Getting Started in C Programming with Keil MDK-ARM Version 5

Reason for Revision

- This document was revised for Keil MDK-ARM v5.14 on February 18, 2015.
- This document was revised for MSP432 LaunchPad on November 30, 2015.
- This tutorial is based on uVision 5.15.0.0 and Texas Instruments MSP432 LaunchPad, which contains a MSP432P401R microcontroller.
- This tutorial is verified with uVision 5.17 with Texas Instruments MSP432 CMSIS update. On December 29, 2015
- This tutorial is verified with uVision 5.20 with Texas Instruments MSP432 CMSIS update. On July 24, 2016



Install MSP432 CMSIS Update

The register naming in the text follows the CMSIS convention. You need to perform MPS432 CMSIS update of the Keil uVision to use the same syntax.

If you already performed MPS432 CMSIS update during the installation of Keil MDK-ARM, you may skip this procedure.

- 1. Launch Keil uVision.
- 2. Click Pack Installer button and the Pack installer window will open.



3. Click refresh button to reload the latest catalog of all the device software packs. This may take a few minutes.

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🖃 🍄 All Devices	3655 Devices	■ Generic	18 Packs	
ABOV Semi	6 Devices	ARM::CMSIS	Up to d	CMSIS (Cortex Microcontroller So
Ambig Micro	8 Devices	ARM::CMSIS-Dri	Install	CMSIS-Driver Validation
Analog Dev	16 Devices	ARM::CMSIS-RTO	Install	CMSIS-RTOS Validation
+ ARM	26 Devices	ARM::mbedClient	Install	ARM mbed Client for Cortex-M d
🕀 🔶 Atmel	260 Devices	ARM::mbedTLS	Install	ARM mbed Cryptographic and SS
Cypress	425 Devices	ARM::minar	Install	mbed OS Scheduler for Cortex-M
B GigaDevice	40 Devices	Keil::ARM_Comp	🔶 Up to d.	Keil ARM Compiler extensions
Holtek	19 Devices	Keil::Jansson	Install	Jansson is a C library for encodinc
Infineon	151 Devices	Keil::MDK-Middl	🔶 Up to d	Keil MDK-ARM Professional Midc

4. After the pack catalog is refreshed, click on the + sign in front of Texas Instruments in Devices tab to open it then click on MSP432P4xx Series. Under the Packs tab in the other half of the window, the TexasInstruments::MSP432P4xx_DFP will be added.

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• VXP	527 Devices	ARM::CMSIS-Driver_Validation	Install	CMSIS-Driver Validation
Renesas	3 Devices	ARM::CMSIS-RTOS_Validation	Install	CMSIS-RTOS Validation
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sonix	49 Devices	ARM::mbedTLS	Install	ARM mbed Cryptograph
+ • STMicroelectronics	841 Devices	ARM::minar	🕸 Install	mbed OS Scheduler for (
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Toshiba	90 Devices	Oryx-Embedded::Middleware	Install	Middleware Package (Cy
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5. Click the + sign before it to expand it and click Unpack button of the latest version. It should be 2.1.0 or later.

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Renesas	3 Devices	ARM::CMSIS	🔶 Up to d	CMSIS (Cortex Microcont
Image: Silicon Labs	397 Devices	ARM::CMSIS-Driver_Validation	Install	CMSIS-Driver Validation

6. When the update is done, the word Unpack will change to Remove and the word Install above also will change to Up to date.

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Silicon Labe	207 Devices		ARM::CMSIS-Driver_Validation	Install	CMSIS-Driver Validation	

Create a Project with Project Wizard

- 7. Create a new folder named **project1** in **My Documents**. (The folder/file name and the location of the folder are arbitrary. They were selected only for the purpose of this demonstration.)
- 8. Launch Keil uVision5.
- 9. From the menu, select Project > New uVision Project...

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File Edit View	Project Flash Debug Peripherals Tools SVCS Window Help	
i 🗈 🗃 🗐 🦉	New µVision Project	a 🖬 🔍
de (2) (2) 📣 🛤	New Multi-Project Workspace	
	Open Project	
Project	Save Project in µVision4 format	
	Close Project	
	Export	•
	Manage	•
	Select Device for Target	

- 10. In the New uVision Project window, browse to the folder **project1** you just created in **My Documents** folder.
- 11. If you did not create a folder for the project before launching uVision, you may create a folder using the **New folder** menu item in the **Create New Project** window.
- 12. Enter a name for the project file. We will call it **project1** and click **Save**.

