loader

0x0000 – 0x0007: Reset Vector

0x0008 – 0x001F: Goto Application Interrupt 0x808

0x0020 – 0x7FF: Bootloader

When done, Goto Application 0x800

0x7FF

0x800 Application

0x800 – 0x807: Reset Vector

0x808 – n: Interrupt Service Routine

n+1 – END: Application

END

Bootloader/Application Common Code

```
#define BOOT_END          (0x7FF)
#define APP_START         (BOOT_END+1)
#define APP_ISR           (APP_START+8)
#define PROGRAM_END
           getenv(“PROGRAM_MEMORY”)
```

Bootloader Example
Loader Code

```
//prevent bootloader from using application
#org APP_START , PROGRAM_END { }

#int_global
void isr(void)  {
  //goto interrupt in application
  jump_to_isr(APP_ISR);
}

void main(void) {
  if (IsBootloadEvent())
       Bootload();
   #asm
    goto APP_START
   #endasm
}
```

Bootloader Example Application Code

```
#import(file=loader.hex, range=0:BOOT_END)

#build(reset=APP_START,interrupt=APP_ISR)

#org 0,BOOT_END { }

#int_timer0
void timer(void) { /* do timer0 isr */ }

Void main(void)  {
   /* code */
}
```

Memory Managemt

addressmod

addressmod

- **Application defined storage**
  - ISO/IEC TR 18037 (Embedded C)
- **typemod, on steroids!**
- **`nv char productId[PID_LEN];`**
- **Can be used on any data type**
  - Pointers, structs, unions and arrays
  - const not allowed

addressmod Syntax

- **addressmod(identifier,[read,write,]start,end)**
  - identifier is the new qualifier
  - read(int32 addr, int8 *ptr, int8 len)
  - write(int32 addr, int8 *ptr, int8 len)
    - **The IO method to access this memory**
    - **Optional**
  - start/end are the memory range

addressmod Declaration

```
addressmod(nv, read_nv, write_nv,
           0, NV_SIZE);

void read_nv(int32 addr,
             int8 *ram, int8 n)
{ /* read n from addr */ }

void write_nv(int32 addr,
              int8 *ram, int8 n)
{ /* write n from ram */ }
```

addressmod Usage

```
nv NVBuffer[8192];
nv NVID;
nv *NVPtr;

#locate NVID=0

NVBuffer[i]=55;
*NVPtr++ = 0;
```

addressmod Block

- **#type default=qualifier**
  - Following declarations will use this qualifier
  - If qualifier blank, goes back to default

```
#type default=nv

char buffer[8192];
#include <memoryhog.h>

#type default=
```

addressmod Ideas

- External RAM / Flash
- Character/Grahic LCD access thru a multi-dimensional array
- Debug/trap critical variables

RTOS

RTOS Basics

- **Multitasking thru time-sharing**
  - Tasks appear to run at same time
- **'Real Time'**
- **Task is in one of three states:**
  - Running
  - Ready
  - Blocked

The CCS RTOS

- Cooperative Multitasking
- Tightly integrated with compiler
- Supports ALL PIC® MCUs with a Timer
- Available to IDE customers

RTOS Setup

- `#use rtos(timer=X, [minor_cycle=cycle_time])`
  - Timer can be any timer available
  - Minor_Cycle is rate of fastest task
  - Example:

```
#use rtos(timer=1, minor_cycle=50ms)
```

RTOS Tasks

- `#task(rate=xxxx, [max=yyyy], [queue=z])`
  - Following function is RTOS task
  - Will be called at specified rate
  - Max is slowest execution time, used for budgeting.
  - Queue defines RX message size

RTOS Start and Stop

- **rtos_run()**
  - Starts the RTOS
  - Will not return until rtos_terminate()
- **rtos_terminate()**
  - Stops the RTOS

```
#use rtos(timer=1)

#task(rate=100ms, max=5ms)
void TaskInput(void)
  { /* get user input */ }

#task(rate=25ms)
void TaskSystem(void)
  { /* do some stuff */ }

void main(void) {
  while(TRUE) {
     rtos_run();
     sleep();
  }
}
```

RTOS Task Control

- **rtos_enable(task)**
- **rtos_disable(task)**
  - Dynamic task control
  - Enable/Disable the specified task
  - Task is the function name
  - All tasks are enabled at start

RTOS Messaging

- **rtos_msg_send(task, char)**
  - Sends char to task
- **avail=rtos_msg_poll()**
  - TRUE if a char is waiting for this task
- **byte=rtos_msg_read()**
  - Read next char destined for this task

RTOS Yielding

- **rtos_yield()**
  - Stops processing current task
  - Returns to this point on next cycle
- **rtos_await(expression)**
  - rtos_yield() if expression not TRUE

```
#task(rate=100ms, max=5ms)
void TaskInput(void) {
  if (KeyReady())
     rtos_msg_send(TaskSystem, KeyGet());
}

#task(rate=25ms, queue=1)
void TaskSystem(void) {
  SystemPrepare();
  rtos_await(rtos_msg_poll());
  SystemDo(rtos_msg_read());
  rtos_yield();
  SystemVerify();
}
```

RTOS Semaphores

- **Semaphore**
  - Determine shared resource availability
  - A user defined global variable
  - Set to non-zero if used
  - Set to zero if free
- **rtos_wait(semaphore)**
  - rtos_yield() until semaphore free
  - Once free, sets semaphore as used
- **rtos_signal(semaphore)**
  - Release semaphore

RTOS Timing Statistics

- **overrun=rtos_overrun(task)**
  - TRUE if task took longer than max
- **rtos_stats(task, rtos_stats)**
  - Get timing statistics for specified task

```
typedef struct {
  int32 total;  // total ticks used by task
  int16 min;    // minimum tick time used
  int16 max;    // maximum tick time used
  int16 hns;    // us = (ticks*hns)/10
} rtos_stats;
```

RTOS Application Ideas

- User I/O
- Communication Protocols

Class Summary

- **New Features**
- **Output Files and Messages**
- **Memory Control**
  - RAM
  - ROM
  - Bootloader Example
- **addressmod**
- **RTOS**

Q & A

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