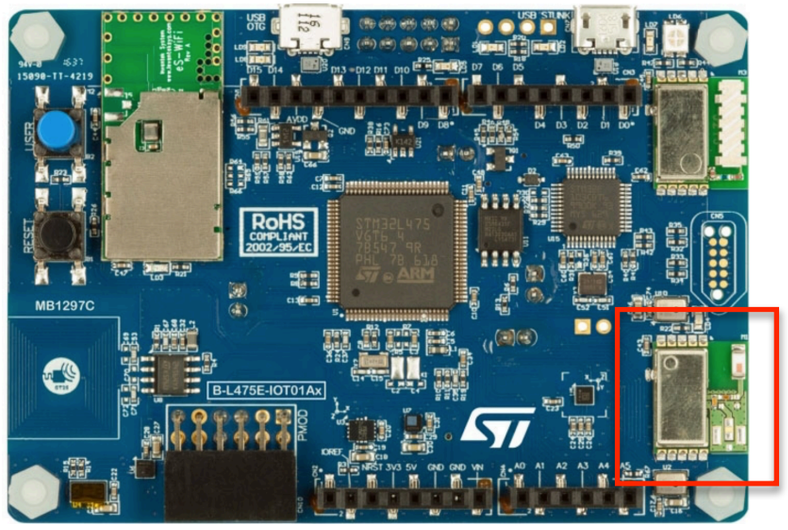
Embedded Systems Hardware Interfacing

BLE

Norman McEntire



Contents

- BLE compared to Wi-Fi
- BLE Concepts
- BLE Data Sheet
- Schematics - BLE on STM32L Discovery Kit for IoT
- Hands-On Project - BLE