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File <u>n</u> ame	project1				~
Save as type	Project Files (*.uvproj; *.uvprojx)				~
Hide Folders			\subset	Save	Cancel

- 13. A window will pop up for you to select the CPU for this project. The device used on the MSP432 LaunchPad is Texas Instruments MSP432P401R. To select this device, first you need to click on the + sign to the left of Texas Instruments to expand the selections than drill down to the expose the exact device. Alternatively, you may start typing in the "Search" field and the possible match will be show below.
- 14. Click to highlight the device than click OK.

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evice: MSP432	2P401R		
oolset ARM			
Search:			
		Des <u>c</u> ription:	
ARM Atmel Atmel Freescale Texas Instru MSP432 MSP Tiva C S	ments Family 432P MSP432P401R eries	The MSP432 family features the ARM Cortex-M4 processor in a wide configuration of device options including a rich set of analog, timing, and communication peripherals, thereby catering to a large number of application scenarios where both efficient data processing and enhanced low-power operation are paramount.	

15. The "Manage Run-Time Environment" window will replace the "CPU" window. Expand and click to add the checkmarks for CMSIS->CORE and Device->Startup. Click "OK" button to close the window.

			Manage Ru	n-Time Environment
Software Component	Sel.	Variant	Version	Description
🛛 🔹 CMSIS	-			Cortex Microcontroller Software Interface Components
- CORE			4.1.0	CMSIS-CORE for Cortex-M, SC000, and SC300
- DSP			1.4.5	CMSIS-DSP Library for Cortex-M, SC000, and SC300
🗄 💠 RTOS (API)			1.0	CMSIS-RTOS API for Cortex-M, SC000, and SC300
🗉 💠 CMSIS Driver				Unified Device Drivers compliant to CMSIS-Driver Specifications
🖲 💠 Compiler				ARM Compiler Software Extensions
🗦 🗇 Device	-			Startup, System Setup
Startup			1.0.0	System Startup for MSP432 Family
🗉 💠 File System		MDK-Pro	6.5.0	File Access on various storage devices
🛛 💠 Graphics		MDK-Pro	5.30.0	User Interface on graphical LCD displays
🗉 🗇 Network		MDK-Pro	7.0.0	IPv4/IPv6 Networking using Ethernet or Serial protocols
🗉 🗇 USB		MDK-Pro	6.5.0	USB Communication with various device classes

16. In the Project window, a target is created with the default name **Target1**. Click on the + sign to the left of Target1 to expand the folder.



17. A default folder for source code files is created with the name **Source Group 1**. The startup_msp432.s and system_msp432.c files are already in the folder.



Add a Source File to the Project

18. Click the **New** button to add a new text file to the display with the default name **Text1**.



19. From the menu, select **File > Save As...** to open the Save As dialog box. Browse to the project folder if it is not already there. Type in the file name **main.c** and click **Save**.

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is PC			
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File name	main.c		~
Save as <u>t</u> ype:	All Files (*.*)		*
Hide Folders		Sa	ve Cancel

20. You will notice the file name in the tab changed to main.c



21. The new file needs be added to the project. Right click on the folder **Source Group 1** in the Project window and select **Add Existing Files to Group 'Source Group 1'...**

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E Project Books D Functions D, Templates	;
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add Evisting Files to current Project Group	ULINK2/ME Cortex Debugs

22. In the dialog box, browse to the project folder if it is not already there. Click select **main.c** then click **Add**.

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system_m	RTE		11/30/2015 1:49 F
	Main.c		11/30/2015 1:57 F
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23. Click Close to close the "Add Files" dialog box. The file should appear in the project window under Source Group 1 folder.



24. Copy and paste the following code into the main.c editor window.

```
/*
* This program toggles P1.0, which is connected to a red LED,
 * at 1 Hz (0.5 sec off, 0.5 sec on).
 */
#include "msp.h"
void delayMs(int n);
int main(void) {
   P1->DIR |= 1 << 0;
                                       /* P1.0 set as output */
    while (1) {
       P1->OUT ^= 1 << 0;
                                        /* toggle P1.0 LED */
       delayMs(500);
    }
}
/* system clock at 3 MHz */
void delayMs(int n) {
   int i, j;
    for (j = 0; j < n; j++)
       for (i = 124; i > 0; i--); /* Delay */
}
```

25. The file name in the tab will have an '*' next to it. It symbolizes that the file has been changed without saving. You may click the save button to save the file or proceed to build the project. The file is automatically saved before a build.



