ME4405 - Fundamentals of Mechatronics (Spring 2020)

Lab Assignment Two

Getting Started with CCS and Reading Spec Sheets

Due Thursday, January 30th, 2020

Objective: The objectives of this lab are to (1) **get acquainted Code Composer Studio (CCS)** which will be used throughout the rest of the course and (2) **practice reading and interpreting component specification sheets**. This lab covers installing CCS, running a first program, debugging the program along with the MSP432 device, and building a theoretical mechatronic system by selecting components that satisfy the system operating requirements and constraints.

Deliverables and Grading:

To get credit for this lab assignment you must:

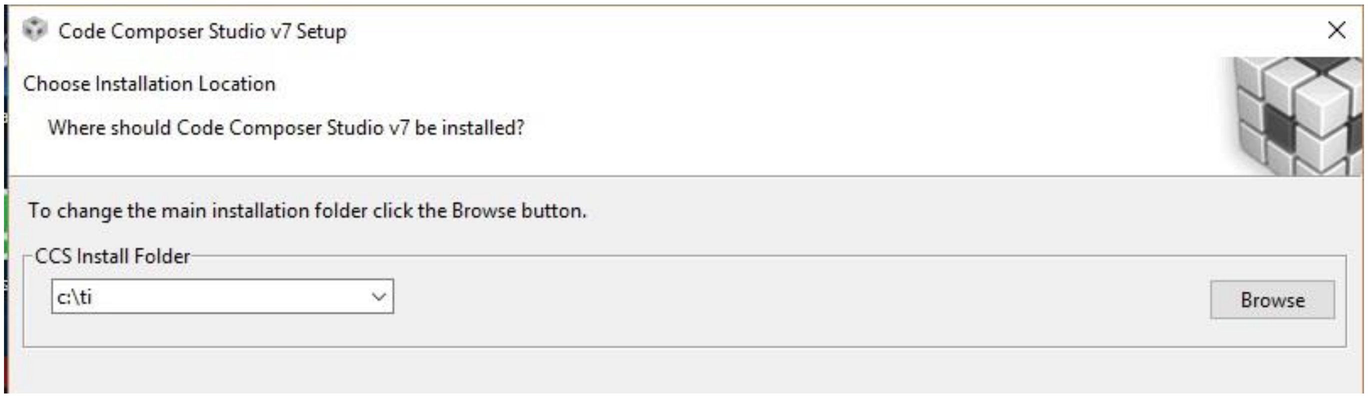
1) Turn in a copy of your typed report answering the questions at the end of the lab manual. This report is due **by 5pm** on Canvas on the above due date. **(50 points)**

2) Lab assignment quiz which will be taken at the beginning of lab section on Friday, January 31st. **(10 points)**

Procedure:

Installation and setting up of the Code Composer Studio (CCS) Integrated Development Environment (IDE):

1. Download the latest version of **Texas Instruments CCS IDE version** from this link **http://processors.wiki.ti.com/index.php/Download_CCS**.
2. Extract the folder to an appropriate location. **It is best to disable any real-time anti-virus protection software before beginning the installation.**
3. Double click the "ccs_setup....exe" file to start installing CCS. Read and accept all the terms and conditions.
4. Choose where to install CCS by browsing to the desired path as shown in the image below.


Code Composer Studio v7 Setup

Choose Installation Location

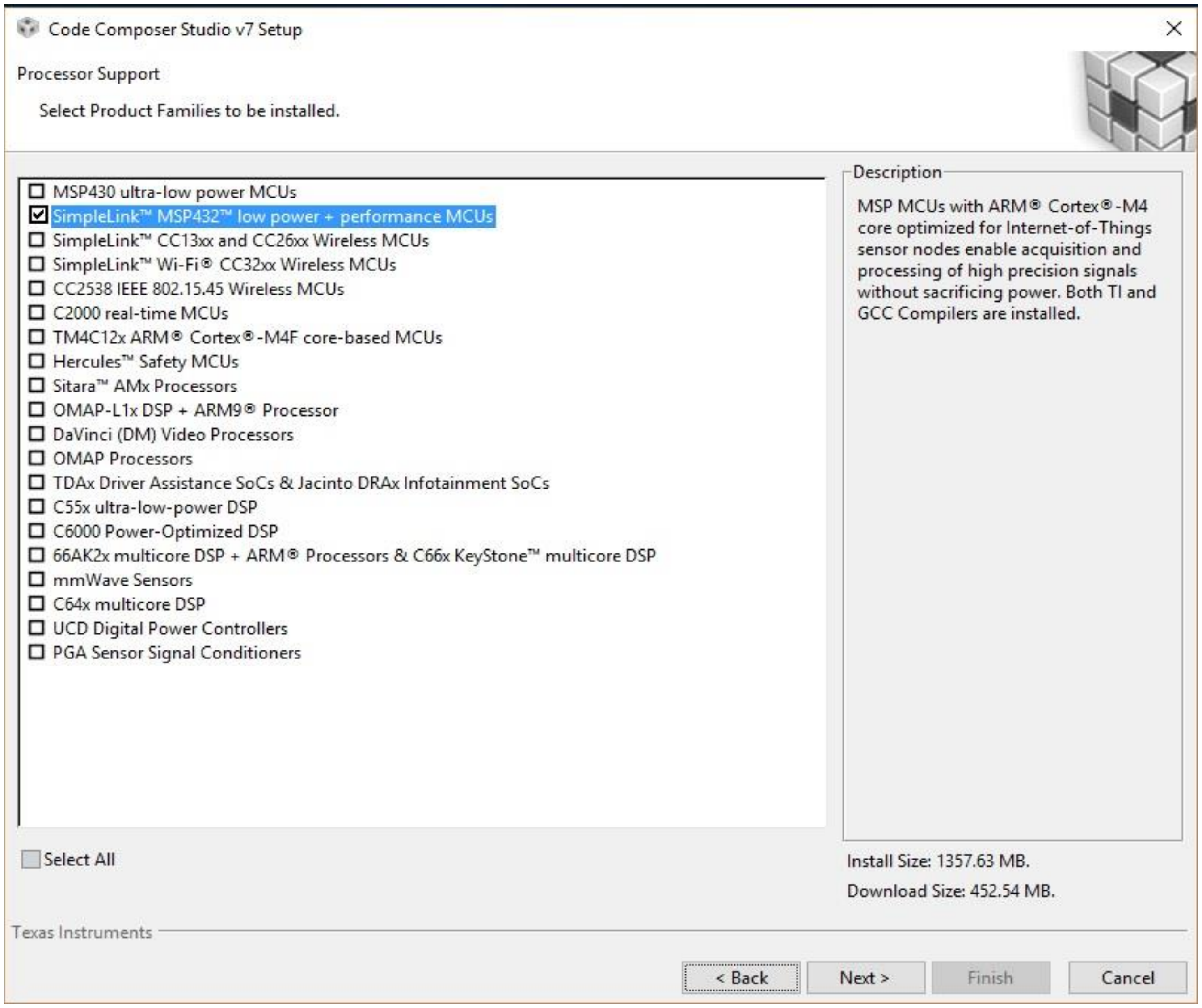
Where should Code Composer Studio v7 be installed?

To change the main installation folder click the Browse button.

CCS Install Folder

c:\ti

5. Select the option: **SimpleLink MSP432 low power + performance MCUs**


Code Composer Studio v7 Setup

Processor Support

Select Product Families to be installed.

- ☐ MSP430 ultra-low power MCUs
- ☑ SimpleLink™ MSP432™ low power + performance MCUs
- ☐ SimpleLink™ CC13xx and CC26xx Wireless MCUs
- ☐ SimpleLink™ Wi-Fi® CC32xx Wireless MCUs
- ☐ CC2538 IEEE 802.15.45 Wireless MCUs
- ☐ C2000 real-time MCUs
- ☐ TM4C12x ARM® Cortex®-M4F core-based MCUs
- ☐ Hercules™ Safety MCUs
- ☐ Sitara™ AMx Processors
- ☐ OMAP-L1x DSP + ARM9® Processor
- ☐ DaVinci (DM) Video Processors
- ☐ OMAP Processors
- ☐ TDAx Driver Assistance SoCs & Jacinto DRAx Infotainment SoCs
- ☐ C55x ultra-low-power DSP
- ☐ C6000 Power-Optimized DSP
- ☐ 66AK2x multicore DSP + ARM® Processors & C66x KeyStone™ multicore DSP
- ☐ mmWave Sensors
- ☐ C64x multicore DSP
- ☐ UCD Digital Power Controllers
- ☐ PGA Sensor Signal Conditioners

Description

MSP MCUs with ARM® Cortex®-M4 core optimized for Internet-of-Things sensor nodes enable acquisition and processing of high precision signals without sacrificing power. Both TI and GCC Compilers are installed.