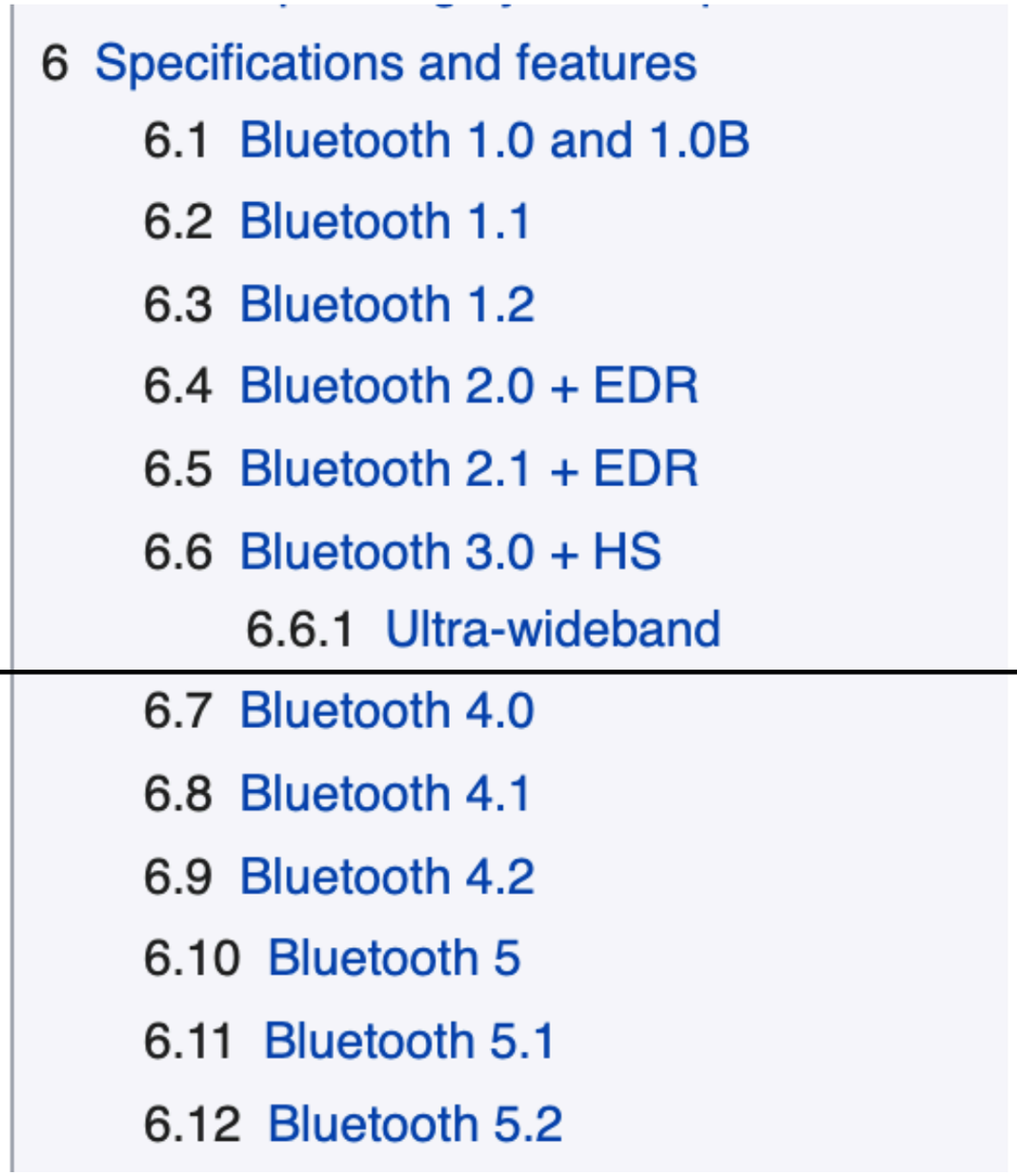
References

- https://en.wikipedia.org/wiki/Bluetooth
- https://en.wikipedia.org/wiki/Bluetooth_Low_Energy
- https://en.wikipedia.org/wiki/Bluetooth_stack
- https://www.bluetooth.com
- https://www.st.com/en/wireless-transceivers-mcus-and-modules/spbtle-rf.html
- https://www.usb.orghttps://www.st.com/resource/en/schematic_pack/b-l475e-iot01ax_sch.zip
- https://www.st.com/resource/en/user_manual/dm00347848-discovery-kit-for-iot-node-multichannel-communication-with-stm32l4-stmicroelectronics.pdf
- https://www.st.com/resource/en/datasheet/stm32l475vg.pdf

BLE Compared to Wi-Fi

- Both have IEEE Standards
  - Wi-Fi - 802.11
  - BLE - 802.15.1 (but no longer maintained)
- Both are ISM (Industrial Scientific Medical) Bands
  - Wi-Fi - 2.4GHz and 5Ghz
  - BLE - 2.4GHz
- Range
  - Wi-Fi - Local Area Networks - 100 meters
  - BLE - Personal Area Networks - 10 meters

