# arm

### **Retargeting output to UART**

Version 1.0

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### Retargeting output to UART

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# Contents

1. Overview	6
2. About semihosting	7
3. Retarget functions to use UART	8
4. Use Telnet to inteface with the UART	10
5. Related information	17
6. Next steps	

# 1. Overview

This guide is the second in a collection of related guides:

- Building your first embedded image
- Retargeting output to UART (this guide)
- Creating an event-driven embedded image
- Changing Exception level and Security state in an embedded image

This guide shows you how to modify the output mechanism to use the UART capability of the target system.

In Building your first embedded image, we relied on semihosting to handle the output from our embedded image. In this guide, you will modify the output mechanism to send output to a UART serial port. This is useful to know, because embedded systems often have limited display capabilities, or no display capabilities. However, during the debug process it is often useful to be able to print diagnostic messages while a program is running.

#### Before you begin

To complete this guide, you will need to have Arm Development Studio Gold Edition installed. If you do not have Arm Development Studio, you can download a 30-day free trial.

Arm Development Studio Gold Edition is a professional quality tool chain developed by Arm to accelerate your first steps in Arm software development. It includes both the Arm Compiler 6 toolchain and the Base\_A76x1 model used in this guide. We will use the command-line tools for most of the guide, which means that you will need to configure your environment in order to run Arm Compiler 6 from the command-line.

The individual sections of this guide contain some code examples. These code examples are available to download as a ZIP file:

• CommonTasks-RetargetToUART.zip

# 2. About semihosting

Semihosting enables code running on a target system, the model, to interface with a debugger running on a host system, the computer, and to use its input and output (I/O) facilities. This means that you can interact with a model or microcontroller that may not possess I/O functionality.

In Building your first embedded image, we used a printf() call in the code to display the "Hello World" message. This printf() call triggers a request to a connected debugger through the library function \_sys\_write. To see how this works, you can use fromelf to inspect the compiled code, as shown in the following instruction:

```
$ fromelf --text -c __image.axf --output=disasm.txt
```

This command generates a disassembly of \_\_image.axf in the file disasm.txt. Within the disassembly, look at \_sys\_write, which contains a HLT instruction:

	d100c3ff a9027bfd	••••	SUB STP	sp,sp,#0x30 x29,x30,[sp,#0x20]
0x00003a9c:	d45e0000	••^•	HLT	#0xf000
0x00003aa8:	d65f03c0	···	RET	

The debugger detects this halt as a semihosting operation, and interprets the <u>sys\_write</u> as a request to output to the console.

You can check if you are using semihosting by adding \_\_asm(".global \_\_use\_no\_semihosting\n \t"); to main(). Linking the image will now throw an error for any functions that use semihosting.

## 3. Retarget functions to use UART

Real embedded systems operate without sophisticated debuggers, but many library functions depend on semihosting. You must modify, or retarget, these functions to use the hardware of the target instead of the host system.

To retarget printf() to use the PLO11 UART of the model:

1. Write a driver for the UART. Copy and paste the following code into a new file with the filename pl011 uart.c:

```
struct pl011 uart {
                                                            // +0x00
     volatile unsigned int UARTDR;
     volatile unsigned int UARTECR; // +0x00
volatile unsigned int UARTECR; // +0x04
     const volatile unsigned int unused0[4]; // +0x08 to +0x14 reserved
     const volatile unsigned int UARTFR; // +0x18 - R0
const volatile unsigned int unused1; // +0x1C reserved
   const volatile unsigned int unused1; //
volatile unsigned int UARTILPR; // +0x20
volatile unsigned int UARTIBRD; // +0x24
volatile unsigned int UARTFBRD; // +0x28
volatile unsigned int UARTCR; // +0x30
volatile unsigned int UARTIFLS; // +0x34
volatile unsigned int UARTIMSC; // +0x38
const volatile unsigned int UARTIMSC; // +0x38
     const volatile unsigned int UARTRIS; // +0x3C - RO
const volatile unsigned int UARTMIS; // +0x40 - RO
volatile unsigned int UARTICR; // +0x44 - WO
volatile unsigned int UARTDMACR; // +0x48
};
// Instance of the dual timer
struct pl011 uart* uart;
// --
void uartInit(void* addr) {
     uart = (struct pl011_uart*) addr;
     // Ensure UART is disabled
     uart->UARTCR = 0 \times 0;
     // Set UART 0 Registers
     uart->UARTECR = 0 \times 0; // Clear the receive status (i.e. error) register
 uart->UARTLCR H = 0x0 | PL011_LCR_WORD_LENGTH 8 | PL011_LCR_FIFO_DISABLE |
PL011_LCR_ONE_STOP_BIT | PL011_LCR_PARITY_DISABLE | PL011_LCR_BREAK_DISABLE;
uart->UARTIBRD = PL011_IBRD_DIV_38400;
     uart->UARTFBRD = PL011_FBRD_DIV_38400;
     uart->UARTIMSC = 0 \times 0;
                                                                     // Mask out all UART interrupts
     uart->UARTICR = PL011_ICR_CLR_ALL_IRQS; // Clear interrupts
     uart->UARTCR = 0x0 | PL011 CR UART ENABLE | PL011 CR TX ENABLE |
 PL011 CR RX ENABLE;
     return;
// _____
int fputc(int c, FILE *f) {
      // Wait until FIFO or TX register has space
     while ((uart->UARTFR & PL011 FR TXFF FLAG) != 0x0) {}
     // Write packet into FIFO/tx register
     uart->UARTDR = c;
      // Model requires us to manually send a carriage return
      if ((char)c == '\n') {
           while ((uart->UARTFR & PL011 FR TXFF FLAG) != 0 \times 0) {}
```

```
uart->UARTDR = '\r';
}
return 0;
}
```

2. Modify hello\_world.c to use the UART driver, so that the updated file contains:

```
#include <stdio.h>
#include "pl011_uart.h"
int main (void) {
    uartInit((void*)(0x1C090000));
    printf("hello world\n");
    return 0;
}
```

By redefining fputc() to use the UART you have retargeted printf(). This is because printf() ultimately calls fputc().

3. Rebuild the image:

```
$ armclang -c -g --target=aarch64-arm-none-eabi startup.s
$ armclang -c -g --target=aarch64-arm-none-eabi hello_world.c
$ armclang -c -g --target=aarch64-arm-none-eabi pl011_uart.c
$ armlink --scatter=scatter.txt --entry=start64 startup.o pl011_uart.o
hello world.o
```

4. Disassemble the image:

```
$ fromelf --text -c __image.axf --output=disasm.txt
```

The disassembly in disasm.txt now shows no calls to \_sys\_write (although other semihosting functions such as \_sys\_exit will be present).

## 4. Use Telnet to inteface with the UART

All output is now directed to the model's UART serial port.

To see this output, we are going to use a Telnet client to connect to the UART. We will use Arm Development Studio to help here, because it automatically starts the Telnet client and connects it to the model.

Note If you want to start a Telnet client and connect to the model manually, you will need to use port 5000 instead of the default port 23. Timing the connection can be difficult, because you must start the client just before the server in the model starts listening.

To interface with the UART using Telnet:

- 1. Import your executable into Arm Development Studio. Click File > Open Projects from File System...
- 2. Click Directory in the Import Projects from File System or Archive dialog to select the folder containing your executable, as this screenshot shows:

🔛 Import Projects from File System or Archive — 🗆 🗙						
Import Projects from File System or Archive This wizard analyzes the content of your folder or archive file to find projects and import them in the IDE.						
Import source:	C:\MyProject		~	Directory	Archive	
type filter text				<u>S</u> e	lect All	
Folder	-t	Import as		Des	elect All	
Use installed provide the search for mean of the search for mean of the search for mean of the search for the s	<u>oject configurators</u> to: sted projects onfigure project natures			0 of 1 selecte	d dy open projects	
Add projec	t to working sets				Ne <u>w</u>	
Working sets:				~	S <u>e</u> lect	
?		< <u>B</u> ack	<u>N</u> ext >	<u>F</u> inish	Cancel	

