STM32 开发实验指导书







更新日志

时间	更新内容	更新人
2020.09.08	完成初始版本	Disp301
	1. 补充第一章第三节 IKS01A3	
	拓展板支持包安装方法;	
2020 00 16	2. 补充第九章 PWM 输出实验;	Dian201
2020.09.10	3. 补充第十章 DAC 实验;	Disp301
	4. 补充第十一章 STTS751 温度	
	获取实验;	
	1. 补充第十一章 ADC 实验	
	2. 补充第十三章 LSM6DSO 六	
	轴加速度获取实验	
	3. 补充第十四章 FreeRTOS 实	
	验	
	5. 修改第四章跑马灯实验中	
2020.10.10	LED 电平翻转部分代码	Disp301
	6. 修改第五章按键输入实验中	
	按键读取部分代码	
	7. 修改第九章 PWM 输出实验	
	中部分实验说明	
	8. 修改第十二章 STTS751 温度	
	获取实验中拓展板初始化操作	
2021.08.05	部分文字修正与软件版本更新	Disp301

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12.2 实验内容	12.1 实验目的	
	12. 2 实验内容	

12.3 实验要求	
12.4 实验步骤	
12.5 实验结果	
第十三章 LSM6DSO 六轴加速度获取实验	
13.1 实验目的	
13. 2 实验内容	
13.3 实验要求	
13.4 实验步骤	
13.5 实验结果	
第十四章 FreeRTOS 实验	
14.1 实验目的	
14.2 实验内容	
14.3 实验要求	
14.4 实验步骤	
14.5 实验结果	

第一章 软件安装

- 1.1 软件下载
- 1. 打开 <u>https://pan.seu.edu.cn</u>,用信息门户账号密码登录东南大学文档云,在**共享文档**中找到名为**杨 海宁**的文件夹。

www. www. southerase universe	ig J Siv			消息(16) 帮助	下载客户端 ▼
文档访问					Q #
▲ 个人文档	共享文档			1	腓序 ∨
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审核管理		共喜文档			
— 权限申请		77713			
▶ 权限审核	- 钱字辉	共享文档			
流程申请	78154	土草文档		2018-07-24 17:41:29	
☆ 流程审核	BP2P/HB	ATAH			
个人中心	🗆 🦰 孙竹山	共享文档			
1 个人资料	田田 (19) 田 (19) 田 (19) 田 (19) 田 (19) 田 (19) 田 (19) (19) (19) 田 (19) 田 (19) 田 (19) 田	共享文档		2019-10-28 08:31:30	
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🔲 移动设备	- 杨海宁	共享文档			
	デ堂家 🦳	共享文档			
	袁伟志	共享文档		2020-04-02 12:13:32	
	□ ■ 张琬磊	共享文档		2016-09-26 21:43:19	

2. 进入 STM32 软件文件夹,下载固件包、软件内的文件到本地。如果出现无法下载的问题,可以下 载东南大学文档云客户端,在客户端内下载文件。

回到上一层 共享文档 > 杨海宁 > STM32软件			
□ 文档名称	类型	大小	修改时间
□	文件夹		2020-09-06 08:52:20
□ 〒发板文档资料	文件夹		2020-09-06 08:54:19
□ □ \$\$件 ◆	文件夹		2020-09-06 09:12:12

1.2 安装 JAVA 开发环境

- 1. 运行 jre-8u261-windows-x64.exe
- 2. 直接点击安装



3. 出现以下界面,等待一会儿即可安装成功

Java 安裝 - 进度 「Java" Java"	– – ×
状态: 安装 Java	
ني Java 25 س	™ 1/5
#1 Development Platform	ORACLE

1.3 安装 STM32CubeMX

- 1. 运行 SetupSTM32CubeMX-6.0.0.exe
- 2. 点击 next->next

STM32Cu	eMX Installation Wizard	_		×
Welcome to th	Installation of STM32CubeMX 6.0.0			MX
	Starting STM32CubeMX 6.0.0 installation			
life.augmente	The homepage is at: <u>https://www.st.com/stm32cube</u>	L		
STM32 Cube				
STMicroelectronic	() Next	8	Quit

3. 勾选后点击 next

STM32CubeMX	Installation Wizard	_		×
STM32CubeMX License	agreement			MX
life.augmented	Please read the following license agreement carefu SOFTWARE PACKAGE LICENSE AGREEMENT Please indicate your acceptance or NON-acc "I ACCEPT" or "I DO NOT ACCEPT" as indicat media.	ally: eptance l ed below	by selec in the	ting
STM32 Cube	BY INSTALLING COPYING, DOWNLOADING, ACCESS USING THIS SOFTWARE PACKAGE OR ANY PART TH RELATED DOCUMENTATION) FROM STMICROELECTRO N. V, SWISS BRANCH AND/OR ITS AFFILIATED CO (STMICROELECTRONICS), THE RECIPIENT, ON BE HERSELF, OR ON BEHALF OF ANY ENTITY BY WHI	EING OR O EREOF (AU NICS INT MPANIES HALF OF I CH SUCH I	THERWISE ND THE BRNATION HIMSELF (RECIPIEN	AL OR T IS V
STMicroelectronics	✓ I accept the terms of this license agreement. ✓ Previous	🕥 Next	⊗	Quit

4. 勾选后点击 next



5. 建议不改变默认路径,如果需要可以修改路径,注意安装路径不能包含中文

STM32CubeM	K Installation Wizard			
STM32CubeMX Install	ation path			МХ
	Select the installatio	n path:		
	E:\STM32MX	•		🔁 Bro
life.augmented				
STM32 Cube				
STMicroelectronics				
	0	Previous	🕥 Next	🚫 Quit

6. 点击 next

STM32CubeMX Installation Wizard				\times
STM32CubeMX Shortcu	ts setup			MX
Life.augmented	 ✓ Create shortcuts in the Start-Menu ✓ Create additional shortcuts on the desktop Select a Program Group for the Shortcuts: Administrative Tools Altera Altium CustomExplorer C-2009.09 Daum Dolby Electronics Pioneer Git ✓ 		eate sho)current us)all users	r
STMicroelectronics			Deraurt	
	🔇 Previous 🛛 📀	Next	\otimes	Quit

7. 等待安装结束即可

STM32CubeM	X Installation Wizard	_		\times
STN32CubeNX Packag	e installation			MX
Life.augmented	Pack installation progress: E:\STM32cube\db\mcu\STM32L4S5ZIYx.xml Core Overall installation progress: 1 / 6			
STMicroelectronics	C Previous	🔊 Next	8	Quit

8. 安装成功

STM32CubeM	K Installation Wizard	_		\times
STM32CubeMX Install	ation done			MX
life.augmented	Installation has completed successfully An uninstaller program has been created E:\STM32cube\Uninstaller	r. l in: ation	script]
STMicroelectronics			⊘ I)one

9. 下面需要添加固件包,打开软件

STM32CubeMX Untitled	Window	Help	- · · × ® F • ¥ × 57
Existing Projects Open Existing Projects	دی	New Project I need to : Start My project from MCU ACCESS TO MCU SELECTOR Start My project from ST Board ACCESS TO BOARD SELECTOR Start My project from Example ACCESS TO EXAMPLE SELECTOR	

10.点击 help->Manage embedded software packages



11.点击左下角 from local...找到 stm32cubef4_V1.25.0.zip, 点击打开

STM32CubeMX Untitled						- 0
TM32	File	Window	Help		9	🖪 🖸 🄰 🔆 🖌
iome 🔪						
/		Embedded Software P	ackages Manager		×	
Existing Projects		STM32Cube MCU F Releases Information	ackages and embed	ded software packs releases s than one hour ago.	+ - 15	
		STM32Cube MCU	ect a STM32Cube	Package File X		
Open Existing Projects		Loak In STM32F0 Look In STM32F1 STM32F1 STM32F2 STM32F2 STM32F3 STM32F3 STM32F4 Details File [sa File so	Documents be ery softData /IEW Data -LAB aBooks me IJypes STM32Cube F	Avail A	nunevention For ALL /	UPDATES VATES Ware packages REMOVE ST MCU Find All STM32 & ST
		From Local From Ur		Refesh Install Now Remove Now	Close	MCUs in one place

12.正在安装固件包

KTM32CubeMX Untitled									-		×
STM32	File	Window	Help				1	f 🖻	9	\star	57
Home							-				
Existing Projects		Embedded Software P STM32Cube MCU P Releases Information STM32Cube MCU Packages	ackages Manager Packages and embedded n was last refreshed less th ST STMicroelectronics	software packs relea	1505	× + -	IS				
Open Existing Projects		Description STM32F0 STM32F1 STM32F2 STM32F2 STM32F3 STM32F4 Details	Load selected Fi Check File type Load selected Files	ile OK	Cancel	Available Version	and embo CFOR UPD Software ALL / REM	edded soft DATES e package IOVE	s ST M	ckages. CU Fin	der
		From Local From U	L.	Refresh Inst	all Now Remove Now	Close		M	All STM: CUs in c	32 & ST	

13.安装成功后,在 STM32F4 列表下 1.25.0 那一行的方框变绿

🔤 Embedded Software Packages Manager			×
STM32Cube MCU Packages and embedded software packs r	releases		÷ -
Releases Information was last refreshed less than one hour ago.			· ·
STM32Cube MCU Packages STMicroelectronics			
Description SIMJ2F3	Insta	lled Version	Available Version
▼ STM32F4			
TM32Cube MCU Package for STM32F4 Series	1.25.0		1.25.0
STM32Cube MCU Package for STM32F4 Series (Size : 785.0 MB)			1.24.2
STM32Cube MCU Package for STM32F4 Series (Size : 783.0 MB)			1.24.1
Details			
From Local From Url Refresh	Install Now	Remove Nov	v Close

14.点击第二个选项卡 STMicroelectronics

📖 Embedded Software Packages Manager				×
STM32Cube MCU Packages and embedded software packs release	es			
Releases Information was last refreshed 22 hours ago.				- T -
ন্দ STM32Cube MCU Packages ন্দ STMicroelectronics				
Status Description			Availa	ble Version
► X-CUBE-AI				
X-CUBE-ALGOBUILD				
► X-CUBE-BLE1				
► X-CUBE-BLE2				
► X-CUBE-GNSS1				
► X-CUBE-MEMS1				
► X-CUBE-NFC4				
► X-CUBE-SUBG2				
► X-CUBE-TOUCHGFX				
Details				
From Local From Url	Refresh	Install Now	Remove Now	Close

15.点击左下角 from local...找到 8.1.0.zip, 点击打开

MX Embed	lded Software Pack	ages Manager >
	STM32Cube MC	U Packages and embedded software packs releases
- 🕂	Releases Informat	tion was last refreshed 22 hours ago.
ATT STM32	2Cube MCU Packa	ges 🐬 STMicroelectronics
S	Status Descrip	tion Available Version
•	X-CUBE-AI	
•	X-CUBE-AL	GOBUILD
•	X-CUBE-BL	.E1
•	X-CUBE-BL	E2 Select a STM32Cube Package File X
•	X-CUBE-GN	
•	X-CUBE-ME	EMS1 4 admin 合 Install.zip 此电脑
•	X-CUBE-NF	-C4 🧎 库
•	X-CUBE-SU	JBG2 一 网络 一 波治編码 - 仲推方式
•	X-CUBE-TO	DUCHGF
		File Name 8.1.0.zip
		Files of <u>Types</u> STM32Cube Packages File (*.zip, *.pack)
		打开 取消
Details		
Drivers and	a sample applicatio	ns for MILINS components
From Lo	ocal From	Url Refresh Install Now Remove Now Close

16. 点击接受,并点击结束

Embedded S	Software Packa	ges Manager				
STN	132Cube MCU	Packages and embedded software packs releases				
Rele	ases Informati	on was last refreshed 22 hours ago.				
57 STM32Cube	MCU Packag	es STMicroelectronics				
Status	Descript	ion				Available Version
•	X-CUBE-AI					
•	X-CUBE-AL	GOBUILD			_	
•	X-CUBE-BL	K Licensing Agreement			×	
•	X-CUBE-BL	STMicroelectronics X-CUBE-MEMS1 8.1.0 License A	greement			
•	X-CUBE-GN	Please read and accept the following agreement careful	ly to finish the ins	stallation:		
•	X-CUBE-ME					
•	X-CUBE-NF					
•	X-CUBE-SU	Click here to open the lice	nse agreement			
•	X-CUBE-TO					
		 I accept the terms of this license agreement I do not accept the terms of this license agreement 	:	Finish Car	icel	
Details						
Drivers and sam	ple application	s for MEMS components				
From Local	From	Jrl	Refresh	Install Now	Remove	Now Close

17.点击 X-CUBE-MEMS1, 若 8.1.0 版本的拓展板支持变绿,则说明安装成功。

📉 Embe	edded S	oftware Packages Manager	×
	STM	32Cube MCU Packages and embedded software packs releases	. _
E 🕂	Rele	ases Information was last refreshed 22 hours ago.	
ন্দ STM	132Cube	MCU Packages 477 STMicroelectronics	
	Status	Description	Available Version
		X-CUBE-AI	
► ·		X-CUBE-ALGOBUILD	
•		X-CUBE-BLE1	
•		X-CUBE-BLE2	
Þ.		X-CUBE-GNSS1	
v		X-CUBE-MEMS1	
•		Drivers and sample applications for MEMS components	8.1.0
		Drivers and sample applications for MEMS components (Size : 99.43 MB)	8.0.0
		Drivers and sample applications for MEMS components (Size : 108.89 MB)	7.2.0
□ ⊗		Drivers and sample applications for MEMS components (Size : 97.26 MB)	7.1.0
		Drivers and sample applications for MEMS components (Size : 90.51 MB)	7.0.0
		Drivers and sample applications for MEMS components (Size : 79.92 MB)	6.2.0
Details		Driver and annula and institution for MEMO comments (Circ. 10.04 MD)	
Drivers a	and sam	ole applications for MEMS components	
From L	Local	From Url Refresh Install Now Rem	ove Now Close

1.4 安装 MDK-ARM

- 1. 运行 MDK531.exe
- 2. 点击 next->next



3. 推荐使用默认路径安装,也可以使用自己的路径,建议 packs 的文件位置包含在 core 的文件里面。

older Selection Select the folder where SETUP will install files.		arn	n KEII
Press 'Next' to install MDK-ARM to these folders. Press 'Bro	wse' to select di	fferent folders	for installation.
Destination Folders			
Care: FLK 1 F			Browse
Core: E:\KeiLv5			DI00056
Pack: E:\Keil_v5\Arm\Packs			Browse
Pack: E:\Keil_v5 Pack: E:\Keil_v5\Arm\Packs			Browse
Update Installation: Create backup tool folder			Browse

4. 随便填写用户信息, 但要注意必须是英文

etup MDK-ARM V5.31				>
Customer Information Please enter your information.			arm	KEIL
Please enter your r	name, the name of the company	for whom you work an	d your E-mail addre	\$\$.
First Name:	user			
Last Name:	user			
	user			
Company Name.	Jusei			
E-mail:	user			_
E-mail: Keil MDK-ARM Setu	user			

5. 注意:安装过程中如果防火墙拦截程序操作,一定要选"允许程序所有操作";如果出现如下图所示的"系统找不到指定的文件"的错误提示,可以下载 ccleaner 清理注册表,之后重新下载.exe 文件或重新解压压缩包,用新的压缩包内的.exe 文件,回到步骤1开始操作。

Ке	il µVision Setup			KEIL
MDK-ARM S Install Files Installing ruiS	Cannot create 'E:\keil-v5\cor System Error C "系统找不到指述 Retry?	destination file. re\ARM\ARMCLANG\bin\ code: 定的文件。"	\ucrtbase.dll'	
		是(Y)	否(N)	

6. 安装成功,取消勾选,点击 finish

Setup MDK-ARM V5.31	×
Keil MDK-ARM Setup completed MDK-ARM V5.31	arm KEIL
MDK-ARM Core Setup has performed all requested ope	erations successfully.
— Keil MDK-ARM Setup ————————————————————————————————————	<< Back Finish Cancel

7. 自动跳出下载固件包的窗口,先取消勾选,然后依次关闭两个窗口。

Pack Installer	×
Welcome to the Keil Pack Installer Pack Installer is a utility for managing Software Packs on the local computer an provides the following windows:	d
Devices : List supported devices. Select a device to show related Packs and examp	es.
Boards : List supported boards. Select a board to show related Packs and example	s.
Packs : List and manage Software Packs. Install a Pack for access within µVision.	
Examples : List example projects. Copy projects and launch µVision for testing examp	oles.
Pack Installer connects to <u>www.keil.com/pac</u> to obtain the published Software Packs. To install a local Software Pack use File - Import from the menu.	
Show this dialog at startup OK He	lp

8. 双击 Keil.STM32F4xx_DFP.2.14.0.pack, 点击 next, 安装固件包。

Welcome to Keil Pack Unzip Release 7/2019	arm KEIL
This program installs the Software Pack:	
Keil STM32F4xx_DFP 2.14.0	
Keil STM32F4xx_DFP 2.14.0 STMicroelectronics STM32F4 Series Device Support, Dri	vers and Examples
Keil STM32F4xx_DFP 2.14.0 STMicroelectronics STM32F4 Series Device Support, Dri	vers and Examples
Keil STM32F4xx_DFP 2.14.0 STMicroelectronics STM32F4 Series Device Support, Dri Destination Folder	vers and Examples
Keil STM32F4xx_DFP 2.14.0 STMicroelectronics STM32F4 Series Device Support, Dri Destination Folder C:\Keil_v5\Arm\Packs\Keil\STM32F4xx_DFP\2.14.0	vers and Examples
Keil STM32F4xx_DFP 2.14.0 STMicroelectronics STM32F4 Series Device Support, Dri Destination Folder C:\Keil_v5\Arm\Packs\Keil\STM32F4xx_DFP\2.14.0 Keil Pack Unzip	vers and Examples

9. 安装成功

Pack Unzip: Keil STM32F4xx_DFP 2.14.0	×
Keil Pack Unzip completed Keil STM32F4xx_DFP 2.14.0	arm KEIL
Keil Pack Unzip has performed all requested operations success	fully.
Keil Pack Unzip	Back Finish Cancel

1.5 ST-Link 驱动安装及固件升级

1. 找到 MDK 软件安装路径,定位到 xxxx\Keil_v5\ARM\STLink\USBDriver

2. 根据自己的电脑操作系统选择 64 位或 32 位的驱动程序(一般都选用 64 位的),双击运行.exe 程序

📕 amd64	2020/9/4 9:14	文件夹
📕 x86	2020/9/4 9:14	文件夹
💐 dpinst_amd64.exe	2020/5/22 14:49	应用程序
💐 dpinst_x86.exe	2020/5/22 14:49	应用程序
readme.txt	2020/5/22 14:49	文本文档
🔄 stlink_dbg_winusb.inf	2020/5/22 14:49	安装信息
stlink_VCP.inf	2020/5/22 14:49	安装信息
stlink_winusb_install.bat	2020/5/22 14:49	Windows 批处
💿 stlink_winusb_uninstall.bat	2020/5/22 14:49	Windows 批处
stlinkdbgwinusb_x64.cat	2020/5/22 14:49	安全目录
stlinkdbgwinusb_x86.cat	2020/5/22 14:49	安全目录
stlinkvcp_x64.cat	2020/5/22 14:49	安全目录
stlinkvcp_x86.cat	2020/5/22 14:49	安全目录