BLE Versions

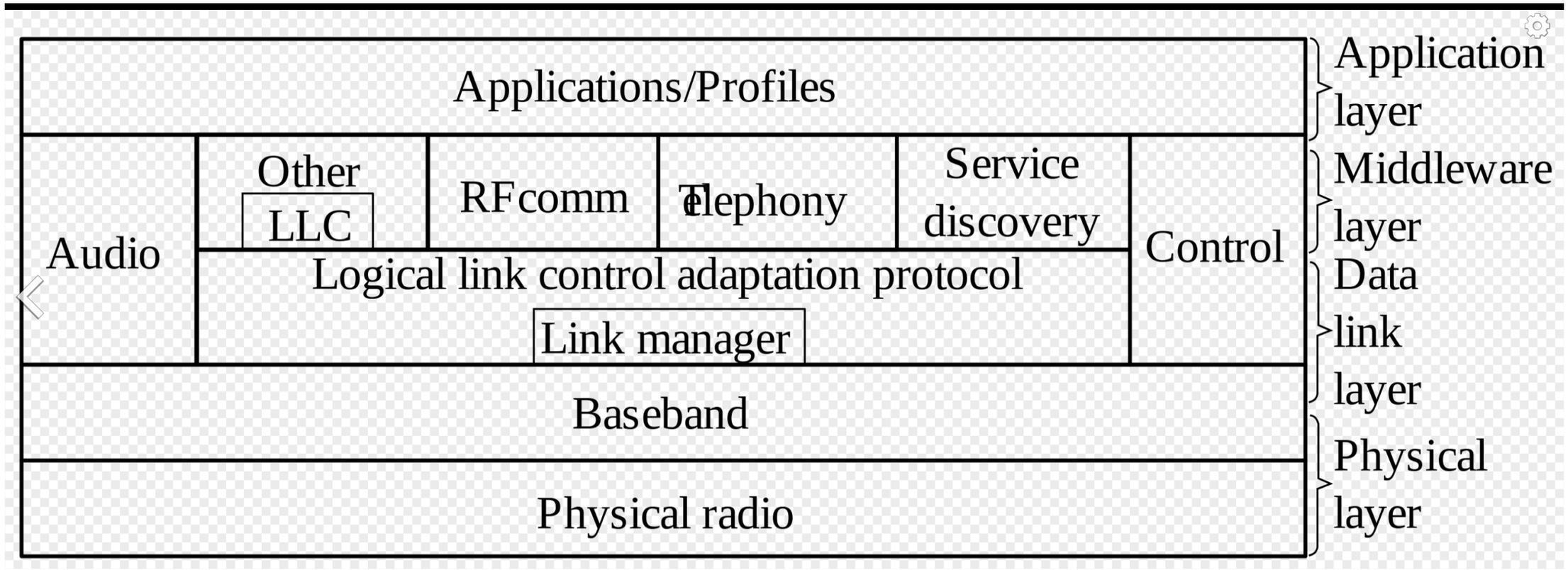


BLE starts w/ 4.0 (Bluetooth Smart)

BLE Concepts

- BLE - Bluetooth Low Energy
  - Sometimes called Bluetooth 4
  - Sometimes called Bluetooth Smart
- BLE makes it easy to get your embedded designs working with mobile devices
  - iPhone, Android, Tablets
  - Laptops

BLE Block Diagram



L2CAP = Logical Link Control and Adaptation Protocol

GAP

- Generic Access Profile
  - Makes your device visible
  - Controls Advertising and Connections
- GAP Defines Two Roles
  - Peripheral - the peripheral that connects to a central device
  - Central - the device (e.g. mobile phone) that allows peripherals to connect

Advertising

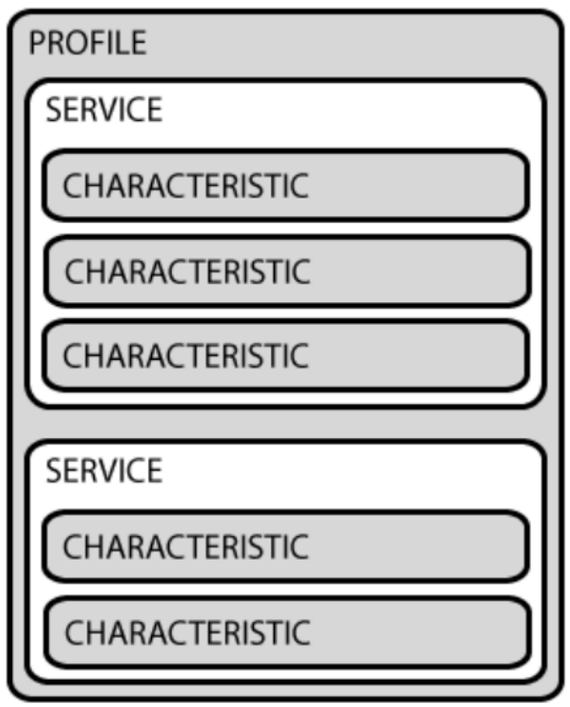
- Two Options to send out advertising with GAP
  - Advertising Data Payload
    - Mandatory
  - Scan Response Payload
    - Optional
- Both can contain up to 31 bytes of data

Advertising Only Devices

- Some BLE devices can be advertising only
  - No need to connect to device - it simply sends out info (e.g. temperature)

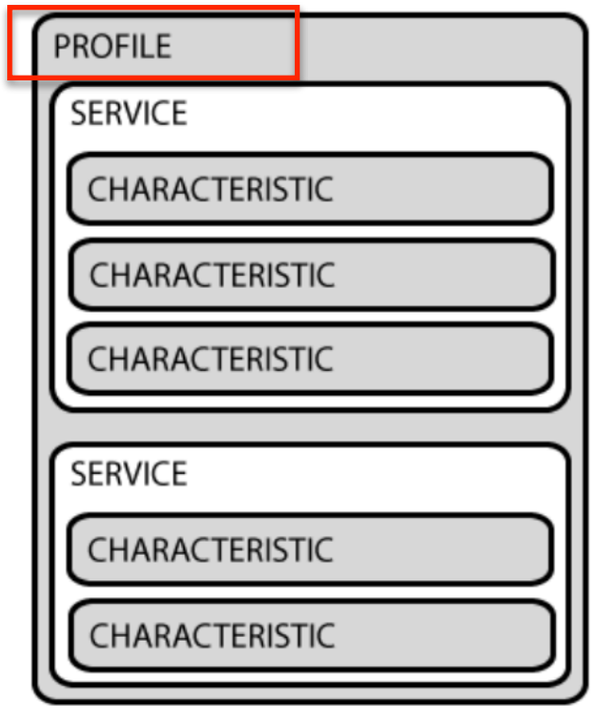
GATT

- Generic Attribute Profile
  - Defines how two BLE devices transfer data using
    - **Profiles**
    - **Services**
    - **Characteristics**