Build the Project and Download to the Target

26. Click on the **Build** button and wait for the build to complete. Make sure there are no error messages and review all the warning messages.



27. Before downloading the program to the target, we need to set up the connection between the uVision IDE and the in-circuit debugger on the target circuit board. Click on the **Target Options** button.



28. Select **Debug** tab and click the radio button on the right and select **CMSIS-DAP Debugger** in the pull-down menu. An additional debug interface was introduced with the newer firmware and Keil MDK-ARM v5.20. It runs much faster than the CMSIS-DAP debugger but has some restrictions. Please check the steps starting at step 39.

C Use Simulato	with restrictions Settings	@ Use: ULI	NK2/ME Cortex Debugger	•	Settings
Limit Speed to	Real-Time	ULI	NK2/ME Cortex Debugger	^	
 Load Application File: 	ion at Startup 🔽 Run to main()	Initializatio	ra Blaster Cortex Debugger Ilaris ICDI num Systems JTAGjet NK / J-TRACE Cortex NK Pro Cortex Debugger	n	nain()
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CPU DLL: SARMCM3.DLL Dialog DLL:	Parameter: -MPU Parameter:	Driver DLL: SARMCM3.DL Dialog DLL:	Parameter: L -MPU Parameter:		

- 29. You should have the XDS110 device drivers installed in your computer. If you have not done so, download XDS110 device drivers from http://energia.nu/files/xds110 drivers.zip and install them when plug in the board with USB cable.
- 30. To verify whether the XDS110 driver is properly installed with the board connected, click **Setting** button and a window should pop up showing debug connection.

evice Target Output Listing User C/C++ Asm Linker	Debug Utilities
C Use Simulator with restrictions Settings ☐ Limit Speed to Real-Time	© Use: CMSIS-DAP Debugger Settings
Load Application at Startup Ivitialization File:	✓ Load Application at Startup ✓ Run to main()

31. Make sure the Port selection has SW and the IDCODE of the debugger should appear in the right panel.

XDS110 (02.02.04.02) with CMSIS	·	IDCODE	Device Name	Mo
Serial No: 00000000	SWDIO	⊙ 0x2BA01477	ARM CoreSight SW-DP	U
Firmware Version: 1.0				Do
SWJ Port SW -	C Aut	omatic Detection	ID CODE:	
Max Clock: 10MHz	J O Mai	nual Configuration	Device Name:	
Max Clock. TOWINZ	Adc	Delete	Update	AP: 0x0

32. To debug the program, click the **Debug** button on the right. The program should automatically download to the target device and the Keil IDE will change the perspective to debug.



33. It takes a few seconds to download the program. If download goes well, the output window at the bottom will show the messages of "Erase Done", "Programing Done" and "Verify OK". If you are running free MDK-ARM Lite Edition, a message window will pop up to warn the code size limitation. Click **OK** to proceed.



34. When entering the debugger, the IDE changes the perspective to the debug. The source code appears in the middle with the disassembly window above it. To the left, a registers display tab is added. To the lower right, the stack/local variables and memory windows are added.