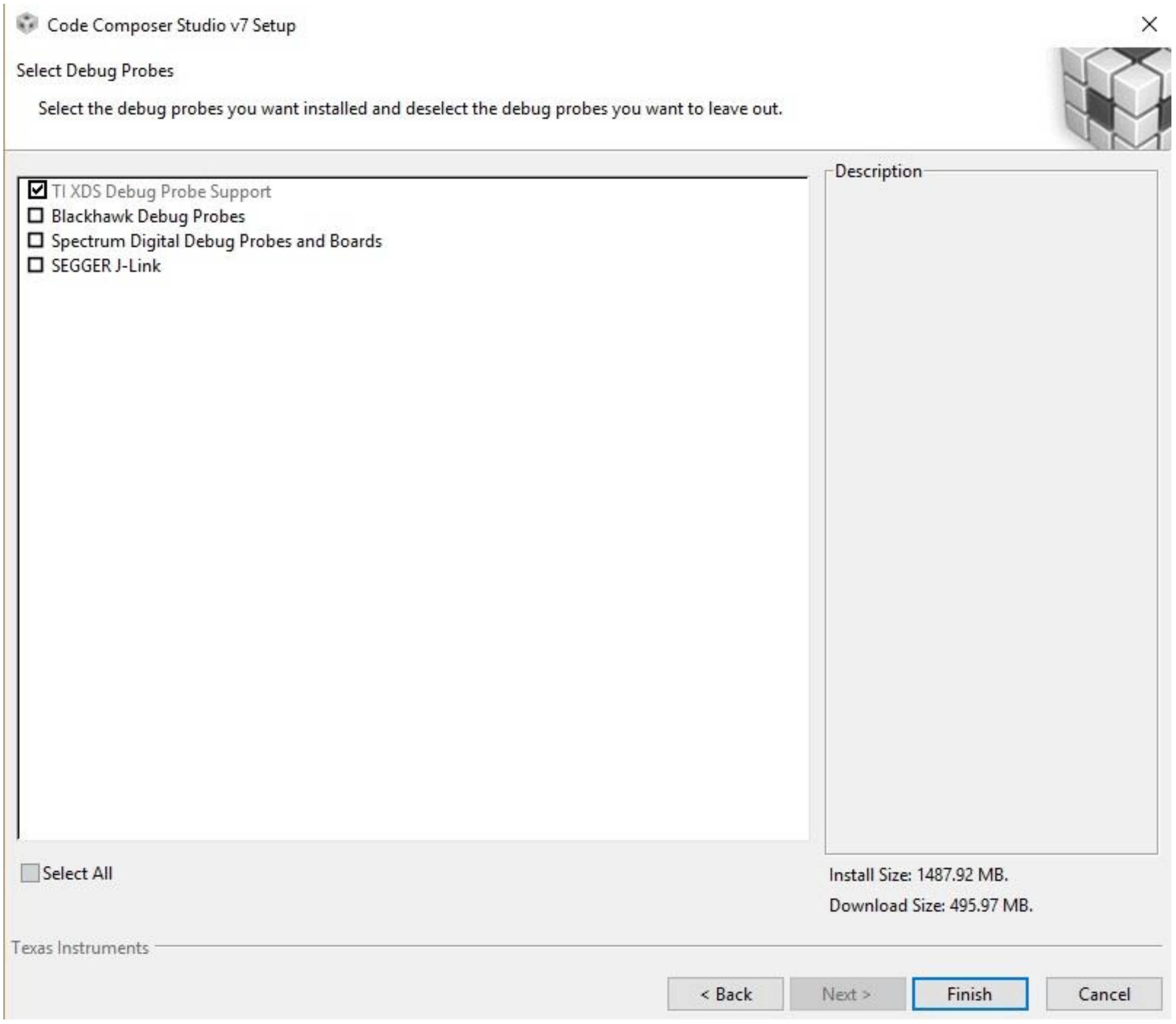
☐ Select All

Install Size: 1357.63 MB.

Download Size: 452.54 MB.

Texas Instruments

6. Install (only) the default probes.


Code Composer Studio v7 Setup

Select Debug Probes

Select the debug probes you want installed and deselect the debug probes you want to leave out.

- [x] TI XDS Debug Probe Support
- [ ] Blackhawk Debug Probes
- [ ] Spectrum Digital Debug Probes and Boards
- [ ] SEGGER J-Link

Description

- [ ] Select All

Install Size: 1487.92 MB.

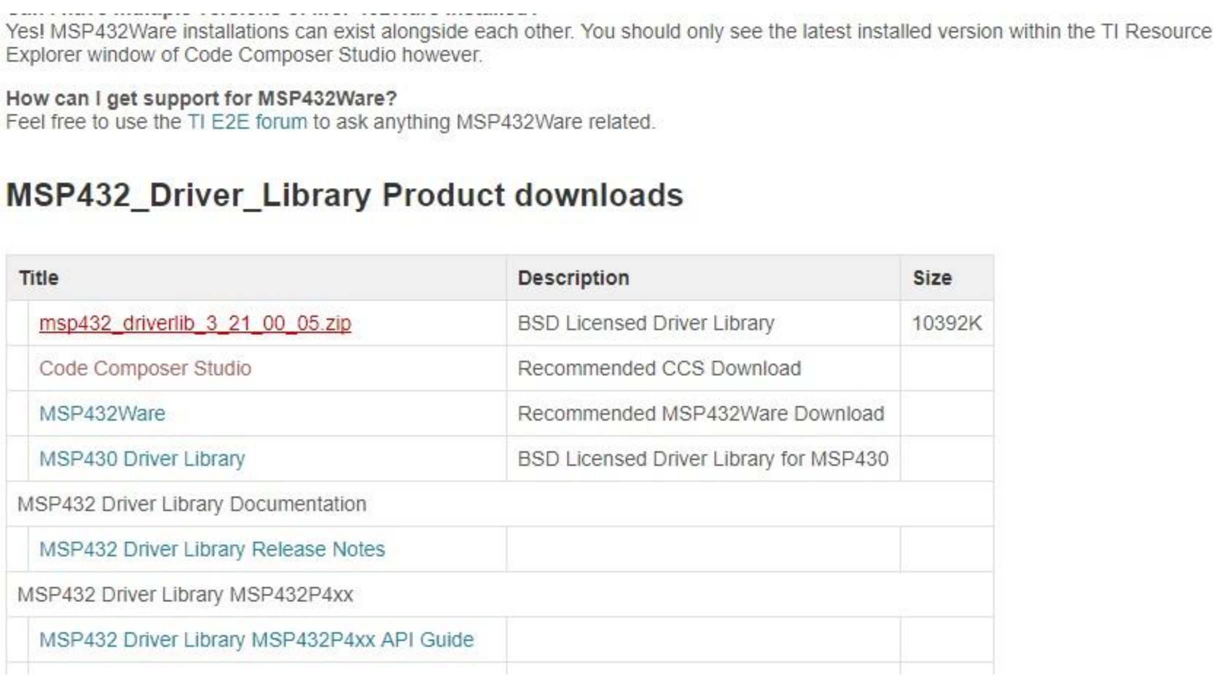
Download Size: 495.97 MB.

Texas Instruments

11. Click Finish to begin installation. This will take a while as it downloads and installs all the necessary components.

Download MSP432 driverlib

1. Download the latest version of the MSP432 driver library from this link: http://software-dl.ti.com/msp430/msp430_public_sw/mcu/msp430/MSP432_Driver_Library/latest/index_FDS.html
   As shown below:

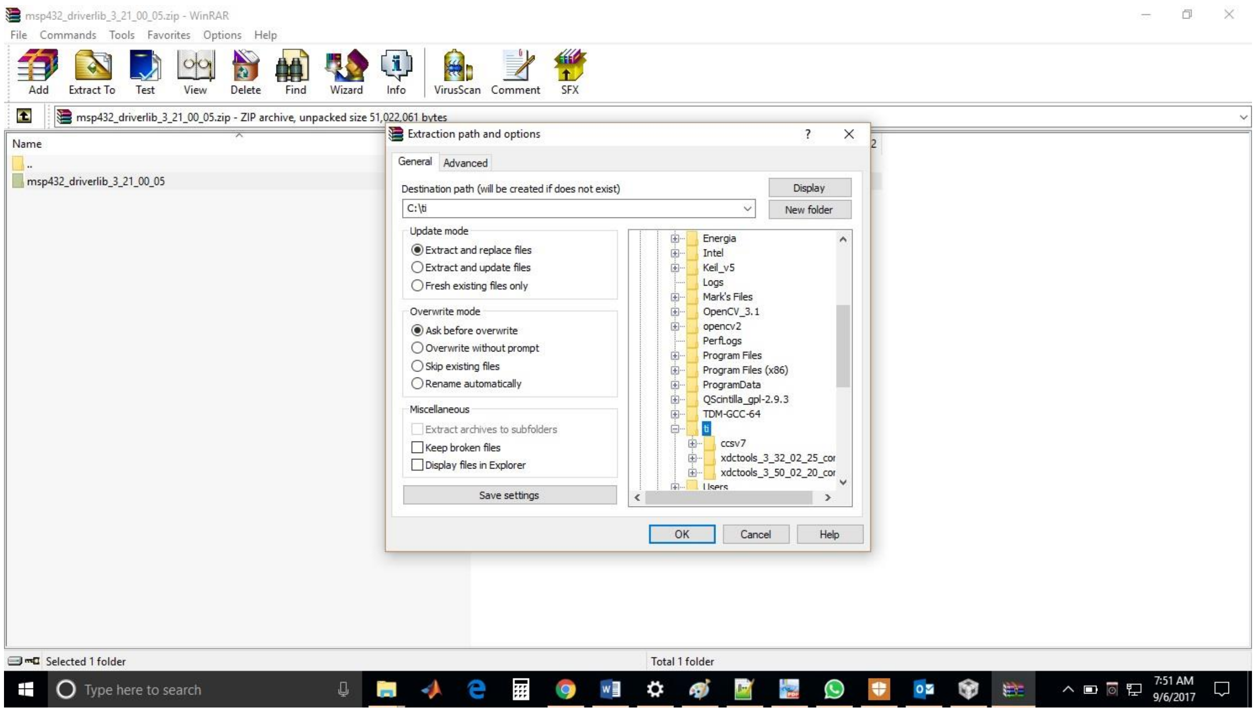

Yes! MSP432Ware installations can exist alongside each other. You should only see the latest installed version within the TI Resource Explorer window of Code Composer Studio however.

How can I get support for MSP432Ware?
Feel free to use the TI E2E forum to ask anything MSP432Ware related.