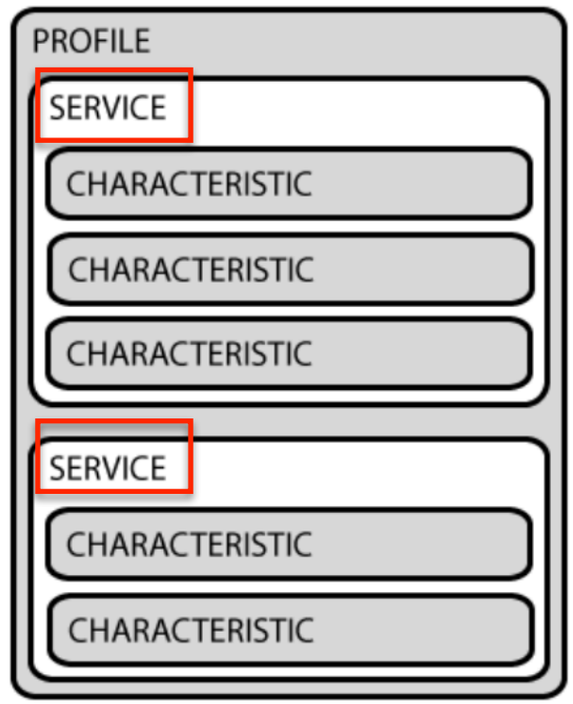
Profile

- Predefined *collection* of services
  - Defined by Bluetooth SIG
  - Or defined by your design
- Example: Heart Rate Profile



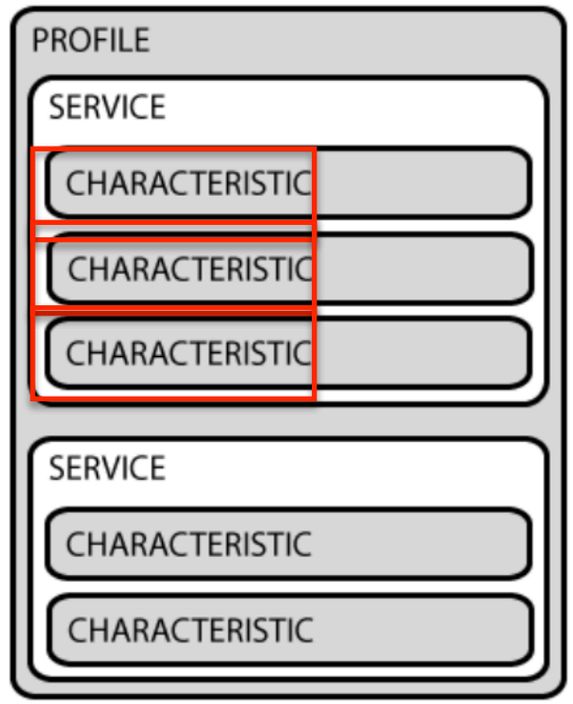
Service

- Breaks profiles into logical entities
- A service can have one or more characteristics



Characteristic

- A single data point
  - Example:
    - Heart Rate - UUID of 0x2A37



https://www.bluetooth.com/specifications/gatt/

Profile Specification		Version	Status	Adoption Date	Informative d
ANP	Alert Notification Profile	1.0	Active	13 Sep 2011	N/A
ANS	Alert Notification Service	1.0	Active	13 Sep 2011	N/A
AIOP	Automation IO Profile	1.0	Active	14 Jul 2015	N/A
AIOS	Automation IO Service	1.0	Active	14 Jul 2015	N/A
BAS	Battery Service	1.0	Active	27 Dec 2011	N/A
BCS	Body Composition Service	1.0	Active	21 Oct 2014	N/A
BLP	Blood Pressure Profile	1.0.1	Active	21 Jan 2019	BLP_1.0.1_shov
BLS	Blood Pressure Service	1.0	Active	25 Oct 2011	N/A
BMS	Bond Management Service	1.0	Active	21 Oct 2014	N/A
BSP	Binary Sensor Profile	1.0	Active	02 Jul 2019	N/A
BSS	Binary Sensor Service	1.0	Active	02 Jul 2019	N/A
CGMP	Continuous Glucose Monitoring Profile	1.0.1	Active	15 Dec 2015	N/A