#### Figure 4-1: Import Projects from File System or Archive

3. Click Finish. Your project files should appear in the Project Explorer tab.

4. Right-click the <u>\_\_image.axf</u> file, then select Debug As > Debug Configurations to display the Debug Configuration dialog box. You can see the dialog box in the following screenshot:

Figure 4-2: Opening Debug Configurations

Development St	udio Workspace - Development Stud	lio - Arm Devel	opment Studio IDE							
File Edit Naviga	te Search Project Run Window	Help								
😂 🕍 🦑 🧏 🔡		-								
Project Explorer	x + □\$\$ % 1 = □ □	Tutorials	and Videos 🖾							
✓  → MyProject		arm	DEVELOPMENT C							
🗟 _image~	<i>A</i>		DEVELOPMENT 3							
📄 disasm.t	New	>		Content upo						
le hello_wo	Open	F3	hat's new Articles, Ex	amples, Tutorials De						
mello_wo	Open With	>								
i pi011_ua	Show in Local Terminal	/	vetopment Studio 2018.0	F. M. Martin and A. M. Martin and A. M. Martin and A. M. M. Martin and A. M. M. Martin and A. M.						
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Debug Contro	Profile As	>								
6 84	Team	>								
	Compare With	>	Jse Mali Graphics Debugger	Main Bottlenecks						
	Replace With	>	1) Connect Mali 2) Get to the perceived problem							
	Properties	Alt+Enter	om the beginning area in your your application ucation and pause							
			3) Run a frame 4) Disconnect the							
			capture, overdraw application as you apture, shader map have everything you							
	-24		nd tragment count need	ARMDS						
New Debug Connection		Console      Commands      M= Variables      E Registers      Hemory      Registers     Hemory      Registers								
						Connect with Existing Config		Pack updates are completed		
								10:19:21:	Processing compileted	

- 5. Select Generic Arm C/C++ Application, then click the New launch configuration button to create a new debug configuration.
- 6. In the Name field, give your debug configuration a name, for example FVP\_Base\_Cortex-A76x1.
- 7. On the Connection tab select ARM FVP (Installed with Arm DS) > Base\_A76x1 > Bare Metal Debug > Cortex-A76, as this screenshot shows:



um 🐽 l 🗂 🕂 .	Name: FVP Base Cortex-A76x1
ype filter text	Secondaria Connection Eles & Debugger @ OS Awareness M: Arguments The Environment + Front
<ul> <li>CMSIS C/C++ Application</li> <li>Generic Arm C/C++ Application</li> <li>New_configuration</li> <li>Java Application</li> </ul>	Select target Select the manufacturer, board, project type and debug operation to use. Currently selected: Arm FVP (Installed with Arm DS) / Base_A76x1 / Bare Metal Debug / Cortex-A76
a" Jython run	Filter platforms
<ul> <li>Launch Group</li> </ul>	<ul> <li>&gt; Base_A55x4_A75x2</li> <li>&gt; Base_A55x4_A76x2</li> <li>&gt; Base_A57x1</li> <li>&gt; Base_A57x2_A53x4</li> <li>&gt; Base_A72x1</li> <li>&gt; Base_A72x1</li> <li>&gt; Base_A73x1</li> <li>&gt; Base_A73x1</li> <li>&gt; Base_A73x1</li> <li>&gt; Base_A75x1</li> <li>&gt; Base_A75x1</li> <li>&gt; Base_A76x1</li> <li>Cortex-A76     &gt; Linux Kernel Debug     &gt; Cortex-A9x1 pre-configured to boot Arm Embedded Linux     </li> </ul>
	Arm Debugger will connect to an FVP to debug a bare metal application. The specified FVP is not installed as part of Arm DS. Please ensure it has been installed and is running. Alternatively you can include its location in your PATH environment variable and Arm DS will launch the FVP.
	Bare Metal Debug Model parameters

8. On the Files tab, click File System and select your \_\_image.axf file, as this screenshot shows:

#### Figure 4-4: Debug Configurations - selecting an application on host to download

<ul> <li>Debug Configurations</li> <li>Create, manage, and run configur</li> <li>A file has been specified to be downloped</li> </ul>	ations baded to the target, which will require the core to be stopped, but "Connect Only" has also been specified on the Debugger tab.
Image: Second Secon	Name: FVP_Base_Contex-A76x1  Connection files Debugger OS Awareness & Arguments Environment & Export  Target Configuration  Application on host to download:  C(MyProject_image.axf Files Load symbols  Files Load symbols from file  File System. Workspace.
Filter matched 6 of 19 items	Re <u>v</u> ert Apply
0	Debug Close