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Register Value Value OCOP 11: PIDIR = 1 << 0;	Registers	부 🗙	Disassembly					д 🛛
R0 0-20000068 R1 0-20000068 R2 0-20000068 R3 0-20000068 R4 0-20000004 R4 0-20000000 R6 0-20000000 R7 0-20000000 R6 0-20000000 R7 0-20000000 R7 0-20000000 R7 0-20000000 R14 0-20000000 R14 P10UT ^= 1 <<<0; /* P1.0 set as output	Register	Value 🔺	0x000002D6 000 11: P 12:	00 MOVS 1DIR = 1 << 0;	r0,r0	/* P1.0 set	as output */	^
R3 0x2000008 R4 0x0000000 R5 0x2000000 R6 0x0000000 R7 0x0000000 R8 0x0000000 R10 0x0000000 R11 0x0000000 R12 11 P14 (LR) 0x0000000 R14 (LR) 0x0000000 R15 (PC) 0x0000000 R16 15 delayMs (500); 16 R15 (PC) 0x0000000 17 } 17 Project Registers ** Restricted Version with 32768 Byte Code Size Limit ** Call Stack + Locals * m 0x0000000 * * * SSIGN BreakDisable BreakEnable BreakKill BreakList CM35 DAB Dobuce	R0 R1 R2	0x20000068 0x20000068 0x20000068	0x000002D8 48 0x000002DA 78 0x000002DC F0	09 LDR 00 LDRB 400001 ORR	r0,[pc, r0,[r0, r0 r0 #	#36] ; @0x0000030 #0x00] 0x01	0	
RS 020000000 R6 0x0000000 R7 0x0000000 R8 0x0000000 R9 0x0000000 R10 0x0000000 R11 0x0000000 R12 0x20000268 R14(LR) 0x00000268 R15(PC) 0x0000000 R15(PC) 0x000000 R16(R) 16 17 } 17 } Project Registers ** Restricted Version with 32768 Byte Code Size Limit ** Restricted Version with 32768 Byte Code Size Limit ** Call Stack + Locals ** S21GN BreakDisable BreakEnable BreakKill BreakList	R3 R4	0x20000068 0x00000000	A main.c	startup_msp4	32.s			> • >
R11 0x0000000 R12 0x20000044 R13 (SP) 0x20000044 R14 P10UT ^= 1 << 0;	R9 	0x20000004 0x00000000 0x00000000 0x00000000	8 void 9 10 int r	delayMs(int main(void) { P1DIR = 1 <	n); < 0;	/*	P1.0 set as	output
Image: Stress doc/100000 (17) Image: Stress doc/100000 (17) Image: Stress doc/100000 (17) Image: Stress doc/1000000000000000000000000000000000000	- R11 - R12 - R13 (SP) - R14 (LR) - R15 (PC)	0x00000000 0x20000044 0x20000268 0x000001D3 0x000002D8	12 13 14 15 16	while (1) { P1OUT ^= delayMs(}	1 << 0; 500);	/*	toggle P1.0 :	LED */
Image: Solution with 32768 Byte Code Size Limit Call Stack + Locals Image: Solution with 32768 Byte Solution *** Restricted Version with 32768 Byte Code Size Limit Image: Solution with 32768 Byte Solution Image: Solution	Project	legisters	< 173					>
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35. The program counter is at the first executable line of the main() function as indicated by the yellow arrows in both source file and disassembly window.

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Registers	4	Disassembly	4 🖬
Register	Value	0x000002D6 0000 MOVS r0,r0 11: PIDIR = 1 << 0; /* P1.0 set as o 12:	utput */
R1	0x20000068	x000002DB 4809 LDR r0,[pc,#36]; @0x00000300	
R2	0x20000068	0×0000020C F0400001 ORR +0 +0 ±0×01	× *
R3	0x20000068 0x00000000		
<mark>R5</mark>	0x20000004	main.c startup_msp432.s	▼ ×
R6	0x00000000	<pre>8 void delayMs(int n);</pre>	^
R8	0x000000000	10 int main (woid) /	
R9	0x00000000	11 PIDTR $l = 1 << 0$: /* P1	0 set as output
R10	0x00000330		ro bee ab caepae
R11	0x00000000	13 while (1) {	
B13 (SP)	0x20000268	14 Plout ^= 1 << 0; /* to	ggle P1.0 LED */
R14 (LR)	0x000001D3	15 delayMs(500);	
	0x000002D8	16 }	
	0x21000000	17 }	~
Project Re	egisters	< 10	>
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-		Name Location Type	
*** Restricted	Version with	32768 Byte Code Size Limit	
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1			
ASSIGN BreakDi	sable BreakEna	able BreakKill BreakList	
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36. Click the **Run** button and the program execution should start. If everything has been done properly, the red LED on the LaunchPad should be blinking.



37. On the sides of the **run** button, you will find the **stop** button (red circle with a white cross) and the **reset** button (with RST in it). To stop debug session and return to edit/build perspective, click on the debug button on the right. After you left the debugger, the program in the MSP432 LaunchPad will continue to run. The program will run whenever the power is applied to it.

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Registers	ą	Disassembly	4
Register	Value	0x000002D6 0000 MOVS r0,r0 11: PIDIR = 1 << 0;	^

38. Congratulations! You have finished your first Keil uVision programming for the MSP432 LaunchPad.

Alternate Debug Interface

Although CMSIS-DAP Debugger works fine, its operations are slow. A new debugger was introduced with Keil-MDK **v5.20** that runs much faster. But it requires the newer version of the firmware on the MSP432 LaunchPad.