CHP	BR/EDR Connection Handover Profile	1.0	Active	11 Aug 2020	N/A
CPP	Cycling Power Profile	1.1	Active	03 May 2016	N/A
CPS	Cycling Power Service	1.1	Active	03 May 2016	N/A
CSCP	Cycling Speed and Cadence Profile	1.0	Active	21 Aug 2012	N/A
CSCS	Cycling Speed and Cadence Service	1.0	Active	21 Aug 2012	N/A
CTS	Current Time Service	1.1	Active	07 Oct 2014	N/A
DIS	Device Information Service	1.1	Active	29 Nov 2011	N/A
EMP	Emergency Profile	1.0	Active	02 Jul 2019	N/A
EMCS	Emergency Configuration Service	1.0	Active	02 Jul 2019	N/A
ESP	Environmental Sensing Profile	1.0	Active	18 Nov 2014	N/A
ESS	Environmental Sensing Service	1.0	Active	18 Nov 2014	N/A
FMP	Find Me Profile	1.0	Active	21 Jun 2011	N/A
FTMP	Fitness Machine Profile	1.0	Active	14 Feb 2017	N/A
FTMS	Fitness Machine Service	1.0	Active	14 Feb 2017	N/A

GLS	Glucose Service	1.0	Active	10 Apr 2012	N/A
HIDS	HID Service	1.0	Active	27 Dec 2011	N/A
HOGP	HID over GATT Profile	1.0	Active	27 Dec 2011	N/A
HPS	HTTP Proxy Service	1.0	Active	06 Oct 2015	N/A
HRP	Heart Rate Profile	1.0	Active	12 Jul 2011	N/A
HRS	Heart Rate Service	1.0	Active	12 Jul 2011	N/A
HTP	Health Thermometer Profile	1.0	Active	24 May 2011	N/A
HTS	Health Thermometer Service	1.0	Active	24 May 2011	N/A
IAS	Immediate Alert Service	1.0	Active	21 Jun 2011	N/A
IDP	Insulin Delivery Profile	1.0	Active	24 Jul 2018	N/A
IDS	Insulin Delivery Service	1.0	Active	24 Jul 2018	N/A
IPS	Indoor Positioning Service	1.0	Active	19 May 2015	N/A
IPSP	Internet Protocol Support Profile	1.0	Active	16 Dec 2014	N/A

Heart Rate Service

BLUETOOTH® DOC	Date / Year-Month-Day	Approved	Revision	Document No
	2011-07-12	Adopted	V10r00	HRS_SPEC
Prepared By	E-mail Address			N.B.
MED WG	med-feedback@bluetooth.org			

HEART RATE SERVICE

Heart Rate Service

3 Service Characteristics

The following characteristics are exposed in the Heart Rate Service. Unless otherwise specified, only one instance of each characteristic is permitted within this service.

Characteristic Name	Requirement	Mandatory Properties	Optional Properties	Security Permissions
Heart Rate Measurement	M	Notify		None.
Heart Rate Measurement Client Characteristic Configuration descriptor	M	Read, Write		None.
Body Sensor Location	O	Read		None.
Heart Rate Control Point	C.1	Write		None.

Table 3.1: Heart Rate Service characteristics

C.1: Mandatory if the Energy Expended feature is supported, otherwise excluded.
Notes:

- Security Permissions of “None” means that this service does not impose any requirements.
- Properties not listed as Mandatory or Optional are Excluded.