3. 确认安装成功与否:将 Nucleo 开发板与电脑连接(必须确保 Micro USB 数据线可以传输数据,连接后红色 LD4 指示灯应当常亮,如果闪烁则应更换数据线)->右击"我的电脑"->属性->设备管理器,可以看到通用串行总线设备中有 ST-Link 的驱动,端口中有 ST-Link 的虚拟端口,其中端口号随意。



4. 确保 ST-Link 仿真器与电脑相连后,定位到 xxxx\Keil_v5\ARM\STLink,双击运行 ST-LinkUpgrade.exe

5. 点击 Device Connect , 连接成功,显示仿真器固件库版本和仿真器类型

ST-Link Upgrade	
Device Connect Current Firmware: Version: V2.J29.M18 Type: STM32 Debug +Mass storag	re+VCP
Change Type (Require last USB driver from ST website, else do not use!)	
Upgrade to Firmware:	STM32 Debug+Mass storage+VCP V2.J35.M26
	Yes >>>>

6. 点击 Yes>>>>, 升级成功

7. 最终检测板子是否正常工作: 多次按下蓝色 B1 按键, 用户指示灯变化

第二章 硬件速览

2.1 Nucleo-144



2. 2 IKS01A3







- LSM6DSO: MEMS 3D accelerometer (±2/±4/±8/±16 g) + 3D gyroscope (±125/±250/±500/±1000/±2000 dps)
- LIS2MDL: MEMS 3D magnetometer (±50 gauss)
- LIS2DW12: MEMS 3D accelerometer (±2/±4/±8/±16 g)
- LPS22HH: MEMS pressure sensor, 260-1260 hPa absolute digital output barometer
- HTS221: capacitive digital relative humidity and temperature
- STTS751: Temperature sensor (-40 °C to +125 °C)
- DIL 24-pin socket available for additional MEMS adapters and other sensors
- Free comprehensive development firmware library and example for all sensors compatible with STM32Cube firmware
- I²C sensor hub features on LSM6DSO available
- Compatible with STM32 Nucleo boards
- Equipped with Arduino UNO R3 connector
- RoHS compliant

•

WEEE compliant

第三章 建立程序模板

3.1 实验目的

- 1. 学习 STM32CubeMX、Keil 基本使用
- 2. 建立 STM32 开发的程序模板

3.2 实验内容

利用 STM32CubeMX 生成外设初始化代码

3.3 实验要求

成功建立 Keil 工程,并编译通过

3.4 实验步骤

第一步,首先打开 STM32CubeMX 工具,点击如图所示的按钮新建工程。

MX STM32CubeMX Untitled				
STM32 CubeMX	File	Window	Help	
Home	New Project	Ctrl-N		
Existing Projects	Load Create a New Filmport Project Conserved and the second s	Project trr-I trr-S trr-A		New Project
Open Existing Projects	Recent Projects	•		I pood to :
	Exit	th-X		Start My project from MCU ACCESS TO MCU SELECTOR Start My project from ST Board ACCESS TO BOARD SELECTOR Start My project from Example

第二步,选择 Nucleo-144 的 MCU,型号为 STM32F413ZH,在搜索栏内可快速过滤。

MX New Project					×
MCU/MPU Selector Board Selector Example Sel	ector Cross Selector				
MCU/MPU Filters			da -		
★ 🗟 🗟 こ	Features Block Dia	agram Docs & Resources	🛃 Datasheet	L' Buy	→ Start Project
Part Number STM32F413ZH V	STM32F4 Series			/	
Core >	STM32F413ZH	High-performance access line, A Flash, 100 MHz CPU, ART Acce	ARM Cortex-M4 core lerator, DFSDM	with DSP and FPU, 1,5	MByte
Series >	ACTIVE	Unit Price for 10kU (US\$): 5.774			
Line >	Product is in mass production	Boards: NUCLEO-F413ZH - STM32F413H-D		LQFP144	
Package >	The STM32E413vG/H devices are	based on the bigh-performance Arm@Cort	tev®_M4 32_bit RISC core	operating at a frequency of u	n to 100 MHz
Other >	Their Cortex®-M4 core features a data types. It also implements a fu	Floating point unit (FPU) single precision w Il set of DSP instructions and a memory pro	which supports all Arm sing otection unit (MPU) which	ple-precision data-processing enhances application security	instructions and
Peripheral >	The STM32F413xG/H devices belo while adding a new innovative feat	ong to the STM32F4 access product lines (ure called Batch Acquisition Mode (BAM) a	(with products combining p allowing to save even more	oower efficiency, performance power consumption during d	and integration) ata batching.
	The STM32F413xG/H devices inco extensive range of enhanced I/Os	orporate high-speed embedded memories (and peripherals connected to two APB bus	(up to 1.5 Mbytes of Flash ses, three AHB buses and	memory, 320 Kbytes of SRA a 32-bit multi-AHB bus matrix	M), and an
	All devices offer a 12-bit ADC, two two general-purpose 32-bit timers	12-bit DACs, a low-power RTC, twelve gen and a low power timer.	neral-purpose 16-bit timer	s including two PWM timer for	motor control,
	They also feature standard and ac	dvanced communication interfaces.			
	 Dynamic Efficiency Line with - 1.7 V to 3.6 V power sup - 1.7 V to 3.6 V power sup 	th eBAM (enhanced Batch Acquisition Mod ply	le)		
	40 °C to 85/105/125 °C	temperature range	<u></u>	<u></u>	
	MCUs/MPUs List: 2 items	+ Display similar items			rth Export
	* Part No 🗢 Reference Ma	rketing Sta× Unit Price for 10kU (×	Board	X Package X Flash X	RAM × IO × Freq. ×
	STM32F413ZH STM32F413ZHJx Act	tive 5.774		UFBGA144 1536 kBy 320	kBytes 114 100 MHz
		100 0.114 NOCLEO-F4	51M32F413H-DISCO	LQI F 144 1556 KDy 520	KDytes 114 100 Miliz

第三步,进入 RCC 界面对时钟源进行配置,这里高速时钟选择 BYPASS Clock Source,低速时钟选择 Crystal/Ceramic Resonator,其余保持默认



第四步,进入时钟树界面,对所标注部分分频系数进行修改。



第五步,进入 SYS 界面对调试选项进行配置,这里在 Debug 内选择 Serial Wire 模式,其余保持默认。

STM32CubeMX Untitled*:	STM32F413ZHTx										- 0	×
STM32	File	Window	Help						1	F 🖸 🐧	🗸 🔀	77
Home STM32F413	3ZHTx 🔰 Untitled - Pinout &	& Configuration >							GE	NERATE CODE		
Pir	nout & Configuration		Clock Configurati	on		Project Manage	er			Tools		
			✓ Software F	Packs 🗸 🗸	Pinout							
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System Core ~	System Wake-Up 1			Ľ 🗬		PE2 0					VD0 V88	
¢ DMA	System Wake-Up 2					P84 P85					VCA. PA13 SYS_JTMS.SWDIO	
GPIO	System Wake-Up 3					VEAT					PA12 PA11	
NVIC	Timebase Source SysTick			~		RCC_05C32_N 1014					P10	
✓ RCC ✓ SYS			Configuration			770					PC9	
WWDG		A Warning: This IP ha	s no parameters to be configured.			P#2					PC7 PO8	
						P#4			_		VDD	
Analog >	-					VSS VDD	1				PG8 PG7	- 14
Timers >	_					PFG PF7					P06 P05	- 14
Connectivity >						010					P03	- 14
Multimedia >						RCC_OSC_IN PHO.					PD15	- 14
0	-					NRST PCD	~	TN220744	27UTv		VD0 V88	- 14
Security	-					PC1 PC2	3	1 11/132641	эспіх		PD13 PD12	
Computing >	-					NCO		LQFP1	44		PD11 PD10	
Middleware >	-					VSEA					PD6	
						PAD					7814	
						9.42					P812	
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Middleware > MCUs Selection Cutput STM32F4 © STM32F4		STM32F413/423 STM32F413/423	Lines	N STM32F4132HJx STM32F4132HTx	lcu	Q [] UFBGA144 LQFP144	C Package		A4	Required Periphe	200 05 05 05 05 05 05 05 05 05 05 05 05 0	

第六步,填写工程信息。

- Project Name: 工程名任意即可,这里填写 template。
- Project Location: 工程路径,建议新建空文件夹专门存放所有的工程文件,这里新建了 template 文件夹。注意 路径中不要出现中文字符。

- 0 ×

- Toolchain/IDE: 这里选择我们已经安装好的 Keil5,工具链(Toolchain)选择 MDK-ARM,版本号选择 V5
- 取消勾选 Use latest available version,选择 V1.25.0。
- 其余保持默认,点击右上角的 GENERATE CODE 生成 Keil 工程。

STM32CubeMX Untitled*: STM32F413ZHTx

STM32F4132HTx Untitled - Project Manager CENERATE CODE Pinout & Configuration Clock Configuration Project Manager Tools Project Settings Project Settings Project Location Project Location Polet Location Do not generate the main() Tools and Finder Location Distes_system_designitemplate\ Do not generate the main() Toolshain Folder Location Distes_system_designitemplate\ Distes_system_designitemplate\ Tools of Generator Code Generator Universitemplate\ Advanced Settings Users Settings Iminum Hap Size Docod Iminum Stack Size Docod Iminum Stack Size Docod Iminum Stack Size Docod	57
Pinout & Configuration Clock Configuration Project Manager Tools Project Settings Project Settings Project Manager Tools	
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STM32F4132HTx Finimware Package Name and Version STM32Cube FW_F4 V1.25.0 Image: Comparison of the state stat	
MCUs Selection Output	
Series Lines Mou Package Required Peripherals	-

代码生成完成之后,点击打开 keil 工程。

🚾 STM32CubeMX templa	ate.ioc: STM32F446ZETx				- 0
	File	Window	Help		🎯 🖪 🗖 🎽 😽 🎜
Home > STM32F4	146ZETx > template.ioc - P	roject Manager >			GENERATE CODE
i F	Pinout & Configuration		Clock Configuration	Project Manager	Tools
Project	Project Settings Project Name template Project Location C:\Users\admin\Desktop\template Application Structure	3			
Code Generator	Advanced Toolchain Folder Location [C:\Users\admin\Desktop\template Toolchain / IDE [MDK-ARM]	Vtemplate\ Min Ver: V5.27	O Do not generate the main()		
Advanced Settings	Linker Settings Minimum Heap Size Minimum Stack Size	0×200 0×400	Code Generation The Code is successfully generated und Cpen Felder Cgen	X r Catsers/admin/Desktop/template/template Pert Close	
	Mcu and Firmware Package Mcu Reference				
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	Use Default Firmware Location	1			
	C:/Users/admin/STM32Cube/Rep	ository/STM32Cube_FW_F	4_V1.25.0	Browse	
	L				
				r o contaire to Er	

利用 Keil 打开工程以后,打开 main.c,这里是程序的入口。可以发现 STM32cube 已经帮我们完成了基本的初始化,并且在下方留出了空间让用户添加用户代码。

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File Edit View Project Flash Debug Peripherals	is Tools SVCS Window Help	
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Project # 🛛	a mainc	▼ X
🖃 🍕 Project: template	55 /* Private user code*/	^
😑 🚑 template	56 /* USER CODE BEGIN 0 */	
🖶 🦢 Application/MDK-ARM	57	
startup_stm32f446xx.s	58 /* USER CODE END 0 */	
	60 = /**	
Application/User/Core	61 * @brief The application entry point.	
	62 * gretval int	
stm32f4xc_it.c	63 - v/	
stm32f4xc_hal_msp.c	65	
Drivers/STM32F4xx_HAL_Driver	66 /* USER CODE BEGIN 1 */	
i 🚞 Drivers/CMSIS		
	69 /- USER CODE END 1 -/	
	70 /* MCU Configuration*/	
e	71	
	72 /* Reset of all peripherals, Initializes the Flash interface and the Systick. */	
	73 nat_111c(); 74	
	75 /* USER CODE BEGIN Init */	
n	76	
	77 /* USER CODE END Init */	
	70 79 /* Configure the system clock */	
	80 SystemClock_Config();	
0	81	
8	82 /* USER CODE BEGIN SysInit */	
	84 /* USER CODE END SysInit */	
	85	
e	86 /* Initialize all configured peripherals */	
	87 EX GELO INIT(); 88 (* USER CODE RECEVE 2 */	
	89	
	90 /* USER CODE END 2 */	
	91 / Trefining Joan K/	
	93 /* USE CODE EEGIN WHILE */	
	94 while (1)	~
Project 😚 Books {} Functions 0., Templates		>
Build Output		a 🛛
		^
		v
<		>
	ST-Link Debugger L67 G7	CAP NUM SCRL OVR R/W .at

利用图示的两个按钮进行编译和代码烧录。

🔢 C:\Users\admin\Desktop\led_project\led\MDK-ARM\led.uvprojx - μVision [Non-Commercial Use License] File Edit View Project Flash Debug Peripherals Tools SVCS Window Help 🍪 🍱 🏙 🧼 🕶 🔜 🔤 Ied 🖂 🐔 击 💠 🐡 幽 Project д 🗙 main.c main.h stm32f4xx_hal_gpio.h 🖃 쓚 Proje t: led /* USER CODE BEGIN 0 */ 61 🖮 😓 le🕴 62 /* USER CODE END 0 */ 63 Application/MDK-ARM 64 🔷 🗘 CMSIS 65 -/** in Application/User/Core * @brief The application entr 66 🗄 📄 main.c * @retval int 67 68 L */ 🗄 📄 stm32f4xx_it.c 69 int main (void) stm32f4xx_hal_msp.c 70 🚍 { i Drivers/STM32F4xx_HAL_Driver 71 /* USER CODE BEGIN 1 */ 🗄 🛄 Drivers/CMSIS 72 /* USER CODE END 1 */ 73 74

3.5 实验结果

Build Output
compiling stm32f4xx_hal_cortex.c
compiling system_stm32f4xx.c
compiling stm32f4xx_hal.c
compiling stm32f4xx_hal_exti.c
linking
Program Size: Code=2212 RO-data=500 RW-data=16 ZI-data=1024
FromELF: creating hex file
"template\template.axf" - 0 Error(s), 0 Warning(s).
Build Time Elapsed: 00:00:12

<

可以看到编译结束后0错误0警告,代码生成成功。

第四章 跑马灯实验

4.1 实验目的

- 1. 学习 LED 灯的点亮原理
- 2. 实现对 Nucleo-144 开发板 LED 灯的控制

4.2 实验内容

通过对 GPIO 口拉高或拉低,实现对 LED 状态的控制

4.3 实验要求

Nucleo-144 上 LD1、LD2、LD3 实现闪烁效果

4.4 实验步骤

1. 利用 STM32CubeMX 生成模板代码

STM32CubeMX Untitled

第一步,首先打开 STM32CubeMX 工具,点击如图所示的按钮新建工程。

STM32	File		Window	Help	
Home >	New Project	Ctrl-N			
Existing Projects	Load Create a New Import Project Save Project As Close Project	v Projec CtrI-I CtrI-S CtrI-A	E		New Project
Open Existing Projects	Recent Projects	CtrI-R		िर	I need to :
					Start My project from MCU ACCESS TO MCU SELECTOR
					Start My project from ST Board ACCESS TO BOARD SELECTOR Start My project from Example

第二步,本实验我们采用和第三章不同的方式,点击 Board Selector,直接选择对应的 NUCLEO-144 开发板,点击 YES,选择完成基本配置,打开 RCC 和 SYS 以及 LED 对应的 GPIO,可以看到这些都已经自动配置成功。





- Project Name: 工程名任意即可,这里填写 led_project。
- Project Location: 工程路径,建议新建空文件夹专门存放所有的工程文件,这里新建了 led_project 文件夹。注意路径中不要出现中文字符。
- Toolchain/IDE: 这里选择我们已经安装好的 Keil5,工具链(Toolchain)选择 MDK-ARM,版本号选择 V5。
- 取消勾选 Use latest available version,选择 V1.25.0。
- 其余保持默认,点击右上角的 GENERATE CODE 生成 Keil 工程。

STM32CubeMX Untit	ed*: STM32F413ZHTx NUCLEO-F413ZH				- 🗆 ×
	File	Window	Help		💿 F 🖸 🏏 🥂 🖅
Home > STM32F	413ZHTx - NUCLEO-F413ZH 🔰	Untitled - Project Ma	anager >		GENERATE CODE
	Pinout & Configuration		Clock Configuration	Project Manager	Tools
Project	/Project Settings Project Name led_project Project Location C:UsersVadminUesktop\ Application Structure			Etrasse	
Code Generator	Advanced Toolchain Folder Location C:\Users\udmin\Desktop\\ed_project Toolchain / IDE MDK-ARM	Min Version	Const generate the main()		
Advanced Settings	/Linker Settings Minimum Heap Size Minimum Stack Size	0x200 0x400			
	Mcu and Firmware Package				
	STM32F4132HTx Firmware Package Name and Versic STM32Cube FW_F4 V1.25.0 Use Default Firmware Location	n itory/STM32Cube_FW_F4_\	V Use latest available variance //1.25.0	Browse	

2. 利用 Keil 添加用户代码

int main (void)	
/* USER CODE BEGIN 1 */	
/* USER CODE END 1 */	
/* MCU Configuration*/	
/* Reset of all peripherals, Initializes the Flash interface and the Systick. * HAL_Init();	7
/* USER CODE BEGIN Init */	
/* USER CODE END Init */	
/* Configure the system clock */ SystemClock_Config();	
/* USER CODE BEGIN SysInit */	
/* USER CODE END SysInit */	
<pre>/* Initialize all configured peripherals */ MX_GPIO_Init(); MX_USART3_UART_Init(); MX_USB_OTG_FS_PCD_Init(); /* USER_CODE_BEGIN_2_*/</pre>	
/* USER CODE END 2 */	
<pre>/* Infinite loop */ /* USER CODE BEGIN WHILE */ while (1) { (</pre>	
/* USER CODE END WHILE */	
/* USER CODE BEGIN 3 */	
/* USER CODE END 3 */	

利用 Keil 打开工程以后,打开 main.c,这里是程序的入口。可以发现 STM32cube 已经帮我们完成了关于 LED 引脚的初始化,并且在下方留出了空间让用户添加用户代码。

我们在 while 循环内添加如下语句, 意为 LED 所在的口输出高电平, 延时 500ms, 之后输出低电平, 再延时 500ms。

HAL_GPIO_WritePin(LD1_GPIO_Port,LD1_Pin,GPIO_PIN_SET); HAL_GPIO_WritePin(LD2_GPIO_Port,LD2_Pin,GPIO_PIN_SET); HAL_GPIO_WritePin(LD3_GPIO_Port,LD3_Pin,GPIO_PIN_SET); HAL_Delay(500);

HAL_GPIO_WritePin(LD1_GPIO_Port,LD1_Pin,GPIO_PIN_RESET); HAL_GPIO_WritePin(LD2_GPIO_Port,LD2_Pin,GPIO_PIN_RESET); HAL_GPIO_WritePin(LD3_GPIO_Port,LD3_Pin,GPIO_PIN_RESET); HAL_Delay(500);