9. On the Debugger tab, select Debug from symbol: main as this screenshot shows:

### Figure 4-5: Debug Configurations - debugging from symbol

Debug Configurations		
reate, manage, and run configur Create, edit or choose a configuration to	ations D launch an Arm Debugger session.	Ŕ
🗈 🗶 🖻 🕸 🗸	Name: D/B Race Coster: A76r1	
vne filter text	Mame: FVP_base_Contex-Artox1	
<ul> <li>CMSIS C/C++ Application</li> <li>Generic Arm C/C++ Application</li> <li>FVP_Base Cortex-A76x1</li> <li>Java Application</li> <li>Jython run</li> <li>Launch Group</li> </ul>	Connection initialization debugger view of Arguments in Environment is Export	Workspace
	Host working directory Use default S(workspace_loc) File System	v Workspace_
	File System     Workspace	
ilter matched 6 of 19 items	Reyert	Apply
0	Debug	Close

- 10. Click Apply, then Close.
- 11. On the Debug Control tab, double-click your debug configuration to start the model and run your application. Execution pauses on entry to main(), and you should see the Fast Models window appear, as this screenshot shows:



#### Figure 4-6: Start the model and run your appliaction

1. Click the Continue toolbar button to continue execution. Arm Development Studio automatically starts the Telnet client and connects to the model. The application output, hello world, will appear in the Telnet client window after it has been sent over the UART serial interface, as this screenshot shows:

#### Figure 4-7: Telnet client showing UART output

🔯 Development Studio Workspace - Development Studio - Ci/hello_world.c - Ar	rm Development Studio IDE		- a ×
File Edi E Fast Models - CLCD Cortex-A76x1 Base FVP	- 0 x		
CO COLUMN T B BARRIER DELEDO7 Doughter BARRIER	RUNA LINIT ON		Quick Access
Project Total Instr: 917 Total Time: 14	Grab House: LeftCtr1+Left83t	- D	🕃 Outline 🔢 🍫 Breakpoints 🕂 👘 🗖
<ul> <li>⇒ My</li> </ul>		<u>^</u>	日 法 残 丈 • 数 三
4 int main (ve	oid) (		
id hello_world. 5 uartInit((	(void*)(0x1(090000));		- 🗆 X
B offit wate 6 printf("he	<pre>ello world\n");</pre>		
R p011 with 8 1	hello world		
B pl011 wrt.o 9			
B scatter.txt			
🗎 startup.o			
is startup.s			
Debug Control II + O			
○ · · · · · · · · · · · · · · · · · · ·			
✓ VP_Base_Cortex-A76x1 connected			
Cortex-A76 #1 stopped (EL3h)			
<			
Console 🔳 Comm	sands 🕫 Variables 🗰 Reg		=
🗟 🕲 👻 «Next Instru	uction>		4
Address	Opcode D		
EL3:0x00000000	0000280C A90027E8 ST		^
EL3:0x00000000	A00A2810 32100710 CK		
[L3:0x0000000	00002818 14000000 8		
EL3:0x00000000	NONO281C AA000313 MO NONO2820 F5400000 1D		
Status: connected			· · · · · · · · · · · · · · · · · · ·

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# 5. Related information

Here are some resources related to material in this guide:

- Arm Community
- Arm Compiler 6 documentation
- Arm Development Studio downloads
- Arm Development Studio documentation
- Armv8-a Learn the Architecture series of guides

# 6. Next steps

This guide is the second in a series of four guides on the topic of building an embedded image. In this guide, you learned about semihosting, how to retarget functions to use UART and you to use Telnet to interface with the UART.

You can continue learning about building an embedded image in the next guides in the series:

- Creating an Event-Driven Embedded Image
- Changing Exception Level and Security State in an Embedded Image

In case you missed it, the first guide in the series is:

• Building your First Embedded Image