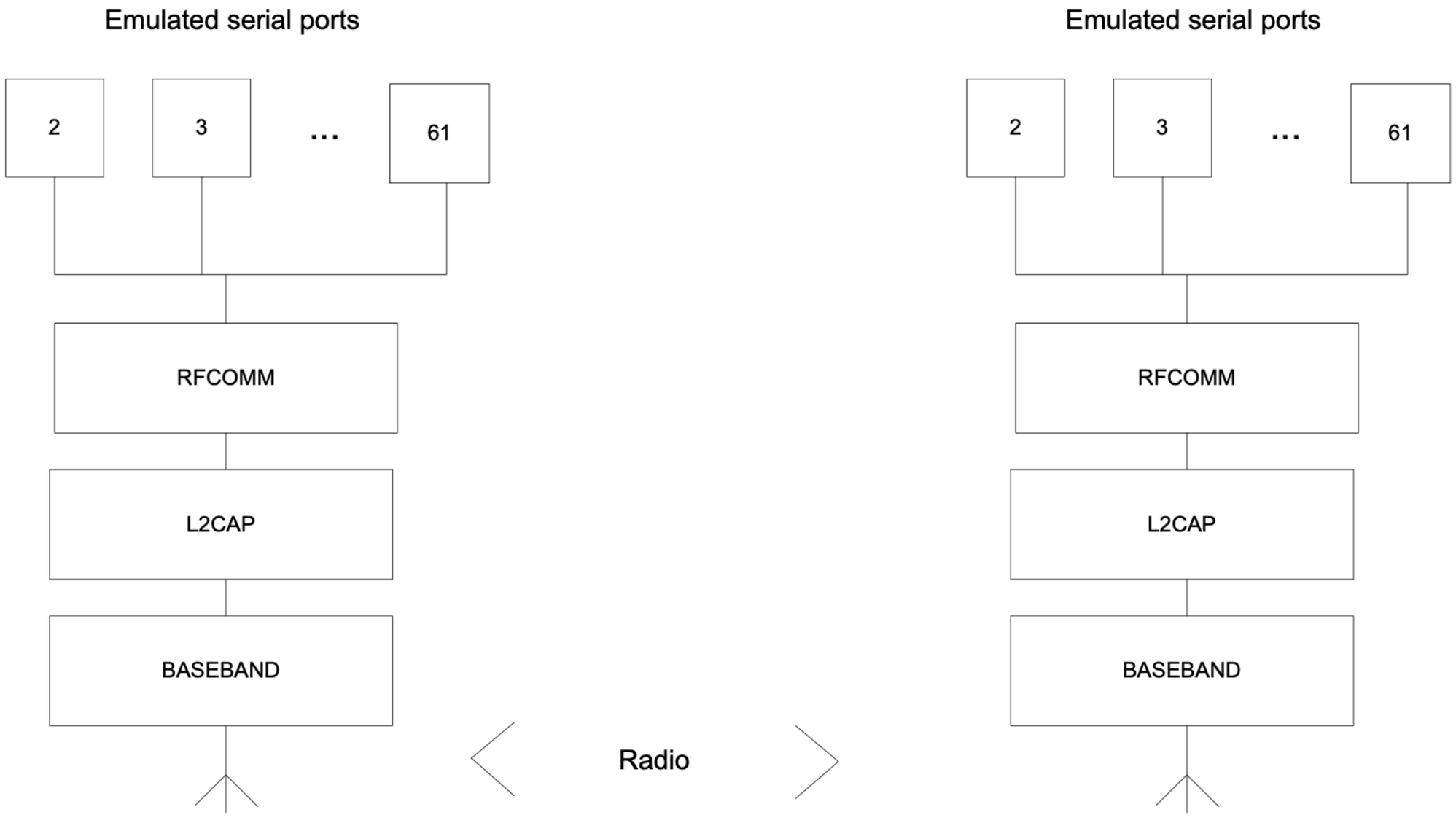
RFCOM

BLUETOOTH® DOC	Date / Year-Month-Day 2012-11-06	Approved Adopted	Revision V12	Document No RFCOMM_SPEC
Prepared By BARB	E-mail Address Barb-main@bluetooth.org			N.B.

RFCOMM WITH TS 07.10

Serial Port Emulation

RFCOM



L2CAP

- Logical Link Control and Adaptation Protocol
- Multiplex multiple logical connections between two devices

SM

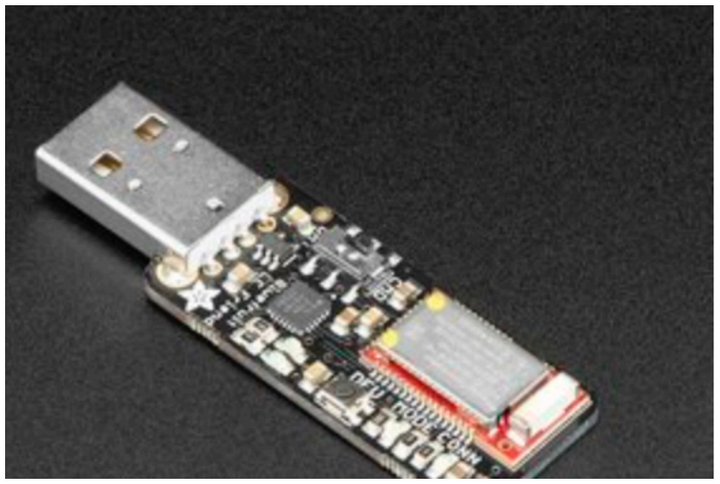
- Streaming Mode
- Simple mode with no retransmission or flow control
- Unreliable L2CAP channel