利用图示的两个按钮进行编译和代码烧录。

🕎 C:\Users\admin\Desktop\led_project\led\MDK-ARM\led.uvprojx - μVision [Non-Commercial Use License] File Edit View Project Flash Debug Peripherals Tools SVCS Window Help 📄 💕 🛃 🗿 🐰 🖻 🖺 🌱 (°) |◆| ⇒ | 陀 陰 陰 殷 | 課 課 准 版 | 🖄 🍪 🔛 🎬 😻 🕶 🔜 🔤 Ied 🖂 🐔 击 💠 🐡 幽 Project д 🔀 main.c 📄 main.h stm32f4xx_hal_gpio.h 🖃 🔧 Proje t: led 61 /* USER CODE BEGIN 0 */ 🖮 😓 le🕴 62 /* USER CODE END 0 */ 63 in Application/MDK-ARM 64 🚸 CMSIS 65 -/** in Application/User/Core * @brief The application entr 66 🗄 📄 main.c 67 * @retval int 68 L */ ⊕ it.c 69 int main(void) im stm32f4xx_hal_msp.c 70 🖂 { Drivers/STM32F4xx_HAL_Driver /* USER CODE BEGIN 1 */ 71 Drivers/CMSIS 72 73 /* USER CODE END 1 */ 74

4.5 实验结果



代码烧录完成之后,按动开发板右下角的 RESET 按钮即可开始运行程序,可见 LED1、LED2、LED3 开始闪

第五章 按键输入实验

5.1 实验目的

- 1. 学习按键的检测原理
- 2. 实现对 Nucleo-144 开发板按键的控制
- 3. 学会使用 STM32CubeMX 工具配置 GPIO

5.2 实验内容

检测用户按键是否按下并通过对 GPIO 口拉高或拉低,实现对 LED 状态的控制

5.3 实验要求

Nucleo-144 上按下按键可以改变 LD1 的亮灭状态

5.4 实验步骤

1. 利用 STM32CubeMX 生成模板代码

MX STM32CubeMX Untitled

第一步,首先打开 STM32CubeMX 工具,点击如图所示的按钮新建工程。

STM32 CubeMX	File	Window	Help	
Home	New Project Ctrl-I	N		
Existing Projects	Load Create a New Pro Import Project Ctrl- Save Project Ctrl- Save Project As Ctrl-	ject S		New Project
Onen Evisting Projects	Close Project Generate Report Ctrl-1	2		
Open Existing Projects	Exit Ctrl-	▶ <	Ľď	l need to :
				Start My project from MCU ACCESS TO MCU SELECTOR
				Start My project from ST Board
				Start My project from Example

第二步,直接选择对应的 NUCLEO-144 开发板,完成基本配置。



第三步,创建工程后填写一下的工程信息并对 GPIO 进行配置。

- Project Name: 工程名任意即可,这里填写 key。
- Project Location: 工程路径,建议新建空文件夹专门存放所有的工程文件,注意路径中不要出现中文字符。
- Toolchain/IDE: 这里选择我们已经安装好的 Keil5,工具链(Toolchain)选择 MDK-ARM,版本号选择 V5。
- 取消勾选 Use latest available version,选择 V1.25.0。
- 点击 Pinout&Configuration,在芯片引脚图中可以看到 PC13 已经被初始化为用户按键(蓝色按键 B1)的 IO 口, 修改其为 GPIO_Input,



查阅 Nucleo-144 的数据手册可以知道 B1 的电平状态很明确,因此在 Configuration 中不需要设置上拉或下拉电 阻,在这里可以设置 User Label 为 B1,方便后面的程序编写。



STM32C	CubeMX Unti	tled*: STM	132F413ZH1	Tx NUCLEO-F4	413ZH												\times
STM32 CubeMX		I	File	W	indow	Help							19	f		X	57
Home >	STM32F413ZF	HTx - NUC	LEO-F413	Untitled - F	Pinout & Con	nfigura								GENERAT	ECODE		
	Pinout & C	onfigurati	ion		Clock C	Configuratio	'n		Proj	ect Manag	jer				Tools		
					✓ Softwar	e Packs		 Pinout 									
Q	~ Ø	1			GPIO Mode a	and Configuration	n					🛄 Pino	ut view	Syste	m view		
Categories	A->Z				Confi	guration				í l			PE2				
System Co	ore 🗸	Group B	y Peripherals						\sim				PE3	•			Í
	÷	Selo) 😔 Single	e Mapped Signal:	s 📀 RCC	📀 SYS 🛛 📀	USART	USB					PE4				
DMA													PE6				
GPIO		Search	Signals										VBAT				
NVIC								Show only I	Aodified Pins			B aa aaaaa	B1 PC13				
A RCC		Pin Name	e 🗢 Signal on	Pin GPIO outpu	GPIO mode	GPIO Pull	Maximum	User Label	Modified			RCC_0SC32_	UT PC14.				
	3	PB0	n/a	Low	Output Pus.	No pull-up	Low	LD1 [Green]	✓				PFO				
	0	PB7	n/a	Low	Output Pus.	No pull-up	Low	LD2 [Blue]	~				PF1				
		PB14	n/a	Low	Output Pus.	No pull-up	Low	LD3 [Red]	✓				PF2				
Analog	>	PC13	n/a	n/a	Input mode	No pull-up	n/a	B1	V				PF3				
Analog		PG6	n/a	Low	Output Pus.	No pull-up	Low	USB_Powe	\checkmark				PF4				
Timers	>	PG7	n/a	n/a	Input mode	No pull-up	n/a	USB_Over					PF5				
													VSS				7 8
Connectivit	ty >												PF6				
Multimedia	a >	PC13 Co	onfiguration : -										PF7				
					_								PF8				
Security	>	GPIO m	iode		l l	nput mode			~				PF9 PF10				
Computing	g >	GPIO PI	ull-up/Pull-dov	vn		No pull-up and p	o pull-down					м	CO PHO				
	<pre></pre>		an apri an aor		Ľ	to pair up and n						RCC_OSC_O	UT PH1				
windleware	e /	User La	bel		E	31							NK51				
										Œ	53	Q					Q B1

其余保持默认,点击右上角的 GENERATE CODE 生成 Keil 工程。

2. 利用 Keil 添加用户代码

工程建好后可以点击 open project,或者利用 Keil 打开工程以后,打开 main.c,这里是程序的入口。

Project 📮 🔀	main.c
🖃 😤 Project: botton	1 /* USER CODE BEGIN Header */
🖃 🚂 botton	2 ⊟/**
⊕ ⊇ Application/MDK-A ↓ CMSIS	3 ************************************
🖃 🦾 Application/User/C	
main.c	7 * @attention
stm32f4xx_it.c	8 *
stm32f4xx_hal_r	9 * <n2><center>©: Copyright (c) 2020 SIMicroelectronics.</center></n2>
Drivers/STM32F4xx_	10 * All Fights reserved. (/ Center // hz)
Drivers/CMSIS	12 * This software component is licensed by ST under BSD 3-Clause license,
	13 * the "License"; You may not use this file except in compliance with the
	14 * License. You may obtain a copy of the License at:
	15 * opensource.org/licenses/BSD-3-Clause
	16 *
	19 /* USER CODE END Header */
	20 /* Includes*/
	21 #include "main.h"
	23 /* Private includes
	24 /* USER CODE BEGIN Includes */
	20 / OSER CODE END INCIDUES -/
🔚 Pr 🌀 B {} F 🛛 🕁 Te	

可以发现 STM32cube 已经帮我们完成了关于按键引脚的初始化。


我们在 while 循环内添加如下语段,通过检测 IO 口的是否呈现高电平来检测按键是否被按下。

由于开发板上已经做了硬件消抖,这里就不再做更多的处理。添加 1000ms 的延时为避免多次触发同一次按 注: 动。

if ((HAL GPIO ReadPin(B1 GPIO Port,B1 Pin))==1) HAL GPIO TogglePin(LD1 GPIO Port,LD1 Pin); HAL Delay(1000);

利用图示的两个按钮进行编译和代码烧录。



🜃 C:\Users\admin\Desktop\led_project\led\MDK-ARM\led.uvprojx - µVision [Non-Commercial Use License]

5.5 实验结果

代码烧录完成之后,按动开发板右下角的 RESET 按钮即可开始运行程序,可以观察到,按下按键,LD1亮, 再次按下按键,松开,LD1 灭,如此循环。

第六章 串口通信实验

6.1 实验目的

- 1. 学习串口与上位机的通信原理
- 2. 实现对 Nucleo-144 开发板串口的控制

6.2 实验内容

通过调用串口的发送功能,实现串口与上位机的通信

6.3 实验要求

Nucleo-144 上能够向上位机发送自定义的字符串;

6.4 实验步骤

1. 利用 STM32CubeMX 生成模板代码

STM32 CubeMX	File		Window	Help					
Home	New Project	Ctrl-N							
	Load Create a New	v Projec	at						
	Import Project	Ctrl-I							
Existing Projects	Save Project	Ctrl-S			New Project				
Existing Projecto	Save Project As	Ctrl-A							
	Close Project								
	Generate Report	Ctrl-R		_					
Open Existing Projects	Recent Projects	•	•	La l	I need to :				
	Exit	Ctrl-X							
					Start My project from MCII				
					ACCESS TO MCU SELECTOR				
					Start My project from ST Board				
					ACCESS TO BOARD SELECTOR				
					Start My project from Example				

第二步,直接选择对应的 NUCLEO-144 开发板,完成基本配置。

	Features	Large Picture	Docs & Resources	🛃 Datasheet	☐1 Buy	🕞 Start Project
Commercial NUCLEO-F413ZH ~	*					
Vendor Y		S		ClassB Partner Program		
Check/Uncheck All		Rea	dy Ready	Ready		
STMicroelectronics						
Type >		Build	d your certified s	afety system		
MCU/MPU Series >		with	STM32 and STM	I8	A77	
Other >						
Other > Peripheral >	Boards List: 1 item					🕂 Expor
Other > Peripheral >	Boards List: 1 item	Overview X Co	nmercial Part No 🍵 👔	Type X Marketing St	atus X Unit Price (U	① Expor
Other > Peripheral >	Boards List: 1 item	Overview X Co	nmercial Part No	Type X Marketing St 144 Active	atus 🗙 Unit Price (U 19.0	Expore St) × Mounted Device STM32F413ZHTx
Other > Peripheral >	Boards List: 1 item	Overview X Co	mmercial Part No 1	Type X Marketing St 44 Active	stus X Unit Price (L 19.0	Expore STM32F413ZHTx

第三步,创建工程后填写一下的工程信息。

Project 栏目:

- Project Name: 工程名任意即可,这里填写 UART。
- Project Location: 工程路径,建议新建空文件夹专门存放所有的工程文件,注意路径中不要出现中文字符。
- Toolchain/IDE: 这里选择我们已经安装好的 Keil5,工具链(Toolchain)选择 MDK-ARM,版本号选择 V5。
- 取消勾选 Use latest available version,选择 V1.25.0。

🚾 STM32CubeMX Un	titled*: STM32F413ZHTx	1								- 6	
STM32	File	Window	Help					1	f 🖸	⊻ ⊁	: 57
Home STM32F4	413ZHTx 🔰 Untitled - I	Project Manager >						GEI	IERATE CODE		
Pinou	t & Configuration		Clock Configur	ation		Project Manager			Tools		
Q Project	Project Settings Project Name UART Project Location D:\elec_system_design\tem Application Structure	plate\		Browse							
Code Generator	Advanced Toolchain Folder Location D:\elec_system_design\tem Toolchain / IDE MDK-ARM	plate\UART\ Min Version / V5 ~	ot generate the main()	der Root							
Advanced Settings	Linker Settings Minimum Heap Size Minimum Stack Size	bx200									
	Mcu and Firmware Package Mcu Reference	8									
	STM32F413ZHTx Firmware Package Name ar STM32Cube FW_F4 V1.25 Use Default Firmware Lo C/Usen/tianie//STM32Cube	nd Version .0 V Use ocation #/Repository/STM32Cube	latest available version FW_F4_V1.25.0	Browse							
MCUs Selection Ou	tput										ſ
🔁 o , 😁 🍨	Series	Li STM32F413/423	nes	STM32F413ZHJ×	Mcu	UFBGA144	Package	None	Required Peri	pherals	-

Code Generator 栏目:

- 勾选第一项,可以将外设的初始化函数等生成单独的".h"、".c"文件,避免函数全部放到 main.c 里面。

KTM32CubeMX uart3.ioc*: STM32F413ZHTx NUCLEO-F413ZH



2. 利用 Keil 添加用户代码并烧录

第一步,编写用户代码

i s c	nt main (void)
[/* USER CODE BEGIN 1 */
	/* USER CODE END 1 */
	/* MCU Configuration*/
	/* Reset of all peripherals, Initializes the Flash interface and the Systick. */ ${\tt RAL_Init()}$;
	/* USER CODE BEGIN Init */
	/* USER CODE END Init */
	/* Configure the system clock */ SystemClock_Config();
	/* USER CODE BEGIN SysInit */
	/* USER CODE END SysInit */
	/* Initialize all configured peripherals */ MX_GFIO_Init(); MX_USART3_UART_Init(); MX_USB_GT_FS_FCD_Init(); /*_USER_CODE_BEGIN_2_*/
	/* USER CODE END 2 */
Ξ	<pre>/* Infinite loop */ /* USER CODE BEGIN WHILE */ while (1) { /* USER CODE END WHILE */</pre>
	/* USER CODE BEGIN 3 */ }
}	/* USER CODE END 3 */

利用 Keil 打开工程以后, 打开 main.c, 这里是程序的入口。可以发现 STM32cube 已经帮我们完成了关于 UART 的初始化, 并且在下方留出了空间让用户添加用户代码。

在 Include 处 (21 行), 添加如下头文件

#include "stdio.h"

在 main 函数上方, 添加如下语段, 完成对 printf 函数的重定向。

#ifdef __GNUC__

/* With GCC, small printf (option LD Linker->Libraries->Small printf
 set to 'Yes') calls __io_putchar() */
#define PUTCHAR_PROTOTYPE int __io_putchar(int ch)
#else
#define PUTCHAR_PROTOTYPE int fputc(int ch, FILE *f)
#endif/* __GNUC__ */

PUTCHAR_PROTOTYPE

{

/* Place your implementation of fputc here */
/* e.g. write a character to the USART3 and Loop until the end of transmission */
HAL_UART_Transmit(&huart3, (uint8_t *)&ch, 1, 0xFFFF);

return ch;

};

在 main 函数的 while 循环内,添加如下语段

printf("seu\r\n");

修改完成后的效果如下所示

```
#ifdef
          GNUC
#Inder ___GNOC___
/* With GCC, small printf (option LD Linker->Libraries->Small printf
set to 'Yes') calls __io_putchar() */
#define PUTCHAR_PROTOTYPE int __io_putchar(int ch)
#else
#define PUTCHAR_PROTOTYPE int fputc(int ch, FILE *f)
#endif /* __GNUC__ */
PUTCHAR_PROTOTYPE
 /* Place your implementation of fputc here */
  /* e.g. write a character to the USART3 and Loop until the end of transmission */
 HAL_UART_Transmit(&huart3, (uint8_t *)&ch, 1, 0xFFFF);
 return ch;
1:
int main(void)
 /* USER CODE BEGIN 1 */
 /* USER CODE END 1 */
 /* MCU Configuration-----
  /* Reset of all peripherals, Initializes the Flash interface and the Systick. */
 HAL Init();
  /* USER CODE BEGIN Init */
 /* USER CODE END Init */
  /* Configure the system clock */
 SystemClock_Config();
  /* USER CODE BEGIN SvsInit */
  /* USER CODE END SysInit */
  /* Initialize all configured peripherals */
 MX_GPIO_Init();
  MX_USART3_UART_Init();
 MX USB OTG FS PCD Init();
  /* USER CODE BEGIN 2 */
  /* USER CODE END 2 */
  /* Infinite loop */
  /* USER CODE BEGIN WHILE */
while (1)
  {
    /* USER CODE END WHILE */
   printf("seu\r\n");
    /* USER CODE BEGIN 3 */
  /* USER CODE END 3 */
```

第二步,利用图示的两个按钮进行编译和代码烧录。

🜃 C:\Users\admin\Desktop\led_project\led\MDK-ARM\led.uvprojx - μVision [Non-Commercial Use License]



File Edit View Project Flash Debug Peripherals Tools SVCS Window Help

打开串口调试助手 XCOM V2.0, 按照在 STM32CubeMX 里面查看的串口参数进行对应设置

- Baud Rate: 波特率, 波特率表示每秒钟传送的码元符号的个数, 是衡量数据传送速率的指标, 它用单位时间内载波调制状态改变的次数来表示。这里选择 115200
- Word Length:数据长,这里选择 8bits
- Parity:奇偶校验,分为 无、奇校验、偶校验 三种,这里选择无
- Stop:停止位,分为 1、1.5、2 三种,这里选择 1

B2		File	Window	Help		🧐 f	🕨 🎽 🔀 🗖
ne 🔪	STM32F413ZHTx	- NUCLEO-F413ZH	> uart3.ioc - Pinout	t & Configuration >		GENERATE	CODE
	Pinout & Configu	uration	Clock Con	figuration	Project Manager		Tools
			✓ Software Pa	ncks 🗸 🗸	Pinout		
	~	0			USART3 Mode and Configuration		
eaorie:	A->Z				Mode		
QUA	USPI	Mode Asyroc	ropous				~
SDIC)	Widde Prayrich					•
SPIT		Hardware Flo	w Control (RS232) Disabl	e			~
SPI3							
SPI4					Configuration		
SPIS		Reset Config	uration				
	T4 T5						
UAR	13	🛛 🛛 Parameter S	ettings 🛛 🤡 User Const	ants 🛛 🥝 NVIC Settings	🥑 DMA Settings 🛛 🤡 GPIO Settings		
UAR	Т8	Configure the bel	w parameters :				
UAR	Т9	Q Search (CrtI+	7 © 0				
UAR	T10	 Basic Parameter 	eters				
USA	RT1 PT2	Baud	Rate		115200 Bits/s		
USA	RT3	Word	Length		8 Bits (including Parity)		
USA	RT6	Parity Stop F	lite		None 1		
	_OTG_FS	Advanced Pa	ameters				
		Data [Direction		Receive and Transmit		
ultime	dia	> Over S	ampling		16 Samples		
curity		 >					
mput	na	>					

XCOM V2.0	-		×
^	串口选择		
	COM3:USB-	SERIAL	\sim
	波特率	115200	\sim
	停止位	1	\sim
	数据位	8	\sim
	奇偶校验	无	\sim
	串口操作	💓 关闭	串口
	保存窗口	清除措	ン
	🗌 16进制	記示□ 白頂	潶字
	RTS	🗌 DTR	
~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~	🗌 时间戳((以换行回车	睡师贞)
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	1	发送	
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□ 定时发送 周期: 1000 ms 打开文件	发送文件	停止发	送
□ 16进制发送 □ 发送新行 0% 开源电子 P	∃: www.op	penedv. c	om
☑ ▼ www.openedv.com S:0 R:0 CTS=0 DSR=0 DCD=0 ≥	当前时间 11:5	52:44	.::

6.5 实验结果

XCOM V2.0	_		×
seu A	串口选择		
seu seu	COM13:USB-	SERIAL	~
260 260 260	波特率	115200	~
seu seu	停止位	1	~
Sen Sen	数据位	8	~
seu seu	奇偶校验	无	~
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seu seu			
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sen Antonio An Antonio Antonio		 以换行回车	:断帧)
单条发送 多条发送 协议传输 帮助			
开源电子网:www.openedv.com	1	发送	:
	~	清除发	送
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	当前时间 20:5	8:08	