39. To verify the firmware version, select **Debug** tab and click the radio button on the right and select **CMSIS-DAP Debugger** in the pull-down menu.

	with restrictions	Settings	🛈 🖸 se: 🛛	JLINK2/ME Cortex	Debugger	- Settin	gs
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Load Applicat Initialization File:	ion at Startup 🔽 Run to r	main()	lnitializatio	itellaris ICDI ignum Systems J ⁻ -LINK / J-TRACE (rAGjet Cortex	main()	
		Edit		ILINK Pro Cortex D IULink Debugger	lebugger	Edi	t
Restore Debug	Session Settings		Restore	iLabs UDA Debug	gger		
F Breakpoir	ts 🔽 Toolbox		Bre	MSIS-DAP Debug	iger		
Vatch Wir	ndows & Performance Analyzer		Vato	h Windows	gei	×	
Memory D	isplay 🔽 System Viewer		Mem	ory Display	System View	ver	
	Parameter:		Driver DLL:	Parameter			
CPU DLL:	-MPU		SARMCM3.	DLL -MPU			_
CPU DLL: SARMCM3.DLL	-MPU	L: Parameter:			Parameter:		
CPU DLL: SARMCM3.DLL Dialog DLL:	-MPU Parameter:		Dialog DLL.	r arameter.			

40. With CMSIS-DAP Debugger selected, click on the **Settings** button.

関 Options for Target 'Target 1'	×
Device Target Output Listing User C/C++ Asm Linker	Debug Utilities
C Use Simulator with restrictions □ Limit Speed to Real-Time	Use: CMSIS-DAP Debugger Settings
✓ Load Application at Startup ✓ Run to main() Initialization File:	✓ Load Application at Startup ✓ Run to main() Initialization File:
Edit	Edit

41. Under the CMSIS-DAP-JTAG/SW Adapter, you should see the version number of the XDS110 firmware. If your version number is not 02.03.00.02 or newer, it may not work with the new debug interface. You can always go back to use CMSIS-DAP Debugger even though it runs slower.

Cortex-M Target Driver Setup				
Debug Trace Flash Download Pack	1			
CMSIS-DAP - JTAG/SW Adapter	SW Dev	vice		
XDS110 (02.03.00.02) with CMSIS	>	IDCODE	Device Name	Move
Serial No: 00004662	SWDIO	⊙ 0x2BA01477	ARM CoreSight SW-DP	Up
Firmware Version: 1.0				Down
SWJ Port SW 🔻	G Auto	omatic Detection	ID CODE:	

42. If you have the new firmware, you may proceed to select the TI XDS Debugger. Close the Cortex-M Target Driver Setup window and return to the Debug tab.

main()
main()

- 43. You should have the XDS110 device drivers installed in your computer. If you have not done so, download XDS110 device drivers from http://energia.nu/files/xds110_drivers.zip and install them when plug in the board with USB cable.
- 44. To verify whether the debugger is properly installed with the board connected, click **Setting** button and a window should pop up showing debug connection.

Options for Target 'Target 1'	
Device Target Output Listing User C/C++ Asm Link	ker Debug Utilities
C Use Simulator with restrictions Settings □ Limit Speed to Real-Time	C Use: TIXDS Debugger Settings
✓ Load Application at Startup ✓ Run to main() Initialization File:	Iversity Iversity Iversity Initialization File: Iversity Iversity
Edit	Edit
Restore Debug Session Settings	Restore Debug Session Settings

45. There should be an entry in the SW Device panel at the right and the IDCODE of the debugger should appear in the panel. With TI XDS Debugger, you may choose either SW port or JTAG port.

oug Trace Flash Download		
Debug Adapter	SW Device	
Unit	V IDCODE Device Name	Move
Sorial Number	SWDIO 0x00000000 ARM CoreSight SW-DP	Up
HW Version:		Down
irmware Version:	Automatic Detection ID CODE:	
🗟 SWJ Pott SW 🕤	C Manual Configuration Device Name:	
Max Clock: 10MHz	✓ Add Delete Update IR len:	-

MDK TI XDS Debugger – Target Driver Setup

Debug Adapter	JTAG Device Chain	
Unit	IDCODE Device Name IR len	Move
Serial Number	TDO 0x00000000 ARM CoreSight SW-DP 0	Up
HW Version:	ты	Down
irmware Version:	Automatic Detection ID CODE:	
SWJ Pat JTAG	C Manual Configuration Device Name:	
Max Clock: 10MHz 💌	Add Delete Update IR len:	

×