BLE Example
https://www.adafruit.com/product/4078

nRF52840 Bluetooth Low Energy Module with USB - MDBT50Q-1MV2

PRODUCT ID: 4078

BLE Example
https://www.adafruit.com/product/2269

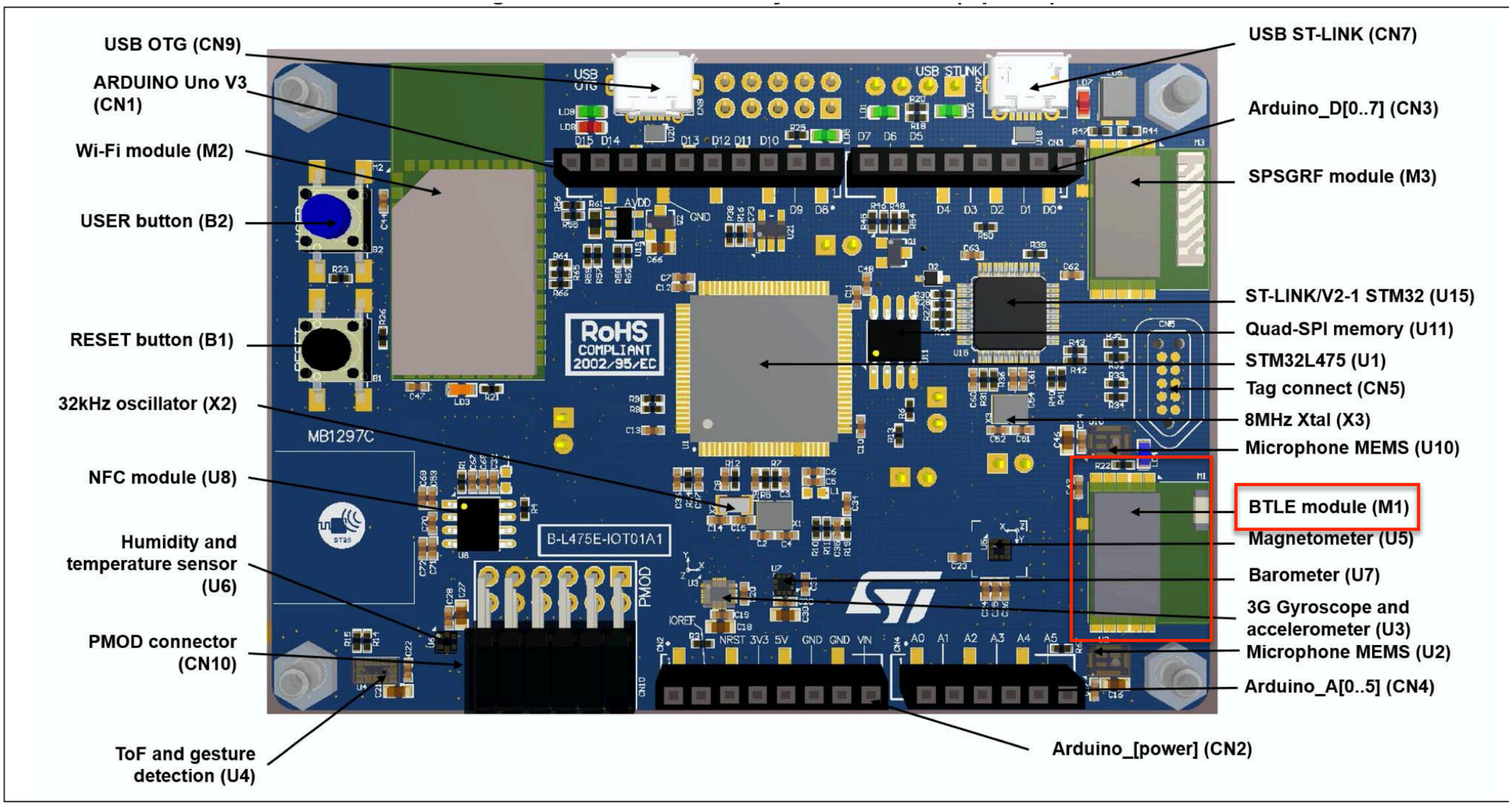


Bluefruit LE Sniffer - Bluetooth Low Energy (BLE 4.0) - nRF51822 - Firmware Version 2

PRODUCT ID: 2269

Interested in learning how Bluetooth Low Energy works down to the packet level? Debugging your own BLE hardware, and trying to spot where something is going wrong? Or maybe you're writing a custom application for your phone or tablet that needs to talk to existing BLE hardware, but you...