MSP432_Driver_Library Product downloads

Title	Description	Size
msp432_driverlib_3_21_00_05.zip	BSD Licensed Driver Library	10392K
Code Composer Studio	Recommended CCS Download	
MSP432Ware	Recommended MSP432Ware Download	
MSP430 Driver Library	BSD Licensed Driver Library for MSP430	
MSP432 Driver Library Documentation		
MSP432 Driver Library Release Notes		
MSP432 Driver Library MSP432P4xx		
MSP432 Driver Library MSP432P4xx API Guide		

2. Download and extract the zip file to the same directory (For example C:\ti\) as the CCS installation directory.



Destination path (will be created if does not exist)
C:\ti

Update mode
- [✓ Extract and replace files]
- Extract and update files
- Fresh existing files only

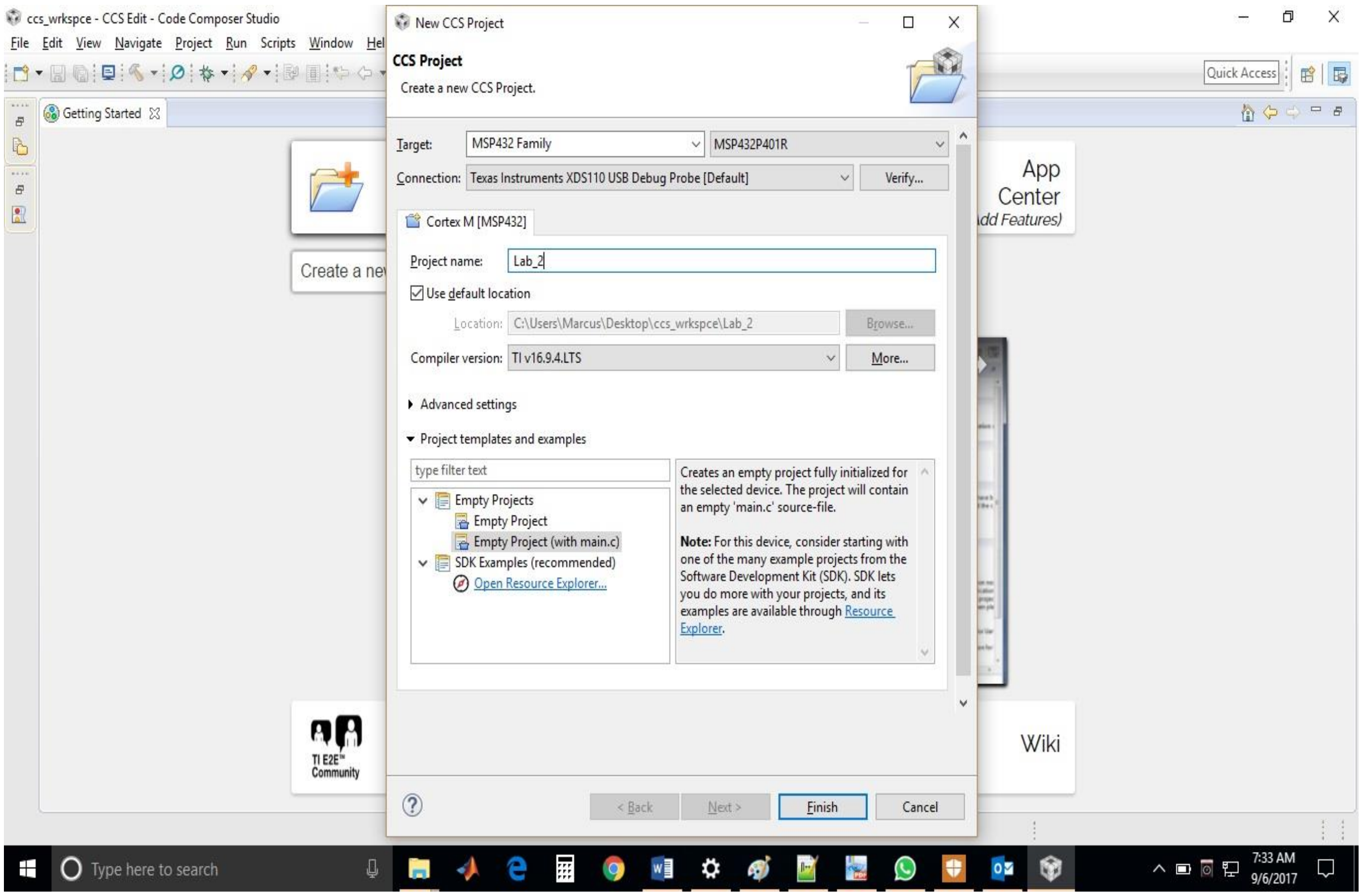
Overwrite mode
- [✓ Ask before overwrite]
- Overwrite without prompt
- Skip existing files
- Rename automatically

Miscellaneous
- Extract archives to subfolders
- Keep broken files
- Display files in Explorer

Starting the Application:

1. Launch Code Composer Studio software by double clicking on the Code Composer Studio icon on the desktop.

2. A new window will pop up. This will ask you to enter a path for the workspace. All the projects and files that you create from here on will be saved at this location. Enter an appropriate address/location. It is recommended to create a new dedicated folder which will serve as your workspace for this course.
3. When launched for the first time, CCS will prompt you to run a few updates. Go ahead and select all the available updates, read and agree to the terms & conditions and install the updates. Following this, CCS will restart.
4. An empty CCS workbench will open with a Getting Started Window.
5. Click on the New Project button. This should open a window with the title "New CCS Project"
6. Give Project name as Lab_2. In the Target dialogue box, put MSP432P401R.



New CCS Project

CCS Project

Create a new CCS Project.

Target: MSP432 Family | MSP432P401R

Connection: Texas Instruments XDS110 USB Debug Probe [Default] | Verify...

Cortex M [MSP432]

Project name: Lab_2

☑ Use default location

Location: C:\Users\Marcus\Desktop\ccs_wrkspce\Lab_2 | Browse...

Compiler version: TI v16.9.4.LTS | More...

▸ Advanced settings

▾ Project templates and examples

type filter text

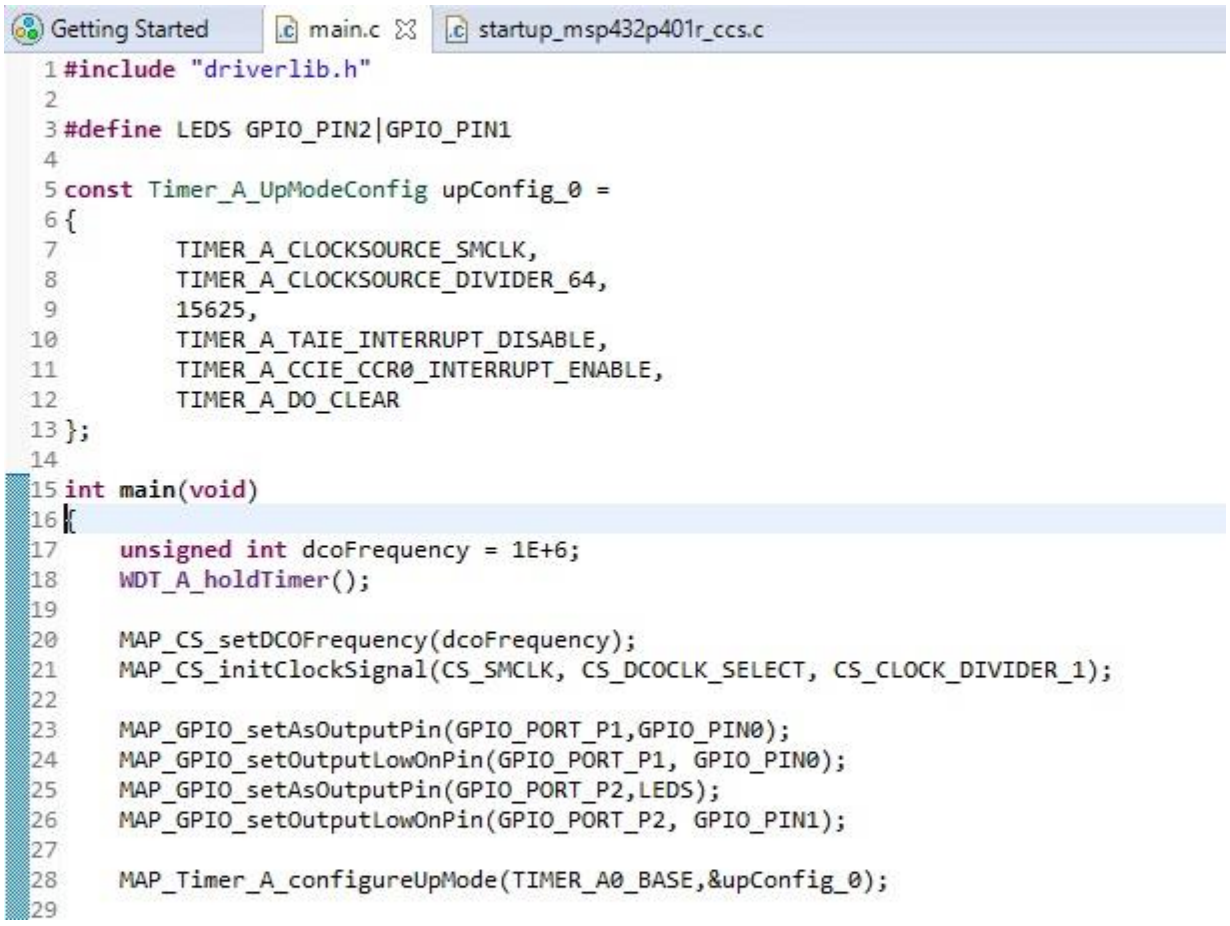
- Empty Projects
  - Empty Project
  - Empty Project (with main.c)
- SDK Examples (recommended)
  - Open Resource Explorer...

Creates an empty project fully initialized for the selected device. The project will contain an empty 'main.c' source-file.

Note: For this device, consider starting with one of the many example projects from the Software Development Kit (SDK). SDK lets you do more with your projects, and its examples are available through Resource Explorer.