可以看到 Nucleo-144 在不断向串口助手输出 seu 的字样。

第七章 外部中断实验

7.1 实验目的

- 1. 学习外部中断的原理
- 2. 利用外部中断实现 Nucelo-144 按键的控制

7.2 实验内容

按键按下时触发外部中断,以此控制 LED 闪烁状态

7.3 实验要求

LED 根据按键状态进行闪烁

7.4 实验步骤

1. 利用 STM32CubeMX 生成模板代码

STM32 CubeMX	File		Window	Help					
Home	New Project	Ctrl-N							
	Load Create a New	w Proje	ct						
	Import Project	Ctrl-I							
Existing Projects	Save Project	Ctrl-S		New Project					
	Save Project As .	Ctrl-A							
	Close Project								
	Generate Report	Ctrl-R		_					
Open Existing Projects	Recent Projects		•	<u>L</u> a	I need to :				
	Exit	Ctrl-X							
					Start My project from MCU				
					ACCESS TO MCU SELECTOR				
					Start My project from ST Board				
					ACCESS TO BOARD SELECTOR				
					Start My project from Example				

第二步,直接选择对应的 NUCLEO-144 开发板,完成基本配置。

🌟 🗟 🖾 🌖	Features	Large Picture	Docs & Resources	🔄 Datasheet	📑 Buy	Start Project
Commercial NUCLEO-F413ZH ~	*					
Vendor V		SI SI		Partner Program		
Check/Uncheck All		Rea	dy Ready Re	ady		
STMicroelectronics		~				
Туре		Build	d your certified sat	tety system		
MCU/MPU Series >		with	STM32 and STM8		~7 /	
Other >						
Devicebergel	Boards List: 1 item					📤 Export
Penpheral /	*	Overview X Cor	nmercial Part No Type	× Marketing St	atus X Unit Price (L	IS\$) × Mounted Device
renprerar 2					10.0	STM32F4137HTx
Penpnerai /	☆	NUC	LEO-F413ZH Nucleo-144	Active	19.0	
Penpnerai /	☆	NUC	LEO-F413ZH Nucleo-144	Active	19.0	

可以看到已经为我们将 PC13 初始化为外部中断模式,其中各参数含义如下:

GPIO Mode: External Interrupt Mode with Rising edge trigger detection 外部中断模式,上升沿触发
 GPIO Pull-up/Pull-down: No pull-up and no pull-down 既不使能上拉,也不使能下拉

STM32CubeMX U	Intitled*: ST	M32F413ZHTx NUCLEO-F4132	н											- 🗆 X
STM32		File	Window	He	lp								🐵 F 🕨 🎽	> 🛧 🖅
Home STN	I32F413Z⊢	ITx - NUCLEO-F413ZH	Untitled - Pi	nout & Configu	ration >								GENERATE CODE	
	Pinou	it & Configuration			Clock Conf	iguration			Project	Manager			Tools	
					🗸 Sof	tware Packs	~	Pinout						
Q	~ 🔕			GPIO Mode and	Configuration						🛱 Pinout view	👯 System view		
Categories A->	Z			Configura	ation			í –						
System Core	\sim	Group By Peripherals					\sim							
÷		🕑 GPIO 🛛 📀 Single Ma	ıpped Signals 🛛 🥝 I	RCC 📀 SYS	🕑 USART 🛛 😔 USB	B 📀 NVIC				[green	8		,	
DMA GPIO		Search Signals										# = 8 o b e o e e e e		
IWDG		Search (CrtI+F)				Show only	Modified Pins		<u>91</u>		2 2 2 2 2 2 2 3 2 2 2	2 2 2 2 2 2 2 2 3 2 2 2 1		
A RCC		Pin Name Signal on	Pin GPIO output I	GPIO mode G	PIO Pull-up/ Maximu	mout Userlabel	Modified		PE3				VSS.	
✓ SYS		PB0 n/a	Low	Output Push N	o pull-up an Low	LD1 [Green]			PE5				RA13 5 TMS RA17 5 USB_DP	
WWDG		PB7 n/a	Low	Output Push N	o pull-up an Low	LD2 [Blue]	\checkmark		USER BILIET				PA11 USB_DW	
		PB14 n/a	Low	Output Push N	o pull-up an Low	LD3 [Red]			RCC_06C32_N				PAGE USE VE	125
Analog	>	PG6 n/a	Low	Output Push N	o pull-up an Low	USB PowerS			RCC_OSC32_OUT DOING				P09	F(TP1)
Timere	>	PG7 n/a	n/a	Input mode N	o pull-up an n/a	USB_OverCu	~		PF1				PC8	
									PT3				PC6	
Connectivity	>								P75				V85	
Multimedia	>								ND0				P07 US8_0v	erCurrent (STMPS2151STR_FAULT) worSwitchCn (STMPS2151STR_EN)
Security	>								PF7 PF8				P06	
									PF0				PG3	
Computing	>								NCO PIO				PD15	
Middleware	>	PC13 Configuration :							NRST.		0714005	4407117.	VCD	
		Ŭ							PG1		STM32F	413ZHIX	P013	
									PC3				PD11	
									VDD VSSA		LQF	17 1 44	POTO STLK_D	K (STM32F103C816_PA2)
									VIDEA				Pot STLK_RO	1 (STM32F103CBT6_PA3)
		GPIO mode	Exte	ernal Interrupt Mode	e with Rising edge trigg	er detection			PA0 PA1				P814 CD3 (Red P813	4
		GPIO Pull-up/Pull-down	No	oull-up and no pull-	down		+	-	PA2 2					
		User Label	USE	R_Btn [B1]							5			
									€ []	ର୍ 🕒	4 01	Q		~
		<u></u>						_						

第三步,在 NVIC 界面使能中断

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		File	Window	Help			💿 🖪 🗖 🎽 🔆 🖅
Home > STM	32F413ZHT	x - NUCLEO-F413ZH	EXIT.ioc - Pinout	& Configuration >			GENERATE CODE
	Pinout	& Configuration		Clock Configurati	on	Project Manager	Tools
				✓ Software F	Packs 🗸 F	Pinout	10
Q Categories A->Z	✓ ⁽⁰⁾		GPIC	O Mode and Configuration		Pinout view	System view
System Core	~	Group By Peripherals		Comiguration	\sim		ľ
÷		📀 GPIO 🛛 📀 Single Mapp	ed Signals 😔 RCC	📀 SYS 😔 USART 😔 USB 😔 N	VIC	i lipe	
DMA GPIO	- 1	NVIC Int EXTI line[15:10] interrupts	errupt Table	Enabled Preemption Pr	iority Sub Priority 0		5 5 5 6 8 8 8 4 8 8 8 8 8 8 5 5 5 5 5 5 5 5 5 5
IWDG NVIC						F22 *	VCO VSS
▲ RCC ✓ SYS						P04 P05	VCL. 2011 7755 2012
WWDG							asu <mark>asus</mark> asu <mark>asus</mark>
Analog	>					RCC_04C22_04 R0511 RCC_04C22_OUT P00	200 _ CSB _ Vecs 200 _ USB_SCF(1P1) 200
Timers	>					PT.	PC8
Connectivity	>					72.00 72.00 72.00	V00. V33
Multimedia	>					vos.	P08
Security	>					470 970 970	Pios Pios Pios
Computing	>					900 m	Pag Pag 2000
Middleware	>					RCC_OBC_OUT PHIL	P04
						STM32F	413ZHTx 🚟
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	_						

第四步,填写以下工程信息。

Project 栏目:

- Project Name: 工程名任意即可,这里填写 EXTI。
- Project Location: 工程路径,建议新建空文件夹专门存放所有的工程文件,这里新建了 EXTI 文件夹。注意路 径中不要出现中文字符。

o ×

- Toolchain/IDE: 这里选择我们已经安装好的 Keil5,工具链(Toolchain)选择 MDK-ARM,版本号选择 V5。
- 取消勾选 Use latest available version,选择 V1.25.0。

	CTM22CubaNX Uptitlads: CTM22E4127UTy NUCLEO E4127L
mA	3119132CUDEIVIA UTILITEU", 3119132F4132F11X NUCLEU-F4132F

STM32 CubeMX	File	Window Help		💿 🖪 🖻 🄰 🔆 🏹
Home 🔰 STM32F	413ZHTx - NUCLEO-F413ZH	VIntitled - Project Manager		GENERATE CODE
Pinout & (Configuration	Clock Configuration	Project Manager	Tools
Project	Project Name EXIT Project Location D:\elec_system_design\templat Application Structure	e\ Browse		
Code Generator	Advanced Toolchain Folder Location D:\elec_system_design\templat Toolchain / IDE Min Vi MDK-ARM V V5			
Advanced Settings	Linker Settings Minimum Heap Size 0x200 Minimum Stack Size 0x400			
	Mcu and Firmware Package Mcu Reference STM32F413ZHTx Firmware Package Name and V STM32Cube FW_F4 V1.25.0	ersion		S # · • • • = * * *

Code Generator 栏目:

- 勾选第一项,可以将外设的初始化函数等生成单独的".h"、".c"文件,避免函数全部放到 main.c 里面。

KTM32CubeMX uart3.ioc*: STM32F413ZHTx NUCLEO-F413ZH

STM32



2. 利用 Keil 添加用户代码并烧录

第一步,编写用户代码

int main(void)
/* USER CODE BEGIN 1 */
/* USER CODE END 1 */
/* MCU Configuration*/
/* Reset of all peripherals, Initializes the Flash interface and the Systick. */ ${\tt HAL_Init()}$;
/* USER CODE BEGIN Init */
/* USER CODE END Init */
<pre>/* Configure the system clock */ SystemClock_Config();</pre>
/* USER CODE BEGIN SysInit */
/* USER CODE END SysInit */
<pre>/* Initialize all configured peripherals */ MX_GPIO_Init(); MX_USART3_UART_Init(); MX_USB_OTG_FS_FCD_Init(); /*_USER_CODE_BEGIN_2_*/</pre>
/* USER CODE END 2 */
<pre>/* Infinite loop */ /* USER CODE BEGIN WHILE */ while (1) {</pre>
/* USER CODE END WHILE */
/* USER CODE BEGIN 3 */
- } /* USER CODE END 3 */ }

利用 Keil 打开工程以后, 打开 main.c, 这里是程序的入口。在 MX_GPIO_Init 函数内已经为我们初始化好了按 键的外部中断。

在 USER CODE BEGIN 4 处(158 行), 添加如下语句:

```
void HAL_GPIO_EXTI_Callback(uint16_t GPIO_Pin)
{
      if (GPIO_Pin == GPIO_PIN_13)
  {
    /* Toggle LED1 */
```

第二步,利用图示的两个按钮进行编译和代码烧录。

🔢 C:\Users\admin\Desktop\led_project\led\MDK-ARM\led.uvprojx - μVision [Non-Commercial Use License]

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								73		/*	USER	CODE	E END) 1 */		
								74								

7.5 实验结果

} }



按动 B1,即可发现 LED1 状态改变。注意按下按键的时间不要太短,否则可能会因为存在硬件消抖而无法触发外部中断。

第八章 定时器中断实验

8.1 实验目的

- 1. 学习定时器中断的配置方法
- 2. 实现 LED 闪烁频率的设定

8.2 实验内容

通过对定时器预分频值、计时周期的设定,实现 LED 不同频率的闪烁

8.3 实验要求

Nucleo-144 上 LD1、LD2 分别以 500ms、1000ms 的时间间隔改变状态

8.4 实验步骤

1. 利用 STM32CubeMX 生成模板代码

STM32CubeMX Untitled

第一步,首先打开 STM32CubeMX 工具,点击如图所示的按钮新建工程。

STM32	File	,	Window	Help	
Home >	New Project 0	Ctrl-N			
	Load Create a New I	Projec	t		
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					ACCESS TO MCU SELECTOR
					Start My project from ST Board
					ACCESS TO BOARD SELECTOR
					Start My project from Example

第二步,直接选择对应的 NUCLEO-144 开发板,完成基本配置。



在定时器配置界面内配置 TIM3,并将时钟源修改为内部时钟。

f 🚾 STM32CubeMX Untitled*:	STM32F446ZETx NUCLEO-F446ZE					– – ×
STM 32	File	Window	Help			💿 🖪 🗗 🎽 🔆 🔙
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	3	TIM3 M	✓ Software Packs ode and Configuration	~	Pinout @ Pinout view	## System view
Q ✓ Image: Apple of the system Core Analog > Analog > Timers ✓ RTC TM41 TM45 TM45 TM46 TM46 TM47 TM48 TM410 TM410 TM411 TM410 TM413 TM412 TM414 Connectivity Multimedia >	Stave Mode Disable Trigger Source Disable Clock Source Internet Disable Channet Disable Channet Disable Channet Disable Channet Disable Channet Disable Channet Disable Combined Channets Disable Combined Channets Disable One Pulse Mode Reset Configuration One Pulse Mode Reset Configuration Oranger the bolicy parameters Configure the bolicy parameters	TIMS M	de and Configuration Mode Configuration Configuration C Sattings			Provide a constraint of the second se
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修改 TIM3 时钟参数:

- Prescaler: 预分频系数,这里应填写 9599,将 96Mhz 的时钟分频为约 10000hz
- Counter Period: 计数周期,这里填写 4999,使得定时器约 500ms 产生一次中断
- auto-reload period:开启自动装载,定时器将在产生中断后继续重新计数



在中断配置界面将 TIM3 中断开启。

🖞 🛄 STM32CubeMX U	ntitled*: STN	132F446ZETx NUCLEO-F446ZE									- 0	×
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÷		Channel2 Disable			~		P62 0			VD		
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TIM4 TIM5		Use ETR as Clearing	Source			RCC_08C32_IN RCC_08C32_OUT	1014 1015			940 - USB 948 - USB	_VBUS _SOF(TP1)	
TIM6		XOR activation					PF1			PC9		
		One Pulse Mode					992		_	PC7 PC6		
TIM9 TIM10							PF5			VSS		
TIM11							VD0			Part Use Part Vuse	OverCurrent (STMP52151STR_FAULT) PowerSwitchOn (STMP52151STR_EN	
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U 11/01/14		Reset Configuration					7710			P03		Ш
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						€ [] Q 🕒	4	Q		~	
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修改 TIM4 时钟参数:

- 时钟源修改为内部时钟
- Prescaler: 预分频系数,这里应填写 9599,将 96Mhz 的时钟分频为约 10000hz

Counter Period: 计数周期,这里填写 9999,使得定时器约 1000ms 产生一次中断
auto-reload period: 开启自动装载,定时器将在产生中断后继续重新计数

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			✓ Software Packs	✓ Pinout		
Q ~ Ø		TIM4 Mode a	nd Configuration		@ Pinout view	🗴 🛗 System view
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	Channel2 Disable			~	162 ·	
LPTIM1	Channel3 Disable			~	PE3 PE4	VSS VCA
RTC	Channels Disable				PES	PA13 _ TMS PA12 _ LUSE OF
TIM1 TIM2	Charliered Observals Disable				VEAT	PATT Suss on
✓ TIM3	Combined Channels Disable					**************************************
		Confi	guration		NGC_05G2_0UT 005	PC8 US8_SOF(1P1)
TIM6	Reset Configuration				PF1 PF2	PC8 PC7
TIM7	🛛 Daramatar Sattinge 🔗 Llear	Constante O MAC Sat	tinge 🔗 DMA Sattinge		PF3	POR
A TIM8 TIM9	Configure the below parameters :		anings Only Countrys			755
TIM10	Search (Cdl+E) O			0		PCIII NOT USB_OverCurrent (STMP521515TR_FAULT)
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TIM12	Prescaler (PSC - 16 bits	value)	9599 🔶		775	POL.
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	Internal Clock Division (C	iad Register - 16 bits value j KD)	No Division			P015
Connectivity >	auto-reload preload		Enable			
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· · · · · · · · · · · · · · · · · · ·	1				VRE	POR STLK_RK (STM22FICECETE_PA3)
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	1					
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						Hannels) E-1

开启定时器4中断。

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		File	Window	Help				🚳 📑 🕒 🖢	/ 🔆 🟹
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	Pinout	& Configuration		Clock Configuration		Project Manager		Tools	
Categories A>Z System Core Analog Timers RTC	> > > ~	Slave Mode Disable Trigger Source Disable Clock Source Internal Channel Disable Channel2 Disable	TIM Diock	✓ Software Packs 4 Mode and Configuration Mode	× × × × × × × × × × × × × × × × × × ×	ि <mark>।</mark> इ.स. हा हा हा हा हा हा	Pinout View P ²¹ System		ţ
TIM1 TIM2 TIM3 TIM5 TIM6 TIM6 TIM7 TIM10 TIM10 TIM11 TIM12 TIM12 TIM13 TIM14	-	Channels Disable Channels Disable Combined Channels Disa Use ETR as Clearing XOR activation One Pulse Mode	ble Source	Configuration	> > >		5		e M D Rođ Rođ Rođ Rođ Rođ Rođ Rođ Rođ Rođ Rođ
Connectivity Multimedia Computing Middleware	> > > >	Paramster Settings NVIC Inter NVIC Inter Interupt	9 User Constants or upt Table	MIC Settings OWA Settings Enabled Preemption Priority Image: Comparison of the set of the s	Sub Priority		STM32F4462 LQFP14		TK (ETMOFYNCHT, PAJ) RY (ETMOFYNCHT, PAJ) RY
						Q [] Q		Q	~

第三步,创建工程后填写一下的工程信息。

- Project Name: 工程名任意即可,这里填写 timer。
- Project Location: 工程路径,建议新建空文件夹专门存放所有的工程文件,这里在桌面新建了 timer 文件夹。注意路径中不要出现中文字符。
- Toolchain/IDE: 这里选择我们已经安装好的 Keil5,工具链(Toolchain)选择 MDK-ARM,版本号选择 V5。
- 取消勾选 Use latest available version,选择 V1.25.0。
- 其余保持默认,点击右上角的 GENERATE CODE 生成 Keil 工程。



2. 利用 Keil 添加用户代码

```
74 int main(void)
75 🖂 {
76
      /* USER CODE BEGIN 1 */
77
78
      /* USER CODE END 1 */
79
      /* MCU Configuration-----*/
80
81
      /* Reset of all peripherals, Initializes the Flash interface and the Systick. */
82
83
      HAL Init();
84
85
      /* USER CODE BEGIN Init */
86
      /* USER CODE END Init */
87
88
89
      /* Configure the system clock */
90
      SystemClock_Config();
91
      /* USER CODE BEGIN SysInit */
92
93
      /* USER CODE END SysInit */
94
95
      /* Initialize all configured peripherals */
96
     MX GPIO Init();
97
     MX TIM3 Init();
98
     MX USART3 UART Init();
99
     MX USB OTG FS PCD Init();
100
     MX TIM4 Init();
101
102
      /* USER CODE BEGIN 2 */
103
      /* USER CODE END 2 */
104
105
      /* Infinite loop */
106
107
      /* USER CODE BEGIN WHILE */
108
      while (1)
109 🚊 - {
       /* USER CODE END WHILE */
110
111
        /* USER CODE BEGIN 3 */
112
113
     ł
      /* USER CODE END 3 */
114
115 }
```

利用 Keil 打开工程以后,打开 main.c,这里是程序的入口。可以发现 STM32cube 已经帮我们完成了关于 LED 引脚的初始化,并且在下方留出了空间让用户添加用户代码。

在 main 函数内 while 上方添加如下语句,开启定时器中断。

HAL_TIM_Base_Start_IT(&htim3); HAL_TIM_Base_Start_IT(&htim4);

在 main 函数结束处下方添加如下语句。

void HAL_TIM_PeriodElapsedCallback(TIM_HandleTypeDef *htim)

{

```
if( htim == &htim3) HAL_GPIO_TogglePin(LD2_GPIO_Port,LD2_Pin);
else if ( htim == &htim4) HAL_GPIO_TogglePin(LD3_GPIO_Port,LD3_Pin);
```

```
}
```

修改完的代码如图

```
74 int main (void)
 75 🖂 {
      /* USER CODE BEGIN 1 */
 76
 77
      /* USER CODE END 1 */
 78
 79
 80
      /* MCU Configuration-----*/
 81
      /* Reset of all peripherals, Initializes the Flash interface and the Systick. */
 82
 83
      HAL Init();
 84
      /* USER CODE BEGIN Init */
 85
 86
 87
      /* USER CODE END Init */
 88
 89
      /* Configure the system clock */
 90
      SystemClock_Config();
 91
      /* USER CODE BEGIN SysInit */
 92
 93
 94
      /* USER CODE END SysInit */
 95
      /* Initialize all configured peripherals */
 96
     MX GPIO Init();
 97
     MX TIM3 Init();
98
     MX USART3 UART Init();
99
100
     MX USB OTG FS PCD Init();
     MX TIM4 Init();
101
      /* USER CODE BEGIN 2 */
102
103
      HAL TIM Base Start IT(&htim3);
    HAL TIM Base Start IT(&htim4);
104
105
      /* USER CODE END 2 */
106
107
     /* Infinite loop */
108
109
     /* USER CODE BEGIN WHILE */
110
     while (1)
111 🚊 - {
112
       /* USER CODE END WHILE */
113
       /* USER CODE BEGIN 3 */
114
115 -
     }
116
      /* USER CODE END 3 */
    }
117
118
119 void HAL TIM PeriodElapsedCallback(TIM HandleTypeDef *htim)
120 🖂 {
    if( htim == &htim3) HAL_GPIO_TogglePin(LD2_GPIO_Port,LD2_Pin);
121
122
     else if ( htim == &htim4) HAL GPIO TogglePin(LD3 GPIO Port,LD3 Pin);
123
    }
124
```

```
利用图示的两个按钮进行编译和代码烧录。
```

🔢 C:\Users\admin\Desktop\timer\timer\MDK-ARM\timer.uvprojx - µVision [Non-Commercial Use License]



8.5 实验结果



代码烧录完成之后,按动开发板右下角的 RESET 按钮即可开始运行程序,可见 LED2、LED3 开始以不同频率闪烁, LED2 每 500ms 改变一次状态, LED3 每 1000ms 改变一次状态。

第九章 PWM 输出实验

9.1 实验目的

- 1. 学习 PWM 原理与应用
- 2. 进一步学习定时器中断的配置方法
- 3. 利用程序改变寄存器 CCRx 的值,产生不同占空比的 PWM 波

9.2 实验原理

Pulse Width Modulation 脉冲宽度调制,简称 PWM。

PWM 对模拟信号电平进行数字编码的方法,计算机只能输出 0 或 5V 的数字电压值而不能输出模拟电压,而 我们如果想获得一个模拟电压值(介于 0 - 5V 的电压值),则需通过使用高分辨率计数器,改变方波的占空比来对一 个模拟信号的电平进行编码。电压是以一种连接(1)或断开(0)的重复脉冲序列被夹到模拟负载上去的,连接即 是直流供电输出,断开即是直流供电断开。通过对连接和断开时间的控制,只要带宽足够,可以输出任意不大于最 大电压值的模拟电压。



我们假定定时器工作在向上计数 PWM 模式,且当 CNT<CCRx 时,输出 0,当 CNT>=CCRx 时输出 1。那 么就可以得到如上的 PWM 示意图:当 CNT 值小于 CCRx 的时候, IO 输出低电平(0),当 CNT 值大于等于 CCRx 的时候,IO 输出高电平(1),当 CNT 达到 ARR 值的时候,重新归零,然后重新向上计数,依次循环。改 变 CCRx 的值,就可以改变 PWM 输出的占空比,改变 ARR 的值,就可以改变 PWM 输出的频率。

9.3 实验内容

本章通过对定时器内部寄存器 CCRx 数值的修改,生成占空比先递增后递减的 PWM,进而控制 LD1,达到呼吸灯的效果

9.4 实验要求

Nucleo-144 上 LD1 能看到暗——亮——暗的循环呼吸效果

9.5 实验步骤

1. 利用 STM32CubeMX 生成模板代码

第一步,首先打开 STM32CubeMX 工具,点击如图所示的按钮新建工程。

MX STM32CubeMX Untitled

STM32	File	Window	Help	
Home	New Project	Ctrl-N		
	Load Create a New	Project		
Existing Projects	Import Project Save Project Save Project As Close Project	CtrI-S CtrI-S CtrI-A		New Project
Open Existing Projects	Generate Report Recent Projects Exit	Ctrl-R	दिव	I need to :
	Law			Start My project from MCU
				Start My project from ST Board ACCESS TO BOARD SELECTOR Start My project from Example

第二步,直接选择对应的 NUCLEO-144 开发板,选择完成基本配置。

rd Filters	lector Cross Selector				
★ 🔂 🛱 ৩	Features Large Picture	Docs & Resources	🛃 Datasheet	📑 Buy	⊡→ Start Project
Commercial NUCLEO-F413ZH ~	STM32F4 Series				
NUCLEO-F413ZH	NUCLEO-F413ZH	STMicroelectronics NUCL	EO-F413ZH Boar	d Support and Ex	amples
/endor	ACTIVE Active	Part Number : NUCLEO-F413ZH		Unit Price (US\$): 19.0	
Check/Uncheck All	Product is in mass production	Commercial Part Number : NUCLEO	-F413ZH	Mounted Device : STM3	32F413ZHTx
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Dther >					
Peripheral >	Boards List: 1 item				📤 Export
	* Overview ×	Commercial Part No 🗢 Type	e X Marketing	Status X Unit Price	(US\$) × Mounted Device
	☆	NUCLEO-F413ZH Nucleo-144	Active	19.0	

在定时器配置界面内配置 TIM3,并将时钟源修改为内部时钟,并选择通道 Channel3,以 PWM 形式输出。

KTM32CubeMX PWM1.ioc: STM32F413ZHTx NUCLEO-F413ZH

FF 🖸 🏏 File Window Help 10 * 47/ Home STM32F413ZHTx - NUCLEO-F413ZH PWM1.ioc - Pinout & Configuration Clock Configuration Project Manager Tools Pinout & Configuration ✓ Pinout Q TIM3 Mode and Configuration 🔯 Pinout view System view ٩ \sim Mode A->Z Slave Mode Disable \sim ▲ RCC ✓ SYS Trigger Source Disable \sim WWDG Clock Source Internal Clock Channel1 Disable Channel2 Disable Analog STM32F4 Channel3 PWM Generation CH3 Timers Channel4 Disable LQFP Combined Channels Disable LPTIM1 RTC Use ETR as Clearing Source TIM1 XOR activation TIM2 One Pulse Mode TIM4 TIM5 V00 946 946 947 947 946 946 946 946 946 946 946 947 947 947 947 15 947 15 TIM6 TIM7 IM3 CH TIM8 TIM9 TIM10 📀 Parameter Settings 🛛 📀 User Constants 🛛 📀 NVIC Settings 🛛 📀 DMA Settings 💿 GPIO Settings TIM11 23 Q ٢ ▲ TIM12 TIM13 Search Signals

σ×

修改 TIM3 时钟参数:

- Prescaler: 预分频系数,这里应填写 95,将 96Mhz 的时钟分频为 1000khz
- Counter Period: 计数周期,这里填写 499,使得定时器产生中断的频率为 2 khz,该频率不可过小
- auto-reload period: 开启自动装载,定时器将在产生中断后继续重新计数
- Mode: 选择 PWM mode1, PWM mode1 与 PWM mode2 的输出电平的极性相反
- Pulse: 通过在程序中修改此数据,改变输出 PWM 的占空比,这里保持默认。

基本计算:

频率= 定时器时钟/ (Prescaler + 1)/ (Counter Period + 1)Hz 占空比= Pulse / Counter Period

STM32CubeMX Ur	ntitled*: STM	32F413ZHTx NUCLEO-F413ZH									– 🗆 X
STM32		File	Window	Help					(1)) 🖪 🗗 🤟	* 5
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	Pinout	& Configuration		Clock Cor	nfiguration		Project Manager			Tools	
				✓ Si	oftware Packs	✓ Pino	ut				
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		Trigger Source Disable				~		2			
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		Channel2 Disable					752			VOD	
LPTIM1		Channel2 DWM C	20 CH2				703			VSS VCA	
RTC		Channels PWW Generatio					P25.			PA13 5 TMS	
TIM1		Channel4 Disable				~	VRAT .			PATT USE ON	
TIM2		Combined Channels Disal	ble			~	USER_801(81) PC11			PA10 USB_ID	
TIM4	_	Use ETR as Clearing	Source				RCC_GSC32_OUT			PAA USB_SOF[TP	н
TIM5		XOR activation					PF0 PF1			PC0 TM3_CH0	
TIM6		One Pulse Mode					772			PCT	
		_					773			VDD.	
TIM9							PT5			V33	
TIM10							VC0			NIT US8_OverCur	writ[STMPS2151STR_FAULT]
TIM11							PP6. PF7			PG6 US8_Power9	witchOn (\$TMPS2151STR_EN)
A IIM12 TIM13				Configuration			PFA			PG4	
TIM14				-			PFID			PG2	
		Reset Configuration								PD15	
		🛛 🛛 Parameter Settings	🔉 User Constants 🛛 📀	NVIC Settings 🛛 📀 DMA Setting	is 😔 GPIO Settings		NEST			VCD	
Connectivity		Configure the below paramete	rs :				PC0.	STM32F	F413ZHTx	V35	
Multimedia	>	Q Search (CrtI+F)	0			0	PC2			PD12	
		✓ Counter Settings				- II-	VED	LQF	-P144	PDIO	
Security	>	Prescaler (PSC - 1	6 bits value)	95			VISA VIS.			PC0 STLK_TX (ST PC0 STLK_RX (ST	M32F103C876_PA2) M32F103C876_PA3)
Commission	· · · ·	Counter Mode	teDelead Desister 16 I	Up			VCCA			Pais	
Computing	I	Internal Clock Divis	sion (CKD)	No Division			PAL			PBIS	
Middleware	>	auto-reload preload	1	Enable						P812	
	_	V Trigger Output (TRGO) Pa	rameters				North Contraction Contraction		International Sector	La Contra	
		Master/Slave Mode	e (MSM bit)	Disable (Trigger input ef	fect not delayed)			e l			
		Ingger Event Selec	ction	Reset (UG bit from TIM)	(_EGR)			9			
		Mode		PWM mode 1							
		Pulse (16 bits value	e)	0							
		Output compare pr	eload	Enable		11	④ [] Q	🕒 🖆 🛙			\sim
	_	Fast Mode		Nicabla							

在中断配置界面将 TIM3 中断开启。

MX STM32Cub	eMX TIMER.ioc:	STM32F413ZHT	Tx NUCLEO-F413ZH								-	o ×
STM32		Fi	le	Window	Help				19	F 🖸 🤰	\checkmark	57
Home >	• STM32F413	ZHTx - NUCL	_EO-F413ZH 🔪	TIMER.ioc - Pine	out & Configuration	n >			GEN	ERATE CODE		
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				✓ Software Page 1	acks	✓ Pinout						
Q	\sim	0				TIM3 N	Node and Configuration					
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			Trigger Source D	isable								~
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L D T I	\$		Channel1 Disable	9								$\overline{}$
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🔥 TIM8			Tilvi3 global interrupt					0		U		
TIM9	0											
TIM1	1											
🔥 TIM1	2											
TIM1:	3											
LIM14	4											
Connecti	ivity	>										

选择 GPIO 口 PB0 为 TIM3_CH3,同时 PB0 能够控制 LD1,这里为复用 PB0 端口



第三步, 创建工程后填写一下的工程信息。

- Project Name: 工程名任意即可,这里填写 PWM。
- Project Location: 工程路径,建议新建空文件夹专门存放所有的工程文件,注意路径中不要出现中文字符。
- Toolchain/IDE: 这里选择我们已经安装好的 Keil5,工具链(Toolchain)选择 MDK-ARM,版本号选择 V5。
- 取消勾选 Use latest available version,选择 V1.25.0。
- 其余保持默认,点击右上角的 GENERATE CODE 生成 Keil 工程。

MX STM32CubeMX PWM1.ioc: STM32F413ZHTx NUCLEO-F413ZH

– 0 ×

	File	Window Hel	р		🐵 🗗 🖻	رجا 🖈 🔰
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Pinout	& Configuration	Clock Configuration		Project Manager	Tool	5
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	May and Eirmyara Daaka			
	Mcu Reference	âs.		
	Firmware Package Name	and Version		
	STM32Cube FW_F4 V1.	25.0 🗸 🗌 Use latest available version		🔁 A 🤫 🙂 🖉 🖁 🖊 🖬

2. 利用 Keil 添加用户代码

```
74 int main (void)
75 🖂 {
76
       /* USER CODE BEGIN 1 */
77
78
       /* USER CODE END 1 */
79
80
       /* MCU Configuration-----
                                                            */
81
       /* Reset of all peripherals, Initializes the Flash interface and the Systick. */
82
83
      HAL_Init();
84
85
       /* USER CODE BEGIN Init */
86
      /* USER CODE END Init */
87
88
       /* Configure the system clock */
89
      SystemClock_Config();
90
91
      /* USER CODE BEGIN SysInit */
92
93
94
      /* USER CODE END SysInit */
95
96
       /* Initialize all configured peripherals */
97
      MX_GPIO_Init();
98
      MX_TIM3_Init();
      MX_USART3_UART_Init();
99
      MX_USB_OTG_FS_PCD_Init();
MX_TIM4_Init();
100
101
      /* USER CODE BEGIN 2 */
102
103
104
       /* USER CODE END 2 */
105
106
       /* Infinite loop */
       /* USER CODE BEGIN WHILE */
107
108
      while (1)
109 🖻
      - {
        /* USER CODE END WHILE */
110
111
        /* USER CODE BEGIN 3 */
112
113
      ł
      /* USER CODE END 3 */
114
115
    }
```

利用 Keil 打开工程以后,打开 main.c,这里是程序的入口。可以发现 STM32cube 已经帮我们完成了关于 LED 引脚的初始化,并且在下方留出了空间让用户添加用户代码。 在 USER CODE BEGIN 1 处,添加如下语句:

uint16_t led0pwmval=0;

在 USER CODE BEGIN 2 处,添加如下语句: HAL_TIM_PWM_Start(&htim3,TIM_CHANNEL_3); /// 使能 tim3 的通道 3 在 USER CODE BEGIN 3 处,添加如下语句: while (led0pwmval< 300) //递增到 300 { led0pwmval++; __HAL_TIM_SetCompare(&htim3, TIM_CHANNEL_3, led0pwmval); //改变比较值,改变占空比 // TIM3->CCR3 = led0pwmval; //与上一行代码作用相同,两者任选其一 HAL_Delay(1); } //再递减到0 while (led0pwmval) { led0pwmval--; __HAL_TIM_SetCompare(&htim3, TIM_CHANNEL_3, led0pwmval); //改变比较值,改变占空比 TIM3 - CCR3 = Ied0pwmval;//与上一行代码作用相同,两者任选其一 // HAL_Delay(1);

```
修改完的代码如图
```

```
int main(void)
- {
   /* USER CODE BEGIN 1 */
    uintl6 t led0pwmval=0;
   /* USER CODE END 1 */
   /* MCU Configuration-----*/
   /* Reset of all peripherals, Initializes the Flash interface and the Systick. */
   HAL Init();
   /* USER CODE BEGIN Init */
   /* USER CODE END Init */
   /* Configure the system clock */
   SystemClock_Config();
   /* USER CODE BEGIN SysInit */
 /* USER CODE END SysInit */
   /* Initialize all configured peripherals */
   MX GPIO Init();
  MX TIM3 Init();
  MX USART3 UART Init();
   MX USB OTG FS PCD Init();
   /* USER CODE BEGIN 2 */
   HAL TIM PWM Start(&htim3,TIM CHANNEL 3);
   /* USER CODE END 2 */
   /* Infinite loop */
   /* USER CODE BEGIN WHILE */
   while (1)
  {
    /* USER CODE END WHILE */
    /* USER CODE BEGIN 3 */
     while (led0pwmval< 300)
Ė
    - {
      led0pwmval++;
      TIM3->CCR1 = pwmVal;
 11
      HAL Delay(1);
     }
     while (led0pwmval)
Ē
     -{
      led0pwmval--;
       ____HAL_TIM_SetCompare(&htim3, TIM_CHANNEL_3, led0pwmval);
       TIM3->CCR1 = pwmVal;
 11
      HAL_Delay(1);
     }
   }
   /* USER CODE END 3 */
 1
```

利用图示的两个按钮进行编译和代码烧录。

🔢 C:\Users\admin\Desktop\timer\timer\MDK-ARM\timer.uvprojx - µVision [Non-Commercial Use License]

File Edit View Project Flash Debug Peripherals	Tools SVCS Window Help
🗋 😂 🛃 🐉 🐰 🛍 隆 😽 🛀 隆	隐隐隐; 律律/////////////////////////////////
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Project 🗸 🗸 🖾	main.c
🖃 쓚 Project: timer	73 4/
🗄 🚂 timer	74 int main(void)
 Application/MDK-ARM startup_stm32f446xx.s Application/User/Core main.c stm32f4xx_it.c stm32f4xx_hal_msp.c Drivers/STM32F4xx_HAL_Driver Drivers/CMSIS CMSIS 	75 □ { 76
	87 /* USER CODE END Init */

9.6 实验结果

代码烧录完成之后,按动开发板右下角的 RESET 按钮即可开始运行程序,可见 LD1 开始以呼吸灯的形式进行闪烁。

第十章 DAC 实验

10.1 实验目的

- 1. 学习 DAC 模块的工作原理
- 2. 实现对 Nucleo-144 开发板 DAC 模块的控制
- 3. 学会使用 STM32CubeMX 工具配置 DAC

10.2 实验原理

STM32F4 的 DAC 模块(数字/模拟转换模块)是 12 位数字输入,电压输出型的 DAC。DAC 可以配置为 8 位或 12 位模式,也可以与 DMA 控制器配合使用。DAC 工作在 12 位模式时,数据可以设置成左对齐或右对齐。DAC 模块有 2 个输出通道,每个通道都有单独的转换器。在双 DAC 模式下,2 个通道可以独立地进行转换,也可以同时进行转换并同步地更新 2 个通道的输出。DAC 可以通过引脚输入参考电压 Vref+(通 ADC 共用)以获得更精确的转换结果。

STM32F4 的 DAC 模块主要特点有:

- 1. 2个 DAC 转换器:每个转换器对应1个输出通道,其输出通道 DAC_OUTx(x=1或2)分别对应引脚 PA4和 PA5。
- 2. 8 位或者 12 位单调输出
- 3. 12 位模式下数据左对齐或者右对齐
- 4. 同步更新功能
- 5. 噪声波形生成
- 6. 三角波形生成
- 7. 双 DAC 通道同时或者分别转换
- 8. 每个通道都有 DMA 功能

DAC 输出是受 DORx 寄存器直接控制的,但是我们不能直接往 DORx 寄存器写入数据,而是通过 DHRx 间接的传给 DORx 寄存器,实现对 DAC 输出的控制。前面我们提到,STM32F4 的 DAC 支持 8/12 位模式,8 位模式的时候是固定的右对齐的,而12 位模式又可以设置左对齐/右对齐。单 DAC 通道 x,总共有 3 种情况:

- 1. 8 位数据右对齐:用户将数据写入 DAC_DHR8Rx[7:0]位(实际存入 DHRx[11:4]位)。
- 2. 12 位数据左对齐:用户将数据写入 DAC_DHR12Lx[15:4]位(实际存入 DHRx[11:0]位)。
- 3. 12 位数据右对齐:用户将数据写入 DAC_DHR12Rx[11:0]位(实际存入 DHRx[11:0]位)。

我们本章使用的就是单 DAC 通道 1,采用 12 位右对齐格式,所以采用第③种情况,且引脚选用 PA4。当 DAC 的参考电压为 Vref+的时候,DAC 的输出电压是线性的从 0~Vref+,12 位模式下 DAC 输出电压与 Vref+以及 DORx 的计算公式如下:

DACx 输出电压=Vref*(DORx/4095)

因此寄存器输入值 DORx=输出电压*4095/Vref,本章 Vref=3.3V。

10.3 实验内容

在 STM32CubeMX 中配置 DAC 的输出通道,在 Keil 中通过代码控制输出的电压值。

10.4 实验要求

控制 Nucleo-144 上 DAC 模块从 PA4 引脚输出固定的电压并测量验证。

10.5 实验步骤

1. 利用 STM32CubeMX 生成模板代码

第一步,首先打开 STM32CubeMX 工具,点击如图所示的按钮新建工程。

STM32CubeMX Untitled				
STM32	File	Window	Help	
Home	New Project	CtrI-N		
Existing Projects	Load Create a New Import Project Save Project Save Project As Close Project	Project Ctrl-I Ctrl-S Ctrl-A		New Project
Open Existing Projects	Recent Projects	Ctrl-X	ित	I need to :
				Start My project from MCU ACCESS TO MCU SELECTOR Start My project from ST Board
				ACCESS TO BOARD SELECTOR Start My project from Example

第二步,直接选择对应的 NUCLEO-144 开发板,省去对于时钟、中断等等的配置。

ard Filters							
* 🔂 🗟	S	Featu	Large Picture	Docs & Resources	Datasheet	🖬 Buy	Start Project
Commercial Part Number	~	STM32F4 S	eries				
Vendor	>	N	UCLEO-F413ZH	STMicroelectronics NUCLE	EO-F413ZH Board Supp	port and Example	5
Type	ŝ	Product	Active	Part Number : NUCLEO-F413ZH Commercial Part Number : NUCLEO-F413ZH		Unit Price (US\$): 19.0	
1990	<u> </u>	Troubert		Iss production Commercial - air Number - NOCLEOF 4 (2011) Mounted Device : STM32F			1132HTx
wcu/wPU Senes		P. 18					
Other	>	1 8 E 8					
				On-board ST-LINK/V2-1 USB VBUS, ext. VIN, ext. 5V, ext +3.3	3V		
				On-board ST-LINK/V2-1 USB VBUS, ext. VIN, ext. 5V, ext +3. 10M/100M Ethernet interface with ex USB OTG FS (Full speed) with micro STMicroelectronics Morpho connect	3V ternal PHY (LAN8742A-CZ-1)-AB Connector or : (2 x 72)	rr)	
		Boards List: 152 it	ems	Dn-board ST-LINKV2-1 USB VBUS, ext. VIN, ext. 5V, ext.+3.3 IOM100M Ethernet interface with ex USB OTG FS (Full speed) with micro STMicroelectronics Morpho connect	3V ternal PHY (LAN8742A-CZ-1 -AB Connector or : (2 x 72)	FR)	<u>ر</u> و
		Boards List: 152 it	ems view × Commercial	On-board ST-LINKV2-1 USB VBUS, ext. VIN, ext. 5V, ext.+3.1 USB VFUS, ext. VIN, ext. 5V, ext.+3.1 USB OTG FS (Full speed) with micro STMicroelectronics Morpho.connect Part tio	V ternal PHY (LAN8742A-CZ-1 -AB Connector or (2 x 72) X Marketing Status	K Unit Price (US\$)	赴臣) X Mounted Device
		Boards List: 152 it	erns View Consercal NUCLEO-F4122G	On-board ST-LIROV2-1 USB VBUS, ext. VN, ext. SV, ext. 45, USB VBUS, ext. VN, ext. 5V, ext. 45, ext. 45	V ternal PHY (LAN8742A-CZ-1 -AB Connector or //2 x 72) X Murketing Status Active	FR) X Unit Price (USS) 19.0	Mounted Devic
		Boards List: 152 if	erris Very Connectual NUCLEO-F4132H	On-board ST-LINEV/2-51 USD-VIDUS and V-N, ext 5-V, ext 4-3, 3 USD-VIDUS and V-N, ext 5-V, ext 4-3, 3 USD-VIDUE To FF-Fig. VIDUE Sector Statistics STMIcroelectronics Mombio connect Part 8:0 Provide Sector Statistics Nucleo-144 Nucleo-144	V demail PHY (LANB7422A-C2-1 AB Connector or: (2 x 72) X Merketing Status Active Active	IR)	Mounted Derice

第三步,创建工程后填写一下的工程信息并对 GPIO 进行配置。

- Project Name: 工程名任意即可,这里填写 DAC1。
- Project Location: 工程路径,建议新建空文件夹专门存放所有的工程文件,注意路径中不要出现中文字符。
- Toolchain/IDE: 这里选择我们已经安装好的 Keil5,工具链(Toolchain)选择 MDK-ARM,版本号选择 V5。
- 取消勾选 Use latest available version,选择 V1.25.0。

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P	Pinout & Configuration	Clock Configuration	Project Manager	Tools
Projec	Project Settings Project Name DAC1 Project Location E-SSTM_projects Application Structure Advanced	Do not generate the main()		
Code Gene	Toolchain Folder Location E-\STM_projects\DAC1\ Toolchain / IDE MDK-ARM	Min Version V5.27 Generate Under	Root	
e Advanced S	Linker Settings Minimum Heap Size Minimum Stack Size	x200		
	Mcu and Firmware Package Mcu Reference STM32F4132HTx Firmware Package Name and Ve STM32Cube FW_F4 V1.25.0	rsion Use latest available version on ory/STM32Cube_FW_F4_V1.25.0	Browse	

- Code Generator: 勾选第一项。

STM32CubeMX	DAC1.ioc: STM32F413ZHTx N	NUCLEO-F413ZH		- 🗆 ×
STM32 CubeMX	File	Window Help		🍥 🖪 🖻 🄰 🔆 ATT
Home > STM32F	F413ZHTx - NUCLEO-F413ZH	DAC1.ioc - Project Manager		GENERATE CODE
Pinout	& Configuration	Clock Configuration	Project Manager	Tools
Project	STM32Cube MCU packages and © Copy all used libraries into th O Copy only the necessary libri O Add necessary library files a	i embedded software packs		
Code Generator	Generate peripheral initializa Back if not checked, all peripheral Keep User Code when re-ge Delete previously generated	tion as a pair of '.c/.h' files per peripheral sheral initialization will be done in the main or in the midd nerating files when not re-generated	eware initialization for perpherals used by the Middleware	
Advanced Settings	HAL Settings HAL Settings Care and the pins as analog (to Care	o optimize the power consumption) stomized code	Settings	

- 点击 Pinout&Configuration,在芯片引脚图中将 PA4 设置为 DAC_OUT1,在 Analog->DAC 中可以看到其他配置, 这里保持默认。



其余保持默认,点击右上角的 GENERATE CODE 生成 Keil 工程。

2. 利用 Keil 添加用户代码

工程建好后可以点击 open project,或者利用 Keil 打开工程以后,打开 dac.c,可以看到 DAC 的相关初始化代码已 完成。



打开 main.c, 这里是程序的入口。



我们在 USER CODE BEGIN 0 (59 行)处,也就是 main 函数前添加如下代码,对设置的电压值进行合理性判断 (是 否超出最大输出电压 3.3V):

```
HAL_StatusTypeDef USER_ADC_SetValue(DAC_HandleTypeDef* hdac, uint32_t Channel, double CValue)
{
    uint32_t Data=0;
    if(CValue>3.3)
        return HAL_ERROR;
    Data=CValue*4095/3.3;
    return HAL_DAC_SetValue(hdac, Channel, DAC_ALIGN_12B_R, Data); //设置 DAC 输出电压的库函数
}

在 while 循环前添加如下代码, 设置输出电压:
    double vout=1.5;

在 while 循环中添加如下代码:
        if(USER_ADC_SetValue(&hdac, DAC_CHANNEL_1,vout)!=HAL_OK)
        {
            Error_Handler();
        }
}
```

```
}
```

HAL_DAC_Start(&hdac, DAC_CHANNEL_1); //如果电压值合理,则使能 DAC 通道

```
修改后的代码如下图所示:
```

```
/* USER CODE BEGIN 0 */
HAL StatusTypeDef USER ADC SetValue (DAC HandleTypeDef* hdac, uint32 t Channel, double CValue)
{
 uint32_t Data=0;
 if(CValue>3.3)
   return HAL ERROR;
// CValue=CValue/3.3;
 Data=CValue*4095/3.3;
 return HAL_DAC_SetValue(hdac, Channel, DAC_ALIGN_12B_R, Data);
1
/* USER CODE END 0 */
1**
 * @brief The application entry point.
 * @retval int
 */
int main (void)
ł
  /* USER CODE BEGIN 1 */
 /* USER CODE END 1 */
 /* MCU Configuration-----*/
  /* Reset of all peripherals, Initializes the Flash interface and the Systick. */
 HAL Init();
  /* USER CODE BEGIN Init */
 /* USER CODE END Init */
  /* Configure the system clock */
 SystemClock Config();
 /* USER CODE BEGIN SysInit */
 /* USER CODE END SysInit */
  /* Initialize all configured peripherals */
 MX GPIO Init();
 MX DAC Init();
 MX USART3 UART Init();
 MX USB OTG FS PCD Init();
  /* USER CODE BEGIN 2 */
 double vout=1.5;
 /* USER CODE END 2 */
  /* Infinite loop */
  /* USER CODE BEGIN WHILE */
 while (1)
 {
   /* USER CODE END WHILE */
   if (USER_ADC_SetValue(&hdac, DAC_CHANNEL_1,vout) != HAL_OK)
 {
   Error_Handler();
  1
 HAL DAC Start(&hdac, DAC CHANNEL 1);
   /* USER CODE BEGIN 3 */
 1
  /* USER CODE END 3 */
3
```

进行编译和代码烧录。

10.6 实验结果

代码烧录完成之后,可以用万用表测得 PA4 和 GND 之间的电压值为 1.5V(将板子反过来,可以找到 PA4 和 GND 对应的焊盘,表笔与之接触即可)。




第十一章 ADC 实验

11.1 实验目的

- 1. 学习 ADC 模块的工作原理
- 2. 在第十章的基础上实现对 Nucleo-144 开发板 ADC 模块的控制
- 3. 学会使用 STM32CubeMX 工具配置 ADC

11.2 实验原理

STM32F4 系列有 3 个 ADC,这些 ADC 可以独立使用,也可以使用双重/三重模式(提高采样率)。STM32F4 的 ADC 是 12 位逐次逼近型的模拟数字转换器。它有 19 个通道,可测量 16 个外部源、2 个内部源和 Vbat 通道的信号。这些通道的 A/D 转换可以单次、连续、扫描或间断模式执行。ADC 的结果可以左对齐或右对齐方 式存储在 16 位数据寄存器中。模拟看门狗特性允许应用程序检测输入电压是否超出用户定义的高/低阀值。

STM32F4的 ADC 最大的转换速率为 2.4Mhz,也就是转换时间为 0.41us(在 ADCCLK=36M,采样周期为 3 个 ADC 时钟下得到),不要让 ADC 的时钟超过 36M,否则将导致结果准确度下降。

STM32F4 将 ADC 的转换分为 2 个通道组:规则通道组和注入通道组。规则通道相当于你正常运行的程序, 而注入通道呢,就相当于中断。在你程序正常执行的时候,中断是可以打断你的执行的。同这个类似,注入通道 的转换可以打断规则通道的转换,在注入通道被转换完成之后,规则通道才得以继续转换。

STM32F4 的 ADC 可以进行很多种不同的转换模式,我们本章仅介绍如何使用规则通道的单次转换模式。与 DAC 相对应的是,ADC 所读取的数据其实是寄存器里的相对电压值,在参考电压为 Vref+的时候,12 位模式下真 实电压为:

真实电压=读取数值*(Vref/4095)

控制 STM32F4 的 ADC 需要对多个寄存器进行赋值配置,非常复杂,利用 STM32CubeMX 工具我们可以更 直观更快速地配置 ADC。

11.3 实验内容

在 STM32CubeMX 中配置 DAC 的输出通道与 ADC 的输入通道,在 Keil 中通过代码控制输出的电压值、ADC 采样该电压值并在串口打印测量结果。

11.4 实验要求

控制 Nucleo-144 上 DAC 模块从 PA4 引脚输出固定的电压并复用 PA4 引脚为 ADC 输入通道, ADC 采样 DAC 的输出电压值并在串口打印出相应的测量结果。

11.5 实验步骤

1. 利用 STM32CubeMX 生成模板代码

第一步,首先打开 STM32CubeMX 工具,点击如图所示的按钮新建工程。

MX STM32CubeMX Untitled

STM32	File		Window Help	
Home	New Project	Ctrl-N		
	Load Create a New	Projec	t	
Existing Projects	Import Project Save Project Save Project As Close Project Generate Report	CtrI-I CtrI-S CtrI-A		New Project
Open Existing Projects	Recent Projects	•	ित	I need to :
	EXI	Ctri-X		Start My project from MCU ACCESS TO MCU SELECTOR Start My project from ST Board ACCESS TO BOARD SELECTOR
				Start My project from Example

第二步,直接选择对应的 NUCLEO-144 开发板,省去对于时钟、中断等等的配置。

Commercial Part Number		STM32F4 Series	Laige ricture	Dots & Resources	Datasileet		C v otat i rojeci
Commercial Part Number	~	STM32F4 Series					
Vendor							
vendor	~	NUCLE	O-F413ZH STM	croelectronics NUCLE	O-F413ZH Board Supp	ort and Examples	
		ACTIVE Activ	Active Part Number : NUCLEO-F4132H Unit Price (US\$) : 19.0				
Туре	>	Product is in mas	s production Comm	Ircial Part Number : NUCLEO-F4	4132H Mot	inted Device : STM32F413	<u>ZHTx</u>
MCU/MPU Series	×	P.+. 8	100 jo g				
Other	>		1.				
Peripheral	>		Features				
	E	Boards List: 152 items	X Commercial Part No	Type	Marketion Status	V Unit Prine (US\$)	Expo
		100					
		ф (14)	NUCLEO-F412ZG	Nucleo-144	Active	19.0	STM32F412ZGTx
		*	NUCLEO-F413ZH	Nucleo-144	Active	19.0	57832841329(Tx

第三步,创建工程后填写一下的工程信息并对 GPIO 进行配置。

- Project Name: 工程名任意即可,这里填写 ADC。
- Project Location: 工程路径,建议新建空文件夹专门存放所有的工程文件,注意路径中不要出现中文字符。
- Toolchain/IDE: 这里选择我们已经安装好的 Keil5。
- 取消勾选 Use latest available version,选择 V1.25.0。

Pinout 8	Configuration Clock Configuration	Project Manager	Tools
Project	Project Settings Project Name ADC Project Location D.STM32projects\ Application Structure	Browse	
Code Generator	Advanced	loot	
Advanced Settings	/ Linker Settings		
	Mcu and Firmware Package Mcu Reference		
	STM32F4132HTx Firmware Package Name and Version STM32Cube FW_F4 V1.25 0 Use latest available version Use Default Firmware Location C/Users/admin/STM32Cube/Repository/STM32Cube_FW_F4_V125.0	Bronse	

- Code Generator: 勾选第一项。

Pinout &	Configuration	Clock Configuration	Project Manager	Tools
Project	STM32Cube MCU packages and © Copy all used libraries into the O Copy only the necessary library O Add necessary library files as	mbedded software packs— project folder y files reference in the toolchain project configuration file		
Code Generator	Generated files Generate peripheral initializati Backup I not checked, in p Keep User Code when re-gen Delete previously generated fil	on as a pair of '.c/ h' files per peripheral phend initialization will be done in the main or in the middlew frafing es when not re-generated	rate initialization for peripherals used by the Middleware	
	HAL Settings	optimize the power consumption)		
tvanced Settings	Template Settings Select a template to generate cut	tamized code	Settings	

- 点击 Pinout&Configuration,在芯片引脚图中将 PA4 设置为 DAC_OUT1,复用为 ADC1_IN4,并且设置为 GPIO_Analog(模拟复用)。设置为模拟复用的原因是:芯片上电默认 GPIO 是浮空输入的,在干扰和噪声环境 下,内部的施密特触发器输出随机电平状态,造成功耗上升;而设置为模拟复用,施密特触发器的输出强制为 0,降低功耗和噪声。



- 在 Analog->ADC1 中可以看到 ADC1 其他配置,保持默认。

	Pinout & Co	nfiguration	Clock Configuration	Pr	oject Manager			Tools
			✓ Software Packs	Pinout		10		
Q	~ 0		ADC1 Mode and Configuration		1	Pinout view	System vier	ni .
Categories A->Z			Mode					
		L 1N0					PF10	
System Core	2	CI N1				MCO	PH0	
Analog	.~					RCC_OSC_OUT	PHI -	
(Z)		F1 IN3					NRST	
🐥 ADC1		P2 194						
V BAC		CT INF					PC0	•
							PC1	N
Timers		1140					PC2	
		E1187					1.00	
Connectivity	>		Computation				PC3	
Multimodia	>	Reset Configuration					VDD	
		Paramèter Settings O User Constants N	VIC Settings OMA Settings OFIO Settings				VSSA	
Security	>	O Search Otree					DEE.	
Committee		× ADC Settings					VREF*	
company		Clock Prescaler	PCLK2 divided by 4				VDDA	
Middleware	>	Resolution	12 bits (15 ADC Clock cycles)				PA0	
		Data Alignment	Right alignment					
		Scan Conversion Mode	Disabled				PA1	S 🗢 🤫 🐨 🕹 🖀 🚢 🖀 🖬
		Continuous Conversion Mode	Disabled				PA2	8
		Discontinuous Conversion Mode	Disabled					
		DMA Continuous Requests	Disabled					
		End Of Conversion Selection	EOC flag at the end of single channel conver	sion			PA	PC PC PA PA
		ADC_Regular_ConversionMode						
		Number Of Conversion	1					LD Eee
		External Trigger Conversion Source	Regular Conversion launched by software					ි.
		External Trigger Conversion Edge	None					011
		> Rank	1					10 11
		ADC_Injected_ConversionMode						ole
		Number Of Conversions	0					~
		✓ WatchDog Enable Analog WatchDog Mode						Old
								4
		DMA Continuous Requests						5 5
		DMA Continuous Requests			100 ID 100			0
		Parameter Description:			Q [] Q		Dil 22	Q
							and the second	

这里从上到下依次为:

ADC 设置>>>

- -分频系数:可选 2/4/6/8 分频,本章选用 4 分频,系统时钟频率约为 96MHz,因此 ADC 的工作频率 24MHz;-分辨率:可选 12/10/8/6 位,本章选用 12 位;
- -对齐方式: 左对齐还是右对齐, 本章选用右对齐;
- -扫描模式: DISABLE, 不开启;
- -开启连续转换模式: DISABLE;
- -开启单次转换模式: DISABLE;
- -开启 DMA 请求连续模式: DISABLE;
- -转换结束标志选择:单个通道转换结束的 EOC 标志;