< Back | Next > | Finish | Cancel

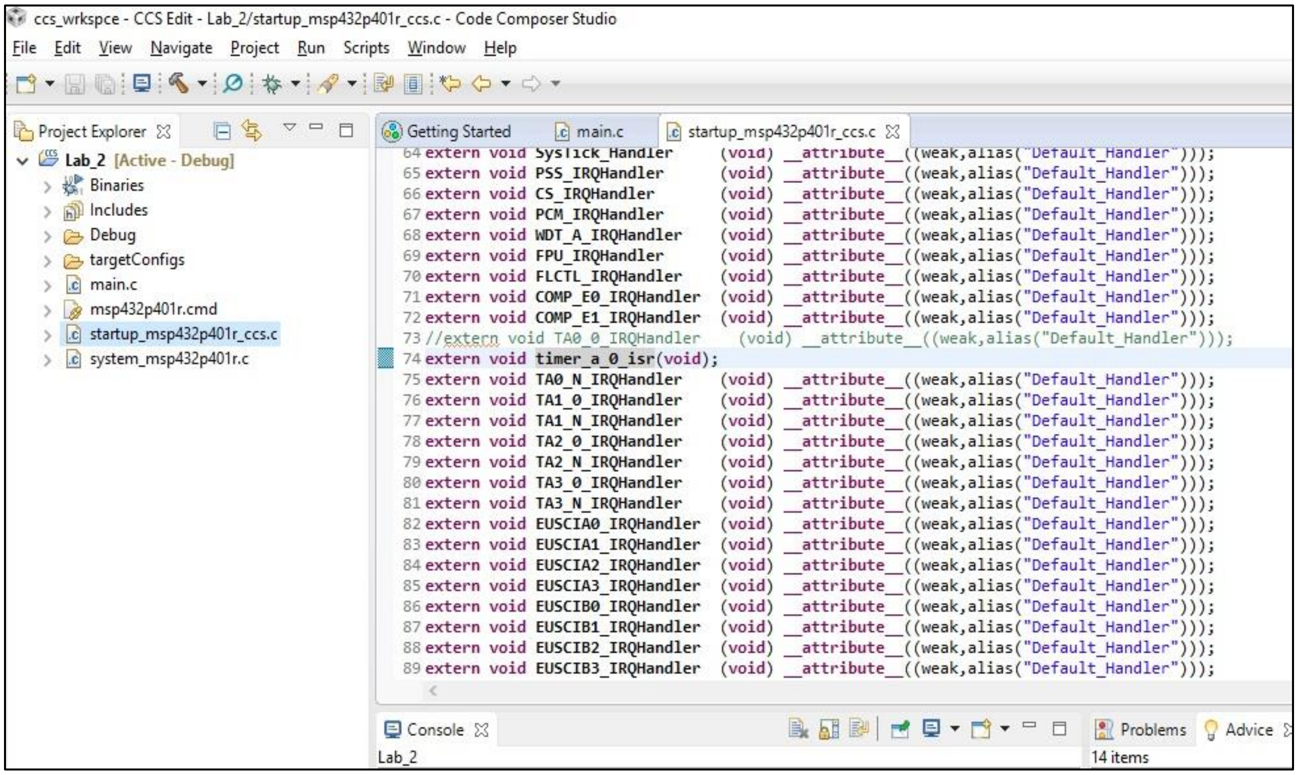
7. In the adjacent drop down menu select MSP432P401R.
8. In the Project templates, select **Empty Project (with main.c)**. Click Finish.
9. A main.c file opens with a part of code already written in the editor.
10. Delete the contents created in the main.c by default and replace it with the main.c provided with this lab manual on Canvas.



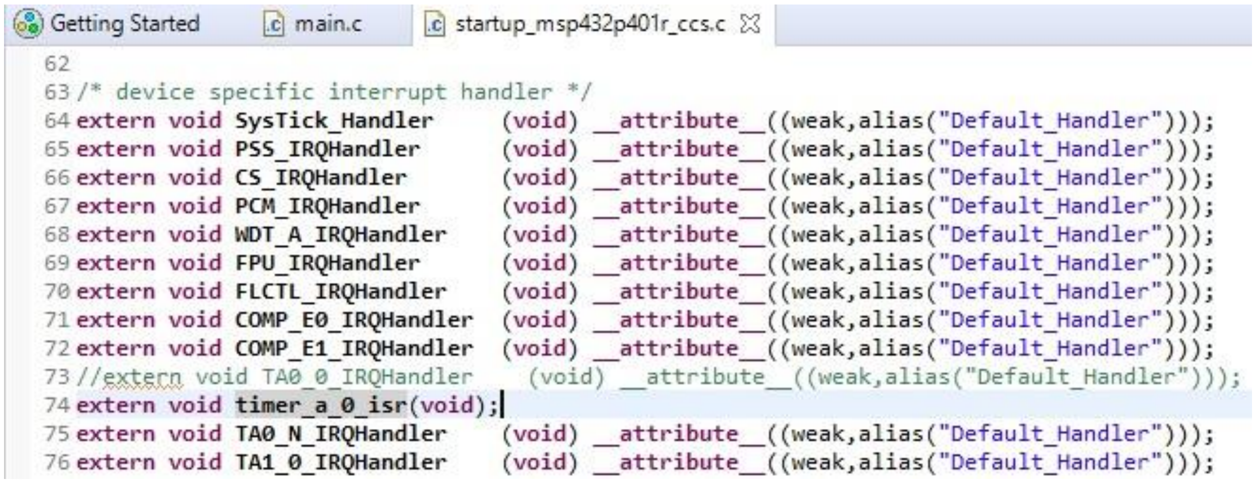
```c
#include "driverlib.h"

#define LEDS GPIO_PIN2|GPIO_PIN1

const Timer_A_UpModeConfig upConfig_0 =
{
        TIMER_A_CLOCKSOURCE_SMCLK,
        TIMER_A_CLOCKSOURCE_DIVIDER_64,
        15625,
        TIMER_A_TAIE_INTERRUPT_DISABLE,
        TIMER_A_CCIE_CCR0_INTERRUPT_ENABLE,
        TIMER_A_DO_CLEAR
};

int main(void)
{
    unsigned int dcoFrequency = 1E+6;
    WDT_A_holdTimer();

    MAP_CS_setDCOFrequency(dcoFrequency);
    MAP_CS_initClockSignal(CS_SMCLK, CS_DCOCLK_SELECT, CS_CLOCK_DIVIDER_1);

    MAP_GPIO_setAsOutputPin(GPIO_PORT_P1,GPIO_PIN0);
    MAP_GPIO_setOutputLowOnPin(GPIO_PORT_P1, GPIO_PIN0);
    MAP_GPIO_setAsOutputPin(GPIO_PORT_P2,LEDS);
    MAP_GPIO_setOutputLowOnPin(GPIO_PORT_P2, GPIO_PIN1);

    MAP_Timer_A_configureUpMode(TIMER_A0_BASE,&upConfig_0);

```

11. Now, open the **startup_msp432p401r_ccs.c** file in the Project Explorer by double clicking on it and scroll down to line 73. Comment out the existing command by prepending the line with a **double-backslash (//)** as shown in the image below. On the next line, type the following : **extern void timer_a_0_isr(void);** as shown in the image below.

DO NOT FORGET THE SEMI-COLON !