ADC 规则通道模式>>>

- -规则序列中有多少个转换:1;
- -外部触发方式: ADC_SOFTWARE_START, 软件触发;

-外部触发边沿;

Rank>>>

-用来设置要配置的通道是规则序列中的第几个转换;

ADC 注入通道模式>>>

-转换通道的数量:0;

看门狗使能>>>

-开启后允许应用程序检测输入电压是否超出用户定义的高/低阀值。

- 在 System Core->GPIO->NVIC 中开启按键的中断



- 其余保持默认,点击右上角的 GENERATE CODE 生成 Keil 工程。

2. 利用 Keil 添加用户代码

工程建好后可以点击 open project,或者利用 Keil 打开工程以后,打开 dac.c 和 adc.c,可以看到 DAC 和 ADC 的相 关初始化代码已完成。

打开 main.c,这里是程序的入口。

C:\Users\admin\Desktop\ADC\MDK-ARM\ADC.uvp	rojx - µVision [Non-Commercial Use License] —	o x
File Edit View Project Flash Debug Peripherals	Tools SVCS Window Help	
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Project 🕂 🗵	main.c	▼ ×
B Project: ADC	1 /* USER CODE BEGIN Header */	^
🗄 😰 ADC		
Application/MDK-ARM	4 * Ofile : main.c	
startup_stmszr41sxx.s	5 * @brief : Main program body	
Application/User/Core	7 # Battention	
main.c	· · · · · · · · · · · · · · · · · · ·	
gpio.c	9 * <h2><center>©: Copyright (c) 2020 STMicroelectronics.</center></h2>	
adc.c	10 * All lights reserved.	
dac.c	12 * This software component is licensed by ST under BSD 3-Clause license,	
	13 * the "License"; You may not use this file except in compliance with the	
usb_otg.c	15 * Declare Tou may obtain a copy of the Intense at: 15 * opensource.org/license/85D-3-Clause	
stm32f4xx_it.c	16 *	
stm32f4xx_hal_msp.c		
Drivers/STM32F4xx_HAL_Driver	19 /* USER CODE END Header */	
Drivers/CMSIS	20 /* Includes*/	
	21 finclude "main.h" 22 finclude "act b"	
	23 #include "dac.h"	
	24 #include "usart.h"	
	25 #include "usb_otg.h" 26 #include "usb_otg.h"	
	28 /* Private includes*/	
	29 /* USEK CODE BEGIN Includes */ 30	
	31 /* USER CODE END Includes */	
	32	
	33 /* FIVARe Cypeuel	
	35	
	36 /* USER CODE END FTD */	
	38 /* Private define*/	þ
	39 /* USER CODE BEGIN PD */	
	40 /* USER CODE END PD */	
	22 /* Private macro*/	
	43 /* USER CODE BEGIN PM */	
-	19 45. /* IISER CODE END PM */	
	16	
-	47 /* Private variables*/	
	10 19 /* USER CODE BEGIN PV */	
-	50	
	51 /* USER CODE END FV */	
	53 /* Private function prototypes*/	
	54 void SystemClock_Config(void);	
	55 /* USER CODE BEGIN PFP */ 56	
Braiast Reaks O Exactions B. Templates	67 (s need run den s/	, ×
in Project	*	
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```
在 USER CODE BEGIN 0 处,也就是 main 函数前添加如下代码:
float temp;
                  //最终测量的电压值
 uint16 t adcx;
                  //ADC 直接读取到的数值
 extern uint16_t adcx; //声明为全局变量
//对 printf 函数的重定向
 #ifdef __GNUC__
                     /* With GCC, small printf (option LD Linker->Libraries->Small printf
    set to 'Yes') calls __io_putchar() */
 #define PUTCHAR_PROTOTYPE int __io_putchar(int ch)
 #else
 #define PUTCHAR_PROTOTYPE int fputc(int ch, FILE *f)
 #endif /* __GNUC__ */
 PUTCHAR_PROTOTYPE
 {
   /* Place your implementation of fputc here */
   /* e.g. write a character to the USART3 and Loop until the end of transmission */
   HAL_UART_Transmit(&huart3, (uint8_t *)&ch, 1, 0xFFF);
   return ch;
};
//DAC 输出电压范围预判及电压输出函数
 HAL_StatusTypeDef USER_ADC_SetValue(DAC_HandleTypeDef* hdac, uint32_t Channel, double CValue)
 {
     uint32_t Data=0;
     if(CValue>3.3)
         return HAL_ERROR;
     Data=CValue*4095/3.3;
     return HAL_DAC_SetValue(hdac, Channel, DAC_ALIGN_12B_R, Data); //设置 DAC 输出电压的库函数
}
在 USER CODE BEGIN 2 处添加如下代码,设置输出电压:
     double vout=1.630;
         if(USER_ADC_SetValue(&hdac, DAC_CHANNEL_1,vout)!=HAL_OK)
         {
```

Error_Handler();

HAL_DAC_Start(&hdac, DAC_CHANNEL_1); //如果电压值合理,则使能 DAC 通道

在 while 循环中 USER CODE BEGIN 3 处添加如下代码:

adcx=HAL_DAC_GetValue(&hdac,DAC_CHANNEL_1); //适用于 ADC 直接读取 DAC 数

```
值

// HAL_ADC_Start(&hadc1); //使能 ADC 通道

// HAL_ADC_PollForConversion(&hadc1,10); //采用查询方式读取,需等待上一次转换结

束,此处等待 10ms

// adcx=HAL_ADC_GetValue(&hadc1);

//这三句注释掉的语句适用于 ADC 读取外部电压,不限于 DAC,适用范围更广,但在本章中使用

的话精确度较低

temp=(float)adcx*(3.3/4095); //转化成真实电压值

HAL_Delay(20);
```

在 USER CODE BEGIN 4 处添加中断回调函数,使得按键按下一次才在串口打印测量结果,注意中断回调函数内不能使用延时函数,并且尽量进行简单的操作:

```
void HAL_GPIO_EXTI_Callback(uint16_t GPIO_Pin)
{
    if (GPIO_Pin == GPIO_PIN_13)
    {
        printf("%d",adcx); //整型输出直接读取的数值
        printf("\r\n");
        printf("%f",temp); //以小数形式输出真实电压值,注意浮点型不能限制精度,默认保
留小数点后六位
        printf("V\r\n");
    }
}
```

进行编译和代码烧录。

C:\Users\admin\Desktop\ADC\MDK-AKM\ADC.uvprojx - µVision [Non-Commercial Use License]

File Edit View Project Flash Debug F	Peripherals Tools	VCS Window Help	
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roject	P 🛛 📝	main.c	
🖃 🍄 Project: ADC		1 /* USER CODE E	ND Includes */
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- Application/MDK-ARM		3 /* Private typ	edef
ctartun ctm22f412wr c		4 /* USER CODE B	EGIN PTD */
startup_stms21415xx.s		15	
CMSIS		6 /* USER CODE E	ND PTD */
🖨 🦢 Application/User/Core		37	
main.c		88 /* Private def	ine
		9 /* USER CODE B	EGIN PD */
gpio.c		0 /* USER CODE E	ND PD */

12.6 实验结果

打开 XCOM V2.0,选择相应的串口和波特率,打开串口,按下蓝色的用户按键一次,串口打印出一次测量结果,与我们预先设置 DAC 输出的电压值基本一致:

XCOM V2.0	_		\times
2022 A A A A A A A A A A A A A A A A A A	串口选择		
2022 1. 629451V 2002	COM3: USB-	SERIAL	\sim
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第十二章 STTS751 温度获取实验

12.1 实验目的

- 1. 学习 IKS01A3 拓展板的使用
- 2. 学会使用 STM32CubeMX 工具配置 IKS01A3 所需端口

12.2 实验内容

在 STM32CubeMX 中配置 STTS751 所需端口,通过串口输出传感器值

12.3 实验要求

能够在串口上实时获取当前室温

12.4 实验步骤

1. 将 KS01A3 拓展板安装到 NUCLEO-144 开发板上

仔细对照正视图和侧视图,注意扩展版凹口向上,排针与母座的缺口需要对应,两边第一个排针都与第一个外 侧母座相对应。







2. 利用 STM32CubeMX 生成模板代码

第一步,首先打开 STM32CubeMX 工具,点击如图所示的按钮新建工程。

MX STM32CubeMX Untitled

S	TM32 CubeMX	File		Window H	Help	
1	Home >	New Project	Ctrl-N			
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	Open Existing Projects	Recent Projects	•			
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						Start My project from MCU
						Start My project from ST Board
						Start My project from Example

第二步,直接选择对应的 NUCLEO-144 开发板,省去对于时钟、中断等等的配置。

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在 Pinout&Configure 界面点击 Select Components



选择 STMmicroelectronics X-CUBE-MEMS1,并将版本切换到 8.1.0

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۹ 🗌		> STMicroelectronics.X-CUBE-ALGOBUILD 1.1.0 @	
		> STMicroelectronics.X-CUBE-BLE1 6.0.0 @	
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STMicroelectronics		> STMicroelectronics.X-CUBE-GNSS1 5.0.0 @	
		✓ STMicroelectronics.X-CUBE-MEMS1 8.1.0 ✓	
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Board Support		Board Part AccGyr / LSM6DSR Not selected	
		Board Part AccGyr / LSM6DSRX Not selected ~	
		Board Part AccGyr / LSM6DS032 Not selected ~	
DSP Library		Board Part AccMag / LSM303AGR Not selected ~	
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USB			
□ Wireless			
- Show/hide filters - Show/hide	e details	- Show/hide dependencies Ok Cancel	
			_

选中 IKS01A3,并在应用中选择 STTS751 温度读取,点击 OK

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۵		Board Part PressTemp / LPS22HH		Not selected V	
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回到引脚配置界面,对以下引脚进行配置

- PB8: I2C1_SCL
- PB9: I2C1_SDA
- PF5: GPIO_EXITI5

引脚配置完成后如下图所示



到 NVIC 界面使能如下图所示的中断

STM32CubeMX 1	lioc*: STM32	2F413ZHTx NUCLEO-F413ZH					- 0 3							- 🗆 🗙
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Our set to be		Time base: System tick timer			☑ 0	0					GPIO_EXTIS			
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0.5		EXTI line[9:5] interrupts			V 0	0					PF7			
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		EXTI line[15:10] interrupts				0					NCO PO			
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								_				120 00000	CONDUCTOR INCOME	

开启 I2C1,并将模式改成 Fast Mode,其余保持默认



在 SoftWare Packs 对拓展板进行配置,这里我们使能了 IKS01A3。

STM32CubeMX U	ntitled*: STM32F413Z	HTx NUCLEO-F4	113ZH								- 0
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在 Platform Setting 中配置连接方式,按照下图所示的选项连接即可。



创建工程后填写以下的工程信息。

- Project Name: 工程名任意即可,这里填写 temperature。
- Project Location: 工程路径,建议新建空文件夹专门存放所有的工程文件,注意路径中不要出现中文字符。
- Toolchain/IDE: 这里选择我们已经安装好的 Keil5。
- 取消勾选 Use latest available version,选择 V1.25.0。

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- Code Generator: 勾选第一项。

9 🖪 🖻 🄰 🔆 ភ
GENERATE CODE
Tools

其余保持默认,点击右上角的 GENERATE CODE 生成 Keil 工程。

3. 利用 Keil 添加用户代码

打开 main.c,这里是程序的入口。可以看到 CubeMX 已经为我们做好关于 IKS01A3 的初始化,并且完成了用 户代码。

```
int main(void)
67
68 🖂 {
69
      /* USER CODE BEGIN 1 */
70
      /* USER CODE END 1 */
71
72
73
      /* MCU Configuration-----
                                                     -----*/
 74
75
      /* Reset of all peripherals, Initializes the Flash interface and the Systick. */
76
      HAL_Init();
77
78
      /* USER CODE BEGIN Init */
79
      /* USER CODE END Init */
80
81
82
      /* Configure the system clock */
83
      SystemClock_Config();
84
      /* USER CODE BEGIN SysInit */
85
86
87
      /* USER CODE END SysInit */
88
89
      /* Initialize all configured peripherals */
90
      MX GPIO Init();
      MX_USART3_UART_Init();
91
92
      MX USB OTG FS PCD Init();
      MX_MEMS_Init();
93
      /* USER CODE BEGIN 2 */
94
95
96
      /* USER CODE END 2 */
97
      /* Infinite loop */
98
99
      /* USER CODE BEGIN WHILE */
100
      while (1)
101 📋
      {
102
        /* USER CODE END WHILE */
103
104
      MX_MEMS_Process();
       /* USER CODE BEGIN 3 */
105
106
      1
      /* USER CODE END 3 */
107
108 }
109
110 -/**
     * @brief System Clock Configuration
111
112
      * @retval None
113
     */
    ······
```

进行编译和代码烧录。



12.5 实验结果

按动开发板的 RESET 按钮,打开串口助手,选择对应的串口、波特率。开启串口后,即可看到对应点温度在不断打印。

XCOM V2.0	_		×
Temperature: +27.12 degC Temperature: +27.12 degC Temperature: +27.12 degC Temperature: +27.12 degC	串口选择 COM15:USB·	-SERIAL	~
Temperature: +27.12 degC Temperature: +27.12 degC Temperature: +27.12 degC	波特率	115200	~
	停止位	1	~
	数据位	8	~
	奇偶校验	无	~
	串口操作	🥘 关闭	串口
	保存窗口	清除接	瞅
	□ 16进制型 	録□ 白底	黑字
	RTS 时间戳(│ DTR 以换行回车	断帧)
单条发送 多条发送 协议传输 帮助			
开源电子网:www.openedv.com	1	发送	
	~	清除发	送
□ 定时发送 周期: 1000 ms 打开文件	发送文件	停止发	送
□ 16进制发送 🖸 发送新行 0% 开源电子 🛛	∛l: www.op	enedv. c	om
	当前时间 11:1	1:18	

第十三章 LSM6DSO 六轴加速度获取实验

13.1 实验目的

- 1. 学习 IKS01A3 拓展板的使用
- 2. 学会使用 STM32CubeMX 工具配置 IKS01A3 所需端口

13.2 实验内容

在 STM32CubeMX 中配置 LSM6DSO 所需端口,通过串口输出图形,反映板子的面朝方向

13.3 实验要求

能够在串口上实时获取当前板子的偏转角度以及转动加速度。

13.4 实验步骤

1. 将 KS01A3 拓展板安装到 NUCLEO-144 开发板上

仔细对照正视图和侧视图,注意扩展版凹口向上,排针与母座的缺口需要对应,两边第一个排针都与第一个外 侧母座相对应。







2. 利用 STM32CubeMX 生成模板代码

第一步,首先打开 STM32CubeMX 工具,点击如图所示的按钮新建工程。

MX STM32CubeMX Untitled

S	TM32 CubeMX	File		Window H	Help	
1	Home >	New Project	Ctrl-N			
		Load Create a New	Projec	t		
	Existing Projects	Import Project (Save Project (Save Project As (Close Project Generate Report (CtrI-S CtrI-S CtrI-A			New Project
	Open Existing Projects	Recent Projects	•			
		Exit	Ctrl-X	-	-~	Theed to :
						Start My project from MCU
						Start My project from ST Board
						Start My project from Example

第二步,直接选择对应的 NUCLEO-144 开发板,省去对于时钟、中断等等的配置。

Opmendial with lands STM22F4 Saries Vendor > Type > Active Pert Nameser: NACLEO-F4132H Una Price (USS): 18.8 MCUMPU Savies > Other > Perspheral > Perspheral > Strikt Strikt Perspheral Strikt Strikt Perspheral Strikt Strikt One Strikt Strikt Perspheral Strikt Strikt Perspheral Strikt Strikt Perspheral Strikt Strikt Strikt Strikt Strikt Strikt Strikt Strikt Strikt Strikt Strikt Strikt Strikt Strikt Strikt Strikt Strikt Strikt Strikt Strikt Strikt Strikt Strikt Strikt Strikt Strikt Strikt Strikt Strikt	ard Filters	3	Fea	tures Large Picture	Docs & Resources	ڬ Datasheet	🖸 Buy	Start Project
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选中 IKS01A3,并在应用中选择 LSM6DSO_6DOrientation,点击 OK

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回到引脚配置界面,对以下引脚进行配置

- PB8: I2C1_SCL
- PB9: I2C1_SDA
- PF14: GPIO_EXITI14

引脚配置完成后如下图所示



到 NVIC 界面使能如下图所示的中断

MX STM32Cub	eMX 6D_simple.io	c: STM32F413ZHTx NUCLEO-	F413ZH								- 0	×
STM32 CubeMX		File	Window	Help					(19 (19) f 🕻	Þ 🎽 🔀 🖌	57
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开启 I2C1,并将模式改成 Fast Mode,其余保持默认



在 SoftWare Packs 对拓展版进行配置,这里我们使能了 IKS01A3。

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			Reset Configuration								RCC_080_001			
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在 Platform Setting 中配置连接方式,按照下图所示的选项连接即可。

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	-	IKS01A3 BUS IO drive	r 12C:12C	~ [2	201	~	0	BS	P_BUS_DRIVER	R

- 0 ×

ð X

创建工程后填写以下的工程信息。

- Project Name: 工程名任意即可,这里填写 6D。
- Project Location: 工程路径,建议新建空文件夹专门存放所有的工程文件,注意路径中不要出现中文字符。
- Toolchain/IDE: 这里选择我们已经安装好的 Keil5。

- 取消勾选 Use latest available version,选择 V1.25.0。

KTM32CubeMX 6D1.ioc: STM32F413ZHTx NUCLEO-F413ZH

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Pinout &	Configuration	Clock Configuration	Project Manager	Tools
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Advanced Settings	Linker Settings Minimum Heap Size 0x200 Minimum Stack Size 0x400			
	Mcu and r minware Package Mcu Reference STM32F4132HTx Firmware Package Name and Ver STM32Cube FW_F4 V1.25.0	sion		

- Code Generator: 勾选第一项。

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其余保持默认,点击右上角的 GENERATE CODE 生成 Keil 工程。

3. 利用 Keil 添加用户代码

打开 main.c,这里是程序的入口。可以看到 CubeMX 已经为我们做好关于 IKS01A3 的初始化,并且完成了用 户代码。