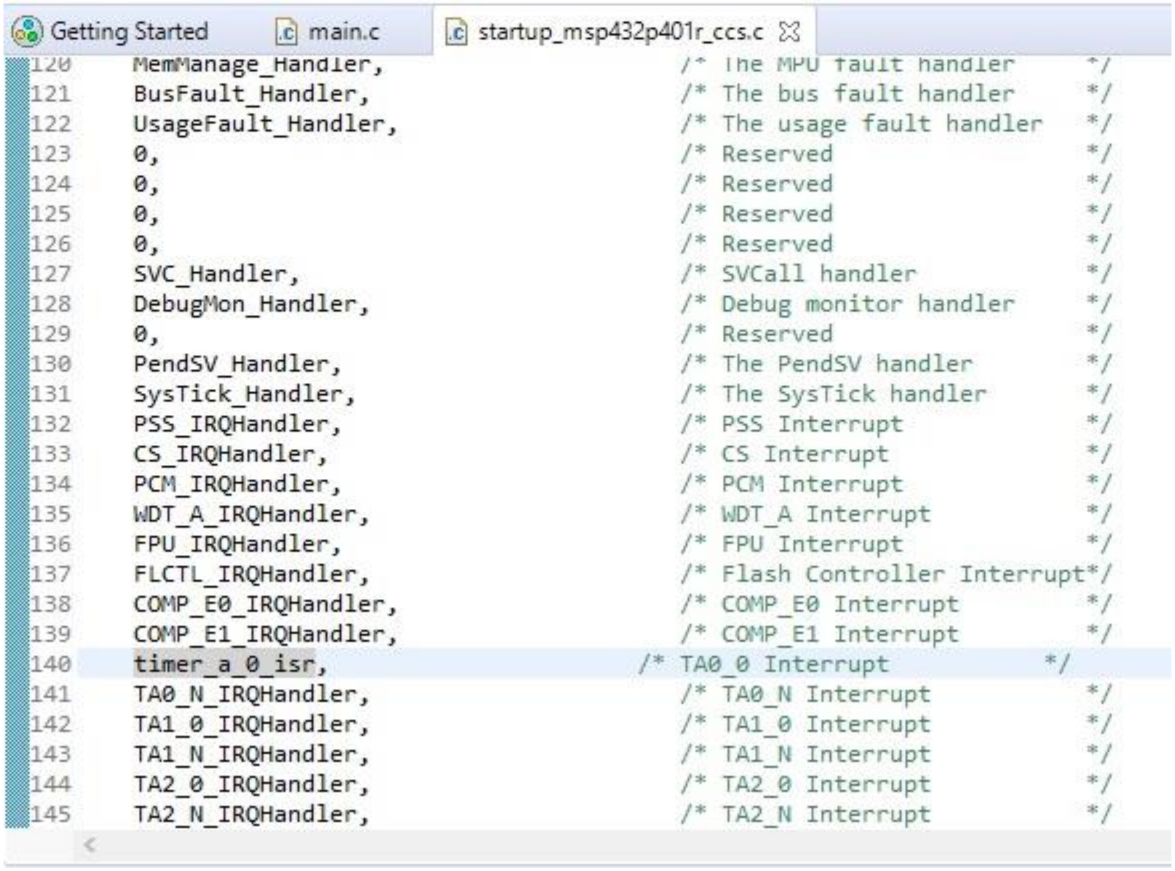

ccs_wrkspce - CCS Edit - Lab_2/startup_msp432p401r_ccs.c - Code Composer Studio
File Edit View Navigate Project Run Scripts Window Help
Project Explorer
Lab_2 [Active - Debug]
Binaries
Includes
Debug
targetConfigs
main.c
msp432p401r.cmd
startup_msp432p401r_ccs.c
system_msp432p401r.c
Getting Started
main.c
startup_msp432p401r_ccs.c
Console
Lab_2
Problems
Advice
14 items

```
64 extern void SysTick_Handler     (void) __attribute__((weak,alias("Default_Handler")));
65 extern void PSS_IRQHandler      (void) __attribute__((weak,alias("Default_Handler")));
66 extern void CS_IRQHandler       (void) __attribute__((weak,alias("Default_Handler")));
67 extern void PCM_IRQHandler      (void) __attribute__((weak,alias("Default_Handler")));
68 extern void WDT_A_IRQHandler    (void) __attribute__((weak,alias("Default_Handler")));
69 extern void FPU_IRQHandler      (void) __attribute__((weak,alias("Default_Handler")));
70 extern void FLCTL_IRQHandler    (void) __attribute__((weak,alias("Default_Handler")));
71 extern void COMP_E0_IRQHandler  (void) __attribute__((weak,alias("Default_Handler")));
72 extern void COMP_E1_IRQHandler  (void) __attribute__((weak,alias("Default_Handler")));
73 //extern void TA0_0_IRQHandler    (void) __attribute__((weak,alias("Default_Handler")));
74 extern void timer_a_0_isr(void);
75 extern void TA0_N_IRQHandler    (void) __attribute__((weak,alias("Default_Handler")));
76 extern void TA1_0_IRQHandler    (void) __attribute__((weak,alias("Default_Handler")));
77 extern void TA1_N_IRQHandler    (void) __attribute__((weak,alias("Default_Handler")));
78 extern void TA2_0_IRQHandler    (void) __attribute__((weak,alias("Default_Handler")));
79 extern void TA2_N_IRQHandler    (void) __attribute__((weak,alias("Default_Handler")));
80 extern void TA3_0_IRQHandler    (void) __attribute__((weak,alias("Default_Handler")));
81 extern void TA3_N_IRQHandler    (void) __attribute__((weak,alias("Default_Handler")));
82 extern void EUSCIA0_IRQHandler  (void) __attribute__((weak,alias("Default_Handler")));
83 extern void EUSCIA1_IRQHandler  (void) __attribute__((weak,alias("Default_Handler")));
84 extern void EUSCIA2_IRQHandler  (void) __attribute__((weak,alias("Default_Handler")));
85 extern void EUSCIA3_IRQHandler  (void) __attribute__((weak,alias("Default_Handler")));
86 extern void EUSCIB0_IRQHandler  (void) __attribute__((weak,alias("Default_Handler")));
87 extern void EUSCIB1_IRQHandler  (void) __attribute__((weak,alias("Default_Handler")));
88 extern void EUSCIB2_IRQHandler  (void) __attribute__((weak,alias("Default_Handler")));
89 extern void EUSCIB3_IRQHandler  (void) __attribute__((weak,alias("Default_Handler")));
```



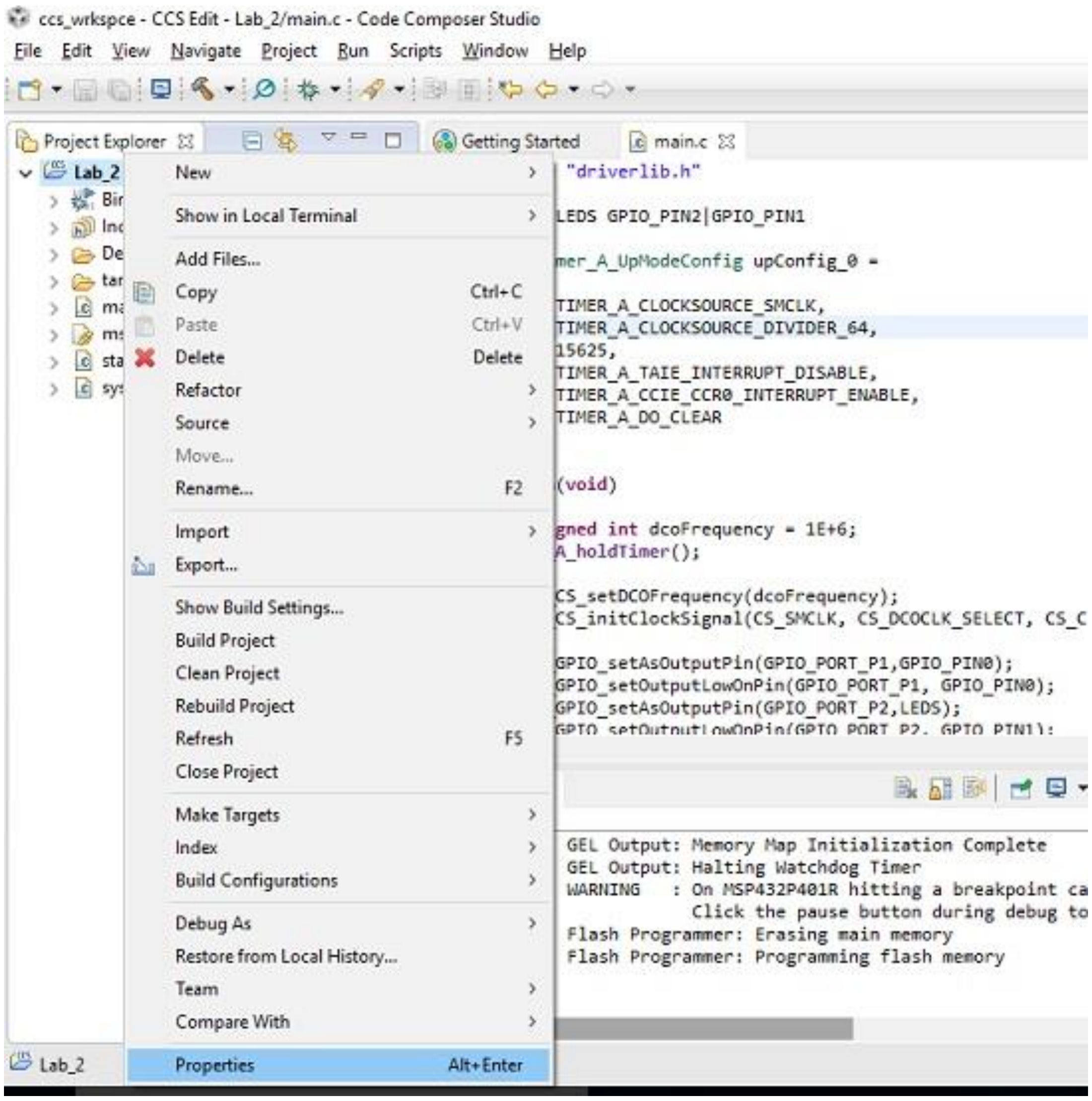
```
62
63 /* device specific interrupt handler */
64 extern void SysTick_Handler     (void) __attribute__((weak,alias("Default_Handler")));
65 extern void PSS_IRQHandler      (void) __attribute__((weak,alias("Default_Handler")));
66 extern void CS_IRQHandler       (void) __attribute__((weak,alias("Default_Handler")));
67 extern void PCM_IRQHandler      (void) __attribute__((weak,alias("Default_Handler")));
68 extern void WDT_A_IRQHandler    (void) __attribute__((weak,alias("Default_Handler")));
69 extern void FPU_IRQHandler      (void) __attribute__((weak,alias("Default_Handler")));
70 extern void FLCTL_IRQHandler    (void) __attribute__((weak,alias("Default_Handler")));
71 extern void COMP_E0_IRQHandler  (void) __attribute__((weak,alias("Default_Handler")));
72 extern void COMP_E1_IRQHandler  (void) __attribute__((weak,alias("Default_Handler")));
73 //extern void TA0_0_IRQHandler    (void) __attribute__((weak,alias("Default_Handler")));
74 extern void timer_a_0_isr(void);
75 extern void TA0_N_IRQHandler    (void) __attribute__((weak,alias("Default_Handler")));
76 extern void TA1_0_IRQHandler    (void) __attribute__((weak,alias("Default_Handler")));
```

12. Next scroll down to line 140 and change the existing line to **timer_a_0_isr** as shown below:



```
    MemManage_Handler,                      /* The MPU fault handler      */
    BusFault_Handler,                       /* The bus fault handler      */
    UsageFault_Handler,                     /* The usage fault handler    */
    0,                                      /* Reserved                   */
    0,                                      /* Reserved                   */
    0,                                      /* Reserved                   */
    0,                                      /* Reserved                   */
    SVC_Handler,                            /* SVCall handler             */
    DebugMon_Handler,                       /* Debug monitor handler      */
    0,                                      /* Reserved                   */
    PendSV_Handler,                         /* The PendSV handler         */
    SysTick_Handler,                        /* The SysTick handler        */
    PSS_IRQHandler,                         /* PSS Interrupt              */
    CS_IRQHandler,                          /* CS Interrupt               */
    PCM_IRQHandler,                         /* PCM Interrupt              */
    WDT_A_IRQHandler,                       /* WDT_A Interrupt            */
    FPU_IRQHandler,                         /* FPU Interrupt              */
    FLCTL_IRQHandler,                       /* Flash Controller Interrupt*/
    COMP_E0_IRQHandler,                     /* COMP_E0 Interrupt          */
    COMP_E1_IRQHandler,                     /* COMP_E1 Interrupt          */
    timer_a_0_isr,                      /* TA0_0 Interrupt            */
    TA0_N_IRQHandler,                       /* TA0_N Interrupt            */
    TA1_0_IRQHandler,                       /* TA1_0 Interrupt            */
    TA1_N_IRQHandler,                       /* TA1_N Interrupt            */
    TA2_0_IRQHandler,                       /* TA2_0 Interrupt            */
    TA2_N_IRQHandler,                       /* TA2_N Interrupt            */
```