```
67
    int main(void)
 68 🖂 {
       /* USER CODE BEGIN 1 */
 69
 70
      /* USER CODE END 1 */
 71
 72
 73
      /* MCU Configuration-----
 74
       /* Reset of all peripherals, Initializes the Flash interface and the Systick. */
 75
 76
      HAL Init();
 77
 78
      /* USER CODE BEGIN Init */
 79
 80
      /* USER CODE END Init */
 81
 82
      /* Configure the system clock */
 83
      SystemClock_Config();
 84
 85
      /* USER CODE BEGIN SysInit */
 86
 87
      /* USER CODE END SysInit */
 88
 89
       /* Initialize all configured peripherals */
      MX GPIO Init();
 90
      MX USART3 UART Init();
 91
      MX_USB_OTG_FS_PCD_Init();
 92
 93
      MX MEMS Init(); <
      /* USER CODE BEGIN 2 */
 94
 95
 96
      /* USER CODE END 2 */
 97
 98
      /* Infinite loop */
      /* USER CODE BEGIN WHILE */
99
100
      while (1)
101 🚍
      {
        /* USER CODE END WHILE */
102
103
104
      MX MEMS Process();
       /* USER CODE BEGIN 3 */
105
106
      1
107
      /* USER CODE END 3 */
108 }
109
110 🖯 / * *
      * @brief System Clock Configuration
111
      * @retval None
112
113 / */
   ------
```

进行编译和代码烧录。



13.5 实验结果

按动开发板的 RESET 按钮,打开串口助手,选择对应的串口、波特率。 开启串口后,旋转开发板,即可看到对应开发板不同位置的形貌打印。

XCOM V2.0						-	٥	\times
					~	串口选择		
						COM4: USB-	SERIAL	\sim
*						波特率	115200	\sim
						停止位	1	\sim
						数据位	8	\sim
l						奇偶校验	无	\sim
*						串口操作	送 🕘	那日
						保存窗口	清除	接收
						□ 16进制	記示[] 白川	底黑字
*						RTS	DTI	R
						□ 时间戳 	以换行回	车断帧)
*								
单条发送 多条发送 协议传输 帮助								
开源电子网:www.openedv.com							发	ž
							清除	发送
□ 定时发送 周期: 1000 ms					打开文件	发送文件	停止发	发送
□ 16进制发送 🗹 发送新行				0%	开源电子	网:www.o	enedv.	com
	R:648	CTS=0 DSR=0 DCD=0	0 当前时	间 15:43:52				

第十四章 FreeRTOS 实验

14.1 实验目的

- 1. 学习 FreeRTOS 的使用
- 2. 学习利用线程操作 NUCLEO-144 外设

14.2 实验内容

利用线程分别控制 LED1、LED2、LED3

14.3 实验要求

Nucleo-144 上 LD1、LD2、LD3 分别以 100ms、200ms、500ms 的时间间隔改变状态

14.4 实验步骤

3. 利用 STM32CubeMX 生成模板代码

第一步,首先打开 STM32CubeMX 工具,点击如图所示的按钮新建工程。

MX STM32CubeMX Untitled				
STM32 CubeMX	File	Window	Help	
Home >	New Project	Ctrl-N		
	Load Create a New	Project		
Existing Projects	Import Project Save Project Save Project As Close Project Generate Report	CtrI-I CtrI-S CtrI-A		New Project
Open Existing Projects	Recent Projects	•		
	Exit	Ctrl-X		Theed to :
				Start My project from MCU ACCESS TO MCU SELECTOR
				Start My project from ST Board
				ACCESS TO BOARD SELECTOR
				Start My project from Example

第二步,直接选择对应的 NUCLEO-144 开发板,完成基本配置。



第三步,进入 SYS 界面,将时基源由 SysTick 改为 TIM1。

时基源表示 HAL 库所使用的时钟来源。FreeRTOS 的接口默认使用 SysTick,倘若 HAL 库同样使用 SysTick 则可能 会产生错误(例如 HAL 库中的 HAL_Delay 与 FreeRTOS 中的 osDelay 会冲突),因此将 HAL 库的时钟源改为定时 器以避免类似情况。

🛛 🔤 STM32CubeMX Unt	titled*: STN	132F413ZHTx NUCLEO-F413ZH									- 🗆 ×
STM32		File	Window	Help					<u>(0)</u>	🗗 🖸 🎽	* 57
Home STM32	2F413ZHT	rx - NUCLEO-F413ZH 🔰	Untitled - Pinout	: & Configuration >					GE	NERATE CODE	
	Pinout	t & Configuration		Clock	Configuration		Project Manager			Tools	
Q	~ (0)		SY	'S Mode and Configuration	 Software Packs 	✓ Pinout		🛱 Pinout view	💾 System view		
Categories A->Z				Mode							
System Core	~	Debug Serial Wire				~	2				
DMA GPIO		System Wake-Up 2					8 5 5 8 8 8 8 8	22 22 22 23 23 23 23 23 23 23 23 23 23 2	5 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	10 10 10 10 10 10 10 10 10 10 10 10 10 1	
IWDG NVIC		Timebase Source TIM1					702 702			V00 V33	
V SYS WWDG		TIM1 TIM2					PES PES			PA13 TMS PA12 USB_CP PA11 USB_CP	
		TIM3 TIM4					USER_BIN (81) RCC_05C32_IN PC10 RCC_05C32_OUT PC10			PATO USE ID PAO USE VEUS PAO USE SOF	(P1)
Analog 1 Timere	<u>></u>	TIM5 TIM6					PF0 PF1 PF2			PC9 PC8 PC7	
Connectivity	>	TIM7					PF5 PF4 PF5			VDD	
Multimedia	>						V35 V00 P96			POS POT US8_Over POT US8_Power	umoni (STMPS2151STR_FAULT) SwitchCin (STMPS2151STR_EN)
Security	>			Configuration			997 998 990			PG6 PG4 PG3	
Computing	>		🔺 Warning: This	IP has no parameters to be	configured.					P02 P016 P014	
Middleware	<u> </u>						NUST. PCO PC1	STM32F	413ZHTx	V00 V03 P013	
							PG2 PG3 V00	LQF	P144	P012 P011 P010	
										POUL STLK_RK (1 POUL STLK_RK (1 POUS	ITM32F103CBT6_PA3)
							745 741 742			P813 P812	
							000 000 000 000 000 000 000 000 000 00	Coord	1100 1100 1100 1100 1100 1100 1100 110		
								5			
							Q [] Q 🗳	· 🕰 💷			~

第四步,在 Middleware 界面开启 FreeRTOS,并使用 CMSIS_V1 版本接口。



第五步,在 Tasks and Queues 界面创建线程。

🛚 🚾 STM32CubeMX Un	titled*: STN	132F413ZHTx NUCLEO-F413ZH							- 🗆 X
STM32		File	Window	Help					🥺 🖪 🗖 🎽 😽 🔊
k Home 🗲 STM3	2F413ZHT	x - NUCLEO-F413ZH	Untitled - Pinout &	Configuration >					GENERATE CODE
	Pinout	& Configuration		Clock C	Configuration		Project Manager		Tools
				~	Software Packs	✓ Pinout			
۹	× 0		FREERTO	OS Mode and Configuration				🛱 Pinout view	P System view
Caregories A->2		Interface CMSIS V1		Mode	~				
System Core								3	
DMA								DAVE D	p A
WDG								Pactor Pa	
NVIC						_	PE3		vos vos
VSYS WWDG					New Task		X Pes		9445 0765 9452 (198.09
					Task Name Priority	myTask02 osPriorityIdle			PAND 5 (58 0 PAND 5 (58 0 PAND 5 (58 10)
Analog	>				Stack Size (Words)	128	T PCIL		008_50F(TP1) PC0
1 Timers	>				Entry Function Code Generation Opt	StartTask02 on Default	V PE1		PC8
Connectivity	>				Parameter	NULL	PTS PT4		V00.
Multimodia					Allocation Buffer Name	Dynamic NULL	V3S V00		P08
	<u> </u>				Control Block Name	NULL	976 957		USB_PowerSwitchDr (\$TUP\$21515TR_EN) P05
Security	<u> </u>			Configuration	ОК	Cancel	PF0 PF0		P34 P23
Computing	<u> </u>	Reset Configuration				_			POIS
CRC		 Tasks and Queues Config parameters 	 Timers and Ser Include parameter 	maphores 🧿 Mutex eters 🥥 Advanced	es 📀 FreeRTOS Heap Usage d settings 📀 User Constants		NRST. POD	STM32EA	
DFSDM1 DFSDM2		Tasks Task Name Priority	Stack Size Entry Funct	Code Gene Parameter	Allocation Buffer Name Control Bl		PC2	511/15214	
		defaultTask osPriorityN	28 StartDefault.	. Default NULL	Dynamic NULL NULL		VDD	LQFF	
Middleware	~						VRE.		Parts
¢ FATES					Add Delete		PAG PA1	,	PB13
 FREERTOS UBJPEG 		- Queues					PAA5 1948 1948 1948 1946	PC6 PC6 PE8 PE8 PE8 PE8 PE88 PE88	100 100 100 100 100 100 100 100 100 100
MBEDTLS		Queue Name Qu	eue Size Item Si	ize Allocation	Buffer Name Control Block Na	ne		D1 [Decei	
USB_DEVICE								-	
USB_HUST		L				_			
					Add Delete		\mathfrak{A}		

界面中已经为用户创建了默认线程,我们仍需要创建两个线程,各个参数含义如下

- Task Name: 任务名,用于区分不同线程。这里使用默认生成的即可
- Priority: 优先级。这里选择最低级即可。注意: 低优先级的线程将无法抢占高优先级使用的时间片
- Stack Size: 堆栈空间。为该线程分配能使用的内存大小,这里默认 128 即可
- Entry Function: 线程函数名。表示线程的执行函数的名字。这里使用默认生成的即可
- Code Generation Option: 代码生成选项,使用默认即可
- Parameter: 传入参数,这里选择 NULL

STM32CubeMX Untitled*: STM32F413ZHTx NUCLEO-F413ZH

- Allocation: 分配方式,这里选择 Dynamic 动态分配,否则需要手动修改缓冲区和控制块的相关配置。

线程创建结束后,界面内将有默认线程、myTask02、myTask03 共三个线程。

STM32 CubeMX	File Winde	ow Help			🐵 🖪 🗖 🎽 🔆 🖅
Home > STM32F413ZF	HTx - NUCLEO-F413ZH 🔰 Untitled	- Pinout & Configuration >			GENERATE CODE
Pino	ut & Configuration	Clock Configuration		Project Manager	Tools
		✓ Software Packs	✓ Pinout		
۵ ۵		FREERTOS Mode and Configuration		Pinout view	P System view
Categories A->2	Interface CMSIS V1	MODE	~		
System Core V				8	
DMA					ž
GPIO IWDG				2000 2000 2000 2000 2000 2000 2000 200	0000 0000 0000 0000 0000 0000 0000 0000 0000
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11100				USER_BIN [81]	AND ARE ON AND ARE D
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				75	
Connectivity				275. V35.	V33
Multimedia >				26	207 V88_ONEXMMIT[STMP321515TR_940LT] 207 V88_ONEXMIT[STMP321515TR_940LT] 207 V88_ONEXMIT[STMP321515TR_50]
Security >		Configuration		P78 P70	P04 P03
Computing ~	Reset Configuration			NC0 1990	P02 P015
¢ CRC	Tasks and Queues	imers and Semaphores 🛛 📀 Mutexes 🔗 FreeRTOS He	eap Usage		PONI. Voo
DFSDM1	Config parameters V In Tasks	iclude parameters 🛛 🔗 Advanced settings 🔤 🤗 User	Constants	STM32F	413ZHTx 🔤
DESDM2	Task Name Priority Stack Size	Entry Funct Code Gene Parameter Allocation Buffer Name	Control Blo		
Middlewara	myTask02 osPriorityIdle 128	StartDelaultDelault NULL Dynamic NULL StartTask02 Default NULL Dynamic NULL	NULL		P00 \$ \$11X, TX (\$17M3P-001C81%, PA2) P01 \$ \$11X, RX (\$17M3P-001C81%, PA3)
wilddieware .	myTask03 osPriorityIdle 128	StartTask03 Default NULL Dynamic NULL	NULL	VCOA PAO	Pass Bitt LD3 (Red)
FATES		Add	Delete	PA1. PA2.	Parsi Parsi
LIBJPEG	Queues	New Circo Allocation Defici News Ocean	of Direct Alassa	900 900 900 900 900 900 900 900 900 900	
MBEDTLS PDM2PCM	Queue Name Queue Size	item Size Allocation Duner Name Contro	OF BIOCK Name	8	
USB_DEVICE					
			D. L.		
		Add	Delete		

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STM32CubeMX Untit	tled*: STM32F413ZHTx NUCLEO-F413ZH	1				- 🗆 X
	File	Window	Help		(Fi 🖸 🄰 🔆 🖅
Home > STM32	F413ZHTx - NUCLEO-F413ZH	> Untitled - Projec	t Manager >		GENE	RATE CODE
	Pinout & Configuration		Clock Configuration	Project Manager		ools
Project	Project Settings Project Name freettos Project Location C:\Users\admin\Desktop\ Application Structure			Browse		
Code Generator	Advanced Toolchain Folder Location C:\Users'admin'Desktop\freetos\ Toolchain / IDE MDK-ARM	Min Ver	O Do not generate the main()			
Advanced Settings	Linker Settings Minimum Heap Size Minimum Stack Size	0x200 0x400]			
	Mcu and Firmware Package Mcu Reference STM32F4132HTx Firmware Package Name and Ver: STM32Cube FW_F4 V1.25.0	sion	Use latest available version			
	Use Default Firmware Location	sitory/STM32Cube_FW_	F4_V1 25.0	Browse		
					97 MX GPIO INIt();	

第六步,创建工程后填写一下的工程信息。

- Project Name: 工程名任意即可,这里填写 freertos。
- Project Location: 工程路径,建议新建空文件夹专门存放所有的工程文件,这里在桌面新建了 freertos 文件夹。 注意路径中不要出现中文字符。
- Toolchain/IDE: 这里选择我们已经安装好的 Keil5。
- Firmware Package Name and Version: 取消勾选使用最新版本,并切换至 1.25.0 版本。
- 其余保持默认,点击右上角的 GENERATE CODE 生成 Keil 工程。

4. 利用 Keil 添加用户代码

```
int main(void)
]{
  /* USER CODE BEGIN 1 */
  /* USER CODE END 1 */
  /* MCU Configuration-----*/
   /* Reset of all peripherals, Initializes the Flash interface and the Systick. */
  HAL_Init();
  /* USER CODE BEGIN Init */
  /* USER CODE END Init */
   /* Configure the system clock */
  SystemClock_Config();
  /* USER CODE BEGIN SysInit */
  /* USER CODE END SysInit */
   /* Initialize all configured peripherals */
  MX_GPIO_Init();
  MX_USART3_UART_Init();
  MX_USB_OTG_FS_PCD_Init();
  /* USER CODE BEGIN 2 */
  /* USER CODE END 2 */
  /* USER CODE BEGIN RTOS_MUTEX */
   /* add mutexes, ... */
  /* USER CODE END RTOS_MUTEX */
  /* USER CODE BEGIN RTOS_SEMAPHORES */
/* add semaphores, ... */
  /* USER CODE END RTOS_SEMAPHORES */
  /* USER CODE BEGIN RTOS_TIMERS */
  /* start timers, add new ones, ... */
/* USER CODE END RTOS_TIMERS */
  /* USER CODE BEGIN RTOS_QUEUES */
  /* add queues, ... */
  /* USER CODE END RTOS_QUEUES */
  /* Create the thread(s) */
  /* definition and creation of defaultTask */
  osThreadDef(defaultTask, StartDefaultTask, osPriorityNormal, 0, 128);
  defaultTaskHandle = osThreadCreate(osThread(defaultTask), NULL);
   /* definition and creation of myTask02 */
  osThreadDef(myTask02, StartTask02, osPriorityIdle, 0, 128);
  myTask02Handle = osThreadCreate(osThread(myTask02), NULL);
  /* definition and creation of myTask03 */
  osThreadDef(myTask03, StartTask03, osPriorityIdle, 0, 128);
  myTask03Handle = osThreadCreate(osThread(myTask03), NULL);
   /* USER CODE BEGIN RTOS_THREADS */
  /* add threads. ... */
```

利用 Keil 打开工程以后,打开 main.c,这里是程序的入口。可以发现 STM32cube 已经帮我们完成了关于 FreeRTOS 的初始化,并创建、启动了我们在 cubeMX 中配置的三个线程。

```
336 /* USER CODE END Header StartDefaultTask */
337 void StartDefaultTask(void const * argument)
338 🖂 {
339
     /* USER CODE BEGIN 5 */
      /* Infinite loop */
340
341
     for(;;)
342 🗄 {
       osDelay(1);
343
     }
344
     /* USER CODE END 5 */
345
    }
346
347
348 /* USER CODE BEGIN Header StartTask02 */
349 -/**
350 * @brief Function implementing the myTask02 thread.
    * @param argument: Not used
351
352
    * @retval None
353 L*/
354 /* USER CODE END Header StartTask02 */
355 void StartTask02 (void const * argument)
356 🖂 {
357
     /* USER CODE BEGIN StartTask02 */
     /* Infinite loop */
358
359
      for(;;)
360 🛱 {
361
       osDelay(l);
362
     }
    /* USER CODE END StartTask02 */
363
364 }
365 -
366 /* USER CODE BEGIN Header StartTask03 */
367 - /**
    * @brief Function implementing the myTask03 thread.
368
    * @param argument: Not used
369
370 * @retval None
371 4*/
372 /* USER CODE END Header StartTask03 */
373 void StartTask03(void const * argument)
374 🖂 {
     /* USER CODE BEGIN StartTask03 */
375
376
     /* Infinite loop */
377
     for(;;)
378 🚊 - {
379
       osDelay(1);
      1
380
      /* USER CODE END StartTask03 */
381
382
    }
```

在下方 337 行以下,已经帮我们构建好了三个线程对应的执行函数 StartDefaultTask、StartTask02、与 StartTask03。

将 StartDefaultTask 函数内的 for 循环改成如下所示语句。

```
for(;;)
{
   HAL_GPIO_TogglePin(LD1_GPIO_Port,LD1_Pin);
   osDelay(100);
}
```
```
for(;;)
{
   HAL_GPIO_TogglePin(LD2_GPIO_Port,LD2_Pin);
   osDelay(200);
}
```

将 StartTask03 函数内的 for 循环改成如下所示语句。

```
for(;;)
{
   HAL_GPIO_TogglePin(LD3_GPIO_Port,LD3_Pin);
   osDelay(500);
}
```

修改完的代码如图

```
336 /* USER CODE END Header StartDefaultTask */
337 void StartDefaultTask(void const * argument)
338 🖂 {
     /* USER CODE BEGIN 5 */
339
      /* Infinite loop */
340
     for(;;)
341
342 🖯 {
      HAL_GPIO_TogglePin(LD1_GPIO_Port,LD1_Pin);
343
344
       osDelay(100);
345 -
     }
      /* USER CODE END 5 */
346
    }
347
348
349 /* USER CODE BEGIN Header StartTask02 */
350 -/**
351 * @brief Function implementing the myTask02 thread.
352 * @param argument: Not used
353 * @retval None
354 L*/
    /* USER CODE END Header StartTask02 */
355
356 void StartTask02(void const * argument)
357 🕀 {
358 /* USER CODE BEGIN StartTask02 */
359
      /* Infinite loop */
360
      for(;;)
361 🛱 {
      HAL_GPIO_TogglePin(LD2_GPIO_Port,LD2 Pin);
362
       osDelay(200);
363
364
    - }
365 /* USER CODE END StartTask02 */
366 }
367
368 /* USER CODE BEGIN Header StartTask03 */
369 -/**
370
    * @brief Function implementing the myTask03 thread.
    * @param argument: Not used
371
372 * @retval None
373 4*/
374 /* USER CODE END Header StartTask03 */
375 void StartTask03(void const * argument)
376 🖂 {
    /* USER CODE BEGIN StartTask03 */
377
     /* Infinite loop */
378
379
      for(;;)
380 🚊 {
      HAL GPIO TogglePin(LD3 GPIO Port,LD3 Pin);
381
382
        osDelay(500);
      }
383
      /* USER CODE END StartTask03 */
384
385 }
```

```
利用图示的两个按钮进行编译和代码烧录。
```

🔢 C:\Users\admin\Desktop\timer\timer\MDK-ARM\timer.uvprojx - µVision [Non-Commercial Use License]



14.5 实验结果

代码烧录完成之后,按动开发板右下角的 RESET 按钮即可开始运行程序,可见 LED1、LED2、LED3 开始以不同频率闪烁, LED1 每 100ms 改变一次状态, LED2 每 200ms 改变一次状态, LED3 每 500ms 改变一次状态。