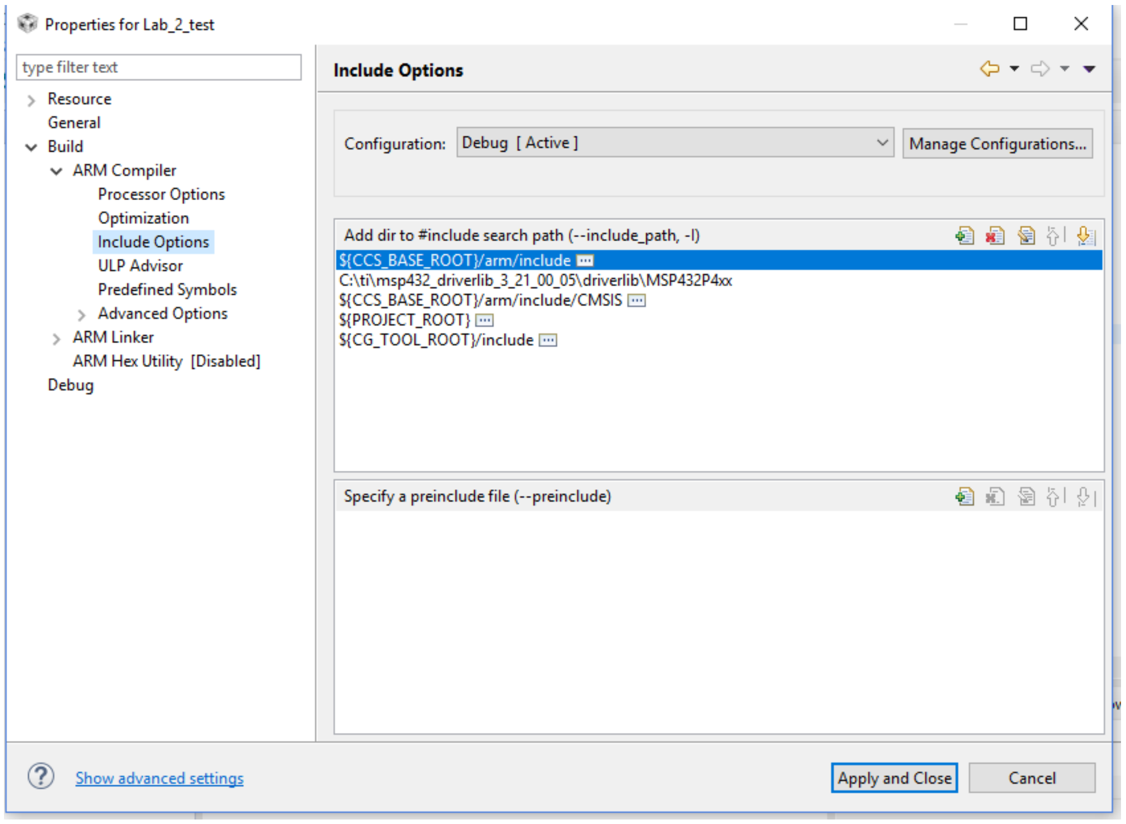
13. Now right click on the Lab_2 folder in the Project Explorer and click on **Properties**



```
 "driverlib.h"

LEDS GPIO_PIN2|GPIO_PIN1

mer_A_UpModeConfig upConfig_0 =

TIMER_A_CLOCKSOURCE_SMCLK,
TIMER_A_CLOCKSOURCE_DIVIDER_64,
15625,
TIMER_A_TAIE_INTERRUPT_DISABLE,
TIMER_A_CCIE_CCR0_INTERRUPT_ENABLE,
TIMER_A_DO_CLEAR


(void)

gned int dcoFrequency = 1E+6;
A_holdTimer();

CS_setDCOFrequency(dcoFrequency);
CS_initClockSignal(CS_SMCLK, CS_DCOCLK_SELECT, CS_C

GPIO_setAsOutputPin(GPIO_PORT_P1,GPIO_PIN0);
GPIO_setOutputLowOnPin(GPIO_PORT_P1, GPIO_PIN0);
GPIO_setAsOutputPin(GPIO_PORT_P2,LEDS);
GPIO_setOutputLowOnPin(GPIO_PORT_P2, GPIO_PIN1);
```

```
GEL Output: Memory Map Initialization Complete
GEL Output: Halting Watchdog Timer
WARNING   : On MSP432P401R hitting a breakpoint ca
            Click the pause button during debug to
Flash Programmer: Erasing main memory
Flash Programmer: Programming flash memory
```

14. Click on **Include Options** under the **ARM Compiler** tab, which is under the **Build** tab. In the adjacent mini-window with the title, "**Add dir to #include search path (--include_path, -I)**", click on the green plus icon (Add) as shown below:


Properties for Lab_2_test

Include Options

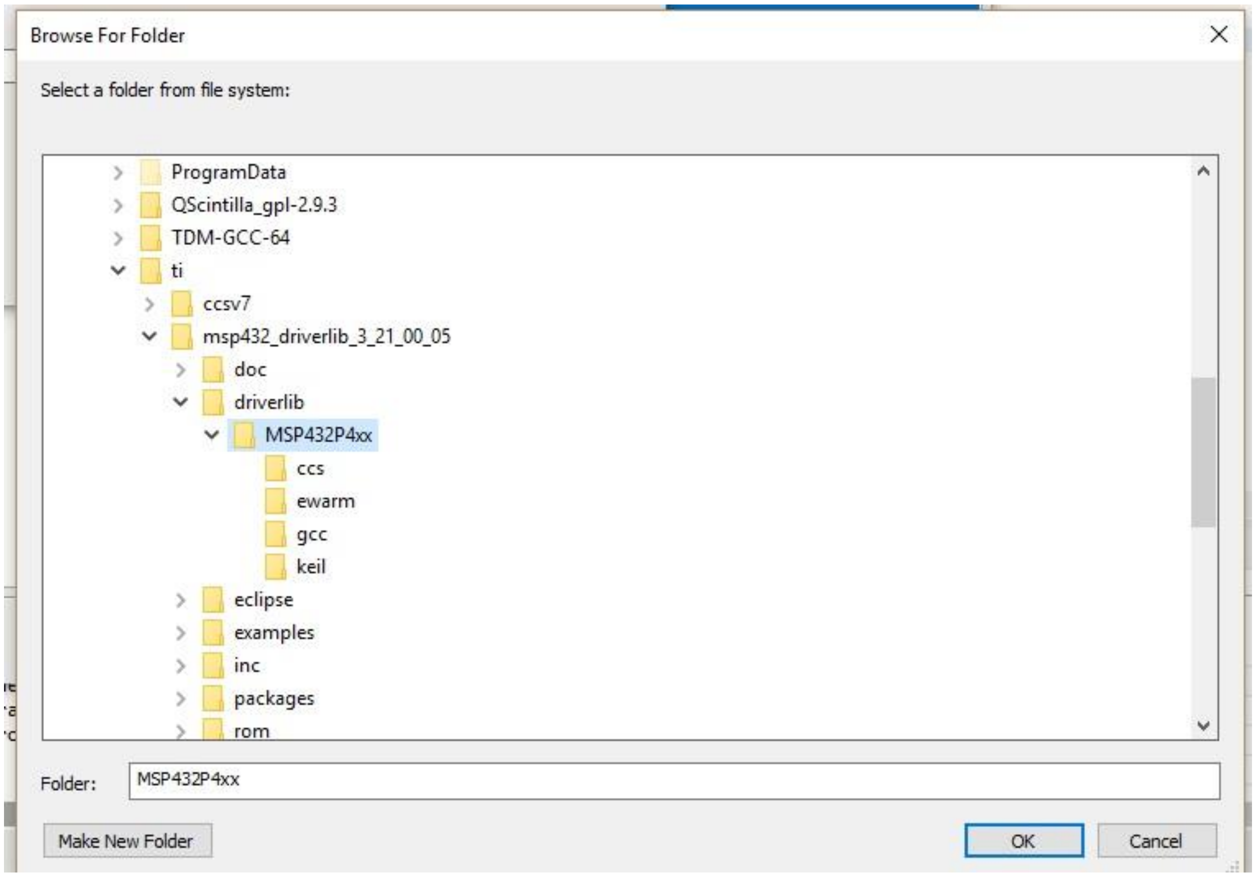
Configuration: Debug [Active]

Add dir to #include search path (--include_path, -I)

```
${CCS_BASE_ROOT}/arm/include
C:\ti\msp432_driverlib_3_21_00_05\driverlib\MSP432P4xx
${CCS_BASE_ROOT}/arm/include/CMSIS
${PROJECT_ROOT}
${CG_TOOL_ROOT}/include
```

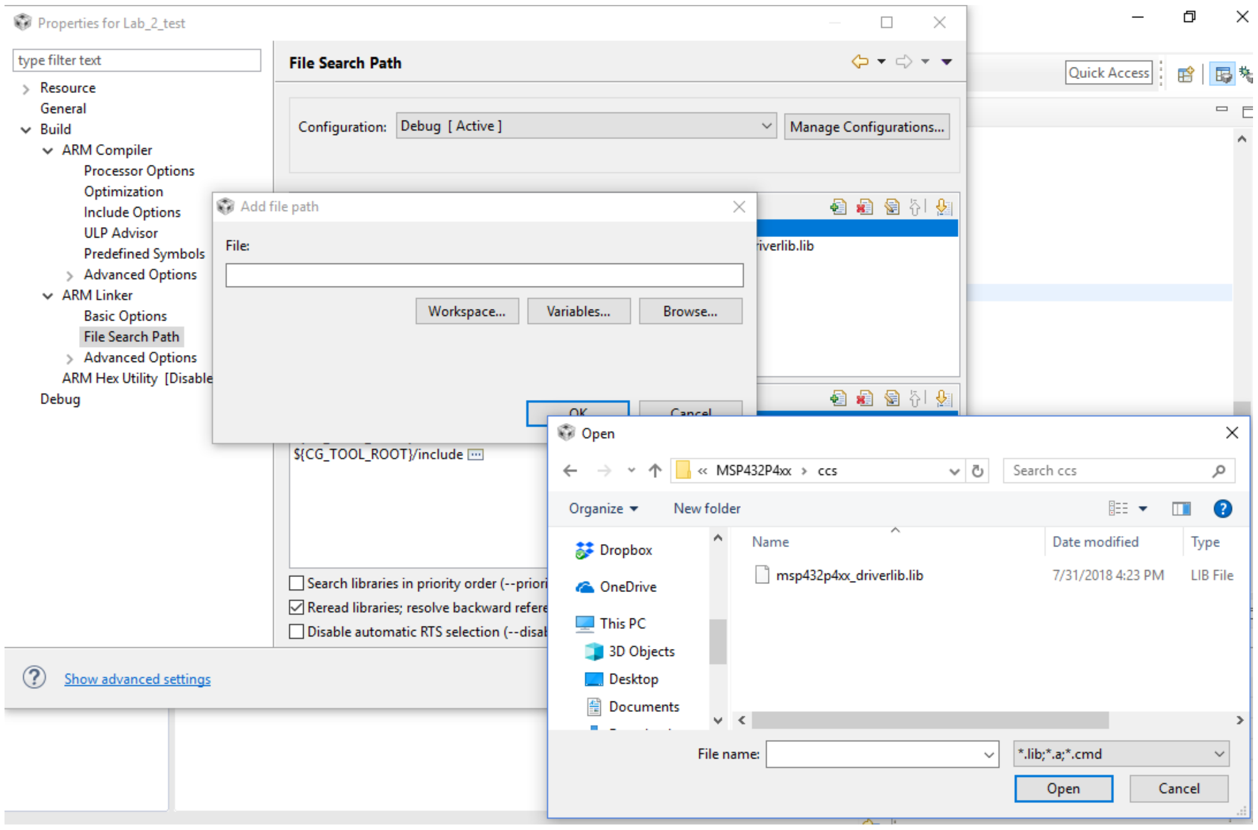
Specify a preinclude file (--preinclude)

Browse to the folder msp432_driverlib_3_21_00_05 containing the extracted MSP432 driver lib as shown below:



Click on the **MSP432P4xx folder** which is within the **driverlib folder** and then click on OK as shown in the image above.

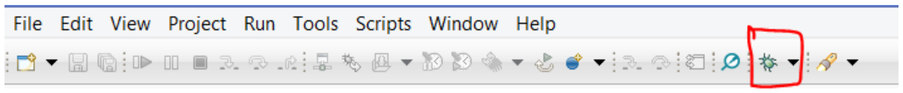
15. Similarly, under the **ARM Linker** tab, click on **File Search Path**. In the "**Include library file or command file as input**" mini-window click on the green plus icon for Add. Browse to the same **…/driverlib/MSP432P4xx/** folder as above. In this directory go to the **ccs** folder and click on **msp432p4xx_driverlib.** Click on open.



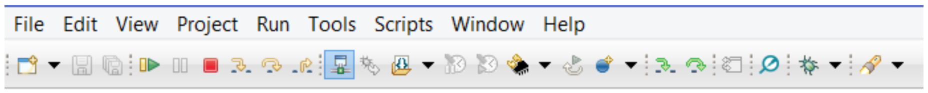
16. Finally click “Apply and Close”.

Flashing the board:

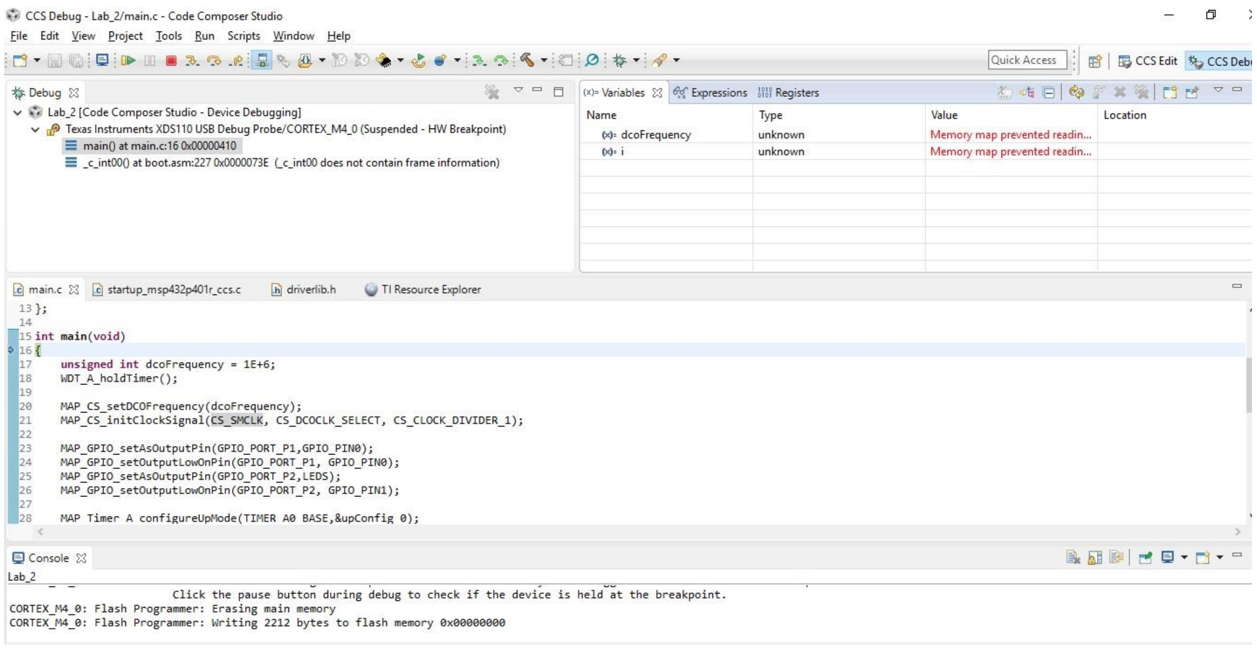
17. Click on the Debug button, shown by a green bug on the Quick Access panel below the menu bar.



18. The project should build without errors. The project is now flashed onto the chip. This code will now execute each time the controller is powered unless it is flashed with a new code in a similar manner.
19. The perspective of the CCS will change. The CCS is now in Debug mode. Additional buttons are now available in the quick access panel.



20. The code is stopped at the first line of the main function. It will continue execution if the resume button is pressed.


CCS Debug - Lab_2/main.c - Code Composer Studio
File Edit View Project Tools Run Scripts Window Help
Quick Access
CCS Edit
Debug
Variables
Expressions
Registers
main.c
startup_msp432p401r_ccs.c
driverlib.h
TI Resource Explorer
Console

Lab_2 [Code Composer Studio - Device Debugging]
Texas Instruments XDS110 USB Debug Probe/CORTEX_M4_0 (Suspended - HW Breakpoint)
main() at main.c:16 0x00000410
_c_int00() at boot.asm:227 0x0000073E (_c_int00 does not contain frame information)

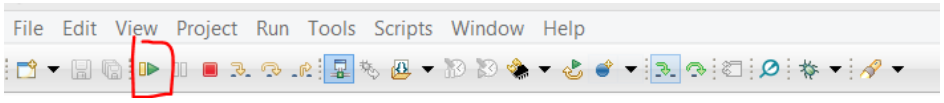
Name	Type	Value	Location
dcoFrequency	unknown	Memory map prevented readin...	
i	unknown	Memory map prevented readin...	

```c
};

int main(void)
{
    unsigned int dcoFrequency = 1E+6;
    WDT_A_holdTimer();

    MAP_CS_setDCOFrequency(dcoFrequency);
    MAP_CS_initClockSignal(CS_SMCLK, CS_DCOCLK_SELECT, CS_CLOCK_DIVIDER_1);

    MAP_GPIO_setAsOutputPin(GPIO_PORT_P1,GPIO_PIN0);
    MAP_GPIO_setOutputLowOnPin(GPIO_PORT_P1, GPIO_PIN0);
    MAP_GPIO_setAsOutputPin(GPIO_PORT_P2,LEDS);
    MAP_GPIO_setOutputLowOnPin(GPIO_PORT_P2, GPIO_PIN1);

    MAP_Timer_A_configureUpMode(TIMER_A0_BASE,&upConfig_0);
```

```
Lab_2
                    Click the pause button during debug to check if the device is held at the breakpoint.
CORTEX_M4_0: Flash Programmer: Erasing main memory
CORTEX_M4_0: Flash Programmer: Writing 2212 bytes to flash memory 0x00000000
```

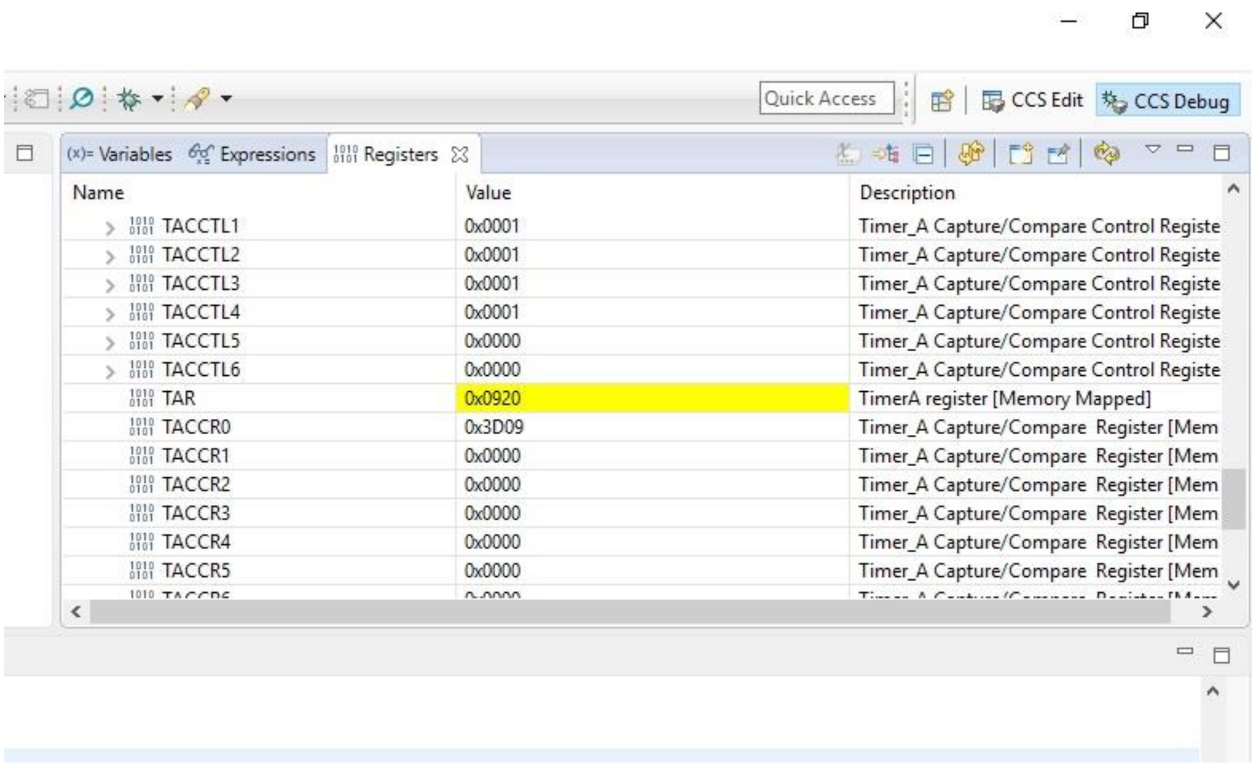
Pausing and debugging the program:

21. Press the resume button.



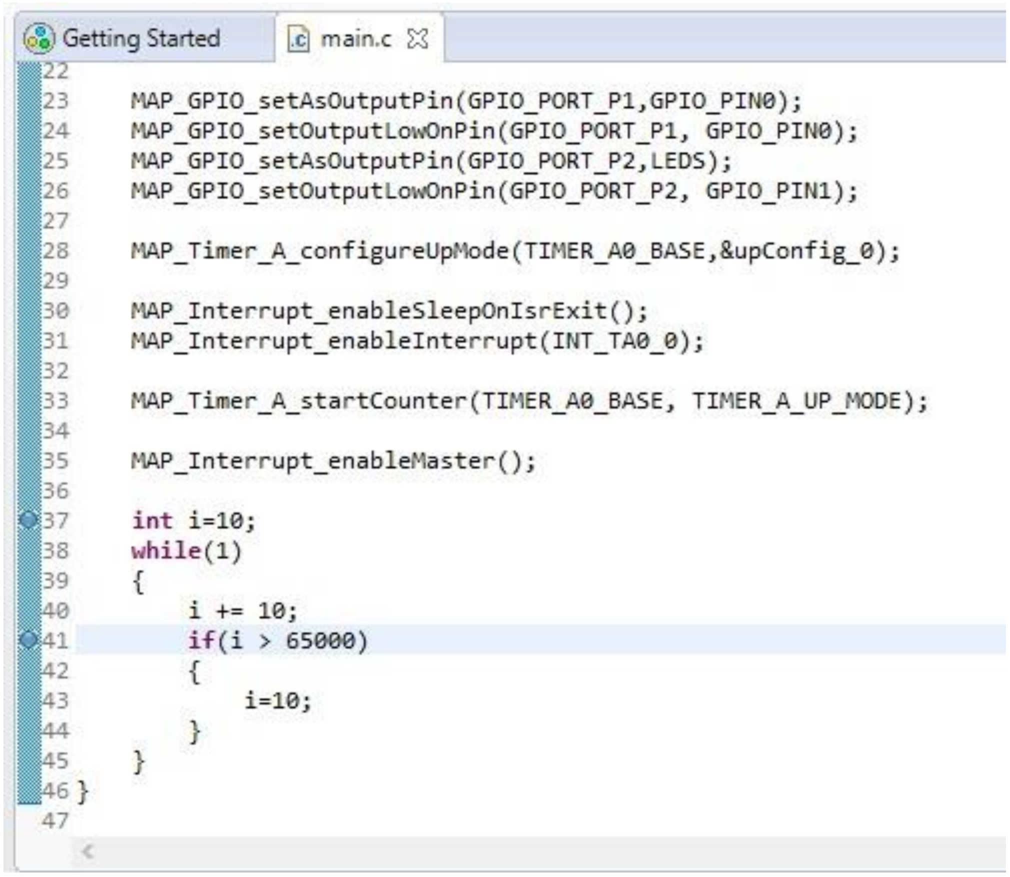
Both the LEDs on the board will start blinking. Pause button will suspend the execution of the code at current step.

22. The current register values can be checked in the registers window embedded in the screen. It may be observed that the TAR register under the Timer_A0 changes value each time it is paused. This is the register that holds current value of the timer.



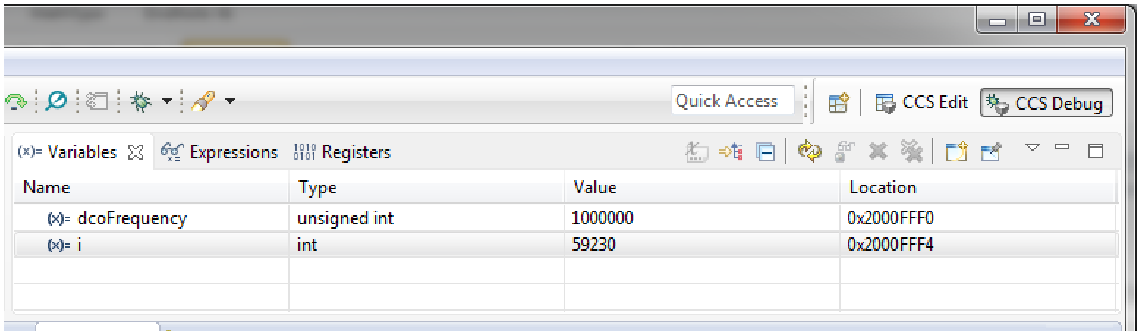
Name	Value	Description
TACCTL1	0x0001	Timer_A Capture/Compare Control Registe
TACCTL2	0x0001	Timer_A Capture/Compare Control Registe
TACCTL3	0x0001	Timer_A Capture/Compare Control Registe
TACCTL4	0x0001	Timer_A Capture/Compare Control Registe
TACCTL5	0x0000	Timer_A Capture/Compare Control Registe
TACCTL6	0x0000	Timer_A Capture/Compare Control Registe
TAR	0x0920	TimerA register [Memory Mapped]
TACCR0	0x3D09	Timer_A Capture/Compare Register [Mem
TACCR1	0x0000	Timer_A Capture/Compare Register [Mem
TACCR2	0x0000	Timer_A Capture/Compare Register [Mem
TACCR3	0x0000	Timer_A Capture/Compare Register [Mem
TACCR4	0x0000	Timer_A Capture/Compare Register [Mem
TACCR5	0x0000	Timer_A Capture/Compare Register [Mem

23. This window can also be used to check the values of variables and place breakpoints during debugging. It may also be observed that under the variables tab, the variable *i* changes value every time the program execution is paused.
24. When paused, code can be executed step by step using the step button. Step by step execution causes the registers whose values have changed to be highlighted in yellow. The Step Into button or F5 (yellow arrow pointing downwards) is the button next to the red square (terminate button). This button executes one action at a time. To execute a function directly and proceed to the next step after the function completes, press the Step Over button or F6 (next to the Step Into button).
25. The Terminate button (red square) terminates the debug session.
26. To set up the debug session to answer the questions below, terminate the debugging session (if you are running one). Set breakpoints at line 37 and 41. This can be done by double clicking next to the line number in the blue bar. Refer to the image below.

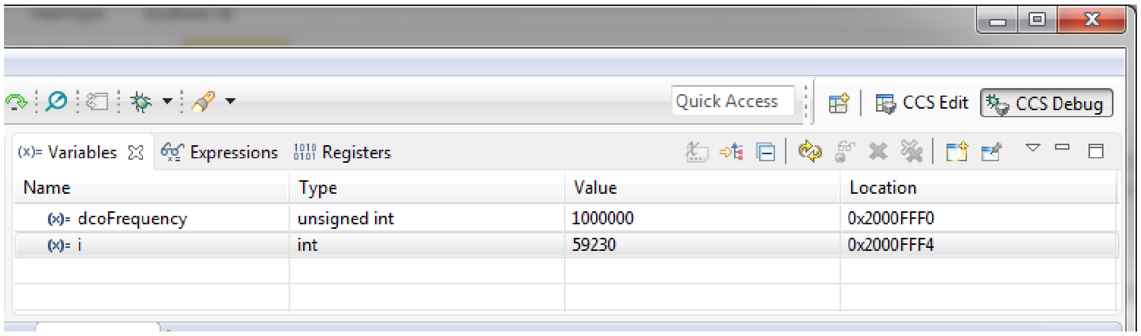


```
22
23      MAP_GPIO_setAsOutputPin(GPIO_PORT_P1,GPIO_PIN0);
24      MAP_GPIO_setOutputLowOnPin(GPIO_PORT_P1, GPIO_PIN0);
25      MAP_GPIO_setAsOutputPin(GPIO_PORT_P2,LEDS);
26      MAP_GPIO_setOutputLowOnPin(GPIO_PORT_P2, GPIO_PIN1);
27
28      MAP_Timer_A_configureUpMode(TIMER_A0_BASE,&upConfig_0);
29
30      MAP_Interrupt_enableSleepOnIsrExit();
31      MAP_Interrupt_enableInterrupt(INT_TA0_0);
32
33      MAP_Timer_A_startCounter(TIMER_A0_BASE, TIMER_A_UP_MODE);
34
35      MAP_Interrupt_enableMaster();
36
37      int i=10;
38      while(1)
39      {
40          i += 10;
41          if(i > 65000)
42          {
43              i=10;
44          }
45      }
46 }
47
```

27. Now press the debug button. Once the code is paused in the main function, press F8 to progress to line 37. The program should pause execution at line 37.
28. Click on the Variables tab in the watch window as shown below. Two variables should be visible: dcoFrequency and i. (The value of i in the picture may not match your initial value of i.)



Name	Type	Value	Location
dcoFrequency	unsigned int	1000000	0x2000FFF0
i	int	59230	0x2000FFF4



Name	Type	Value	Location
dcoFrequency	unsigned int	1000000	0x2000FFF0
i	int	59230	0x2000FFF4

Questions:

Debugging Questions

1. In the variables window, right click on the Value property of dcoFrequency. Change the number format to hexadecimal. What is the value shown? Confirm that this value is equal to the decimal value displayed (show your work). **(10 pts)**

2. You should currently be at line 37 after pressing F8 after starting a new debug session as per the instructions. Now press F5 (Step Into) five times, monitoring the value of *i* in the Variables window. What is the value of *i* after pressing F5 five times (repeating the loop)? After changing the displayed format to binary, how many bits are shown? Why is this number of bits displayed (recall data types)? **(10 pts)**

Circuit Design Questions

3. Design a circuit that uses a solid state (semiconductor) device to switch a DC motor ON or OFF. The circuit should be able to handle high current spikes. The voltage source available is a 30VDC power supply. The motor specifications are given in the "DC motor.pdf" file (use the second motor requiring rated 24VDC supply). Notice the starting current of the motor is a high value. (Hint: Consider using a transistor-based switching circuit such as that shown in Slide 53 of Lecture 2, with appropriate modifications. Assume that the MSP432 GPIO pins will supply the input V_{in}) **(20 pts)**
4. Find a solid state (semiconductor) switching device on the internet that can be used in the above circuit. **Attach the datasheet** for this device. **Point out the important details** in the datasheet of the device that proves the usability of the device. **(5 pts)**

5. Find a solid state (semiconductor) switching device on the internet that **<u>cannot</u>** be used in the above circuit. **Attach the datasheet** for this device. **Point out the important details** in the datasheet which show that this component is not suited to this application. **(5 pts)**