Bluetooth Example Discovery Kit



Data Sheet

Figure 13. SPBTLE-RF module

https://www.st.com/en/wireless-transceivers-mcus-and-modules/spbtle-rf.html

SPBTLE-RF NRND

Not recommended for new designs!

Very low power module for Bluetooth Smart v4.1

---

life.augmented

SPBTLE-RF

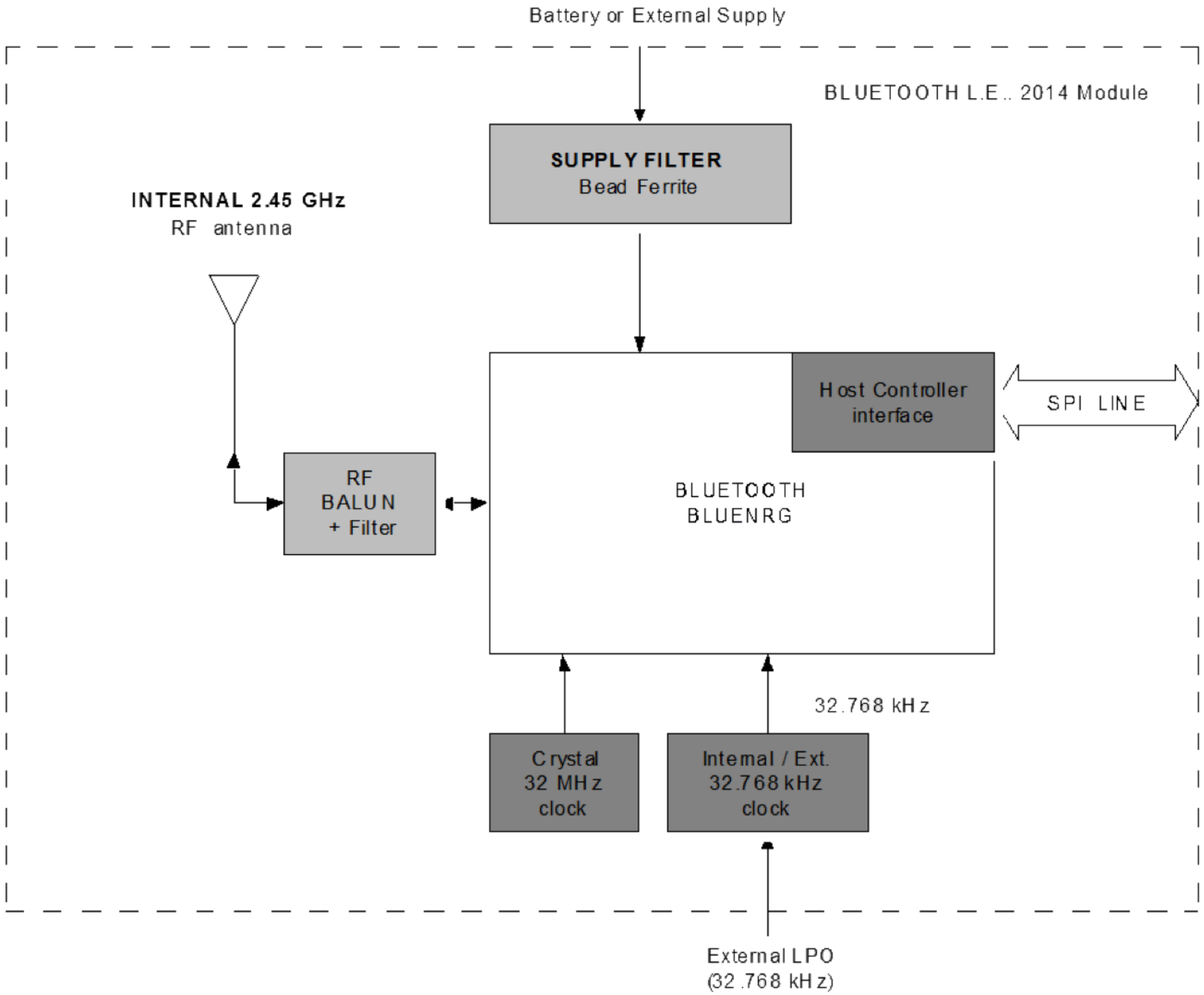
Very low power network processor module for Bluetooth® low energy v4.1

Datasheet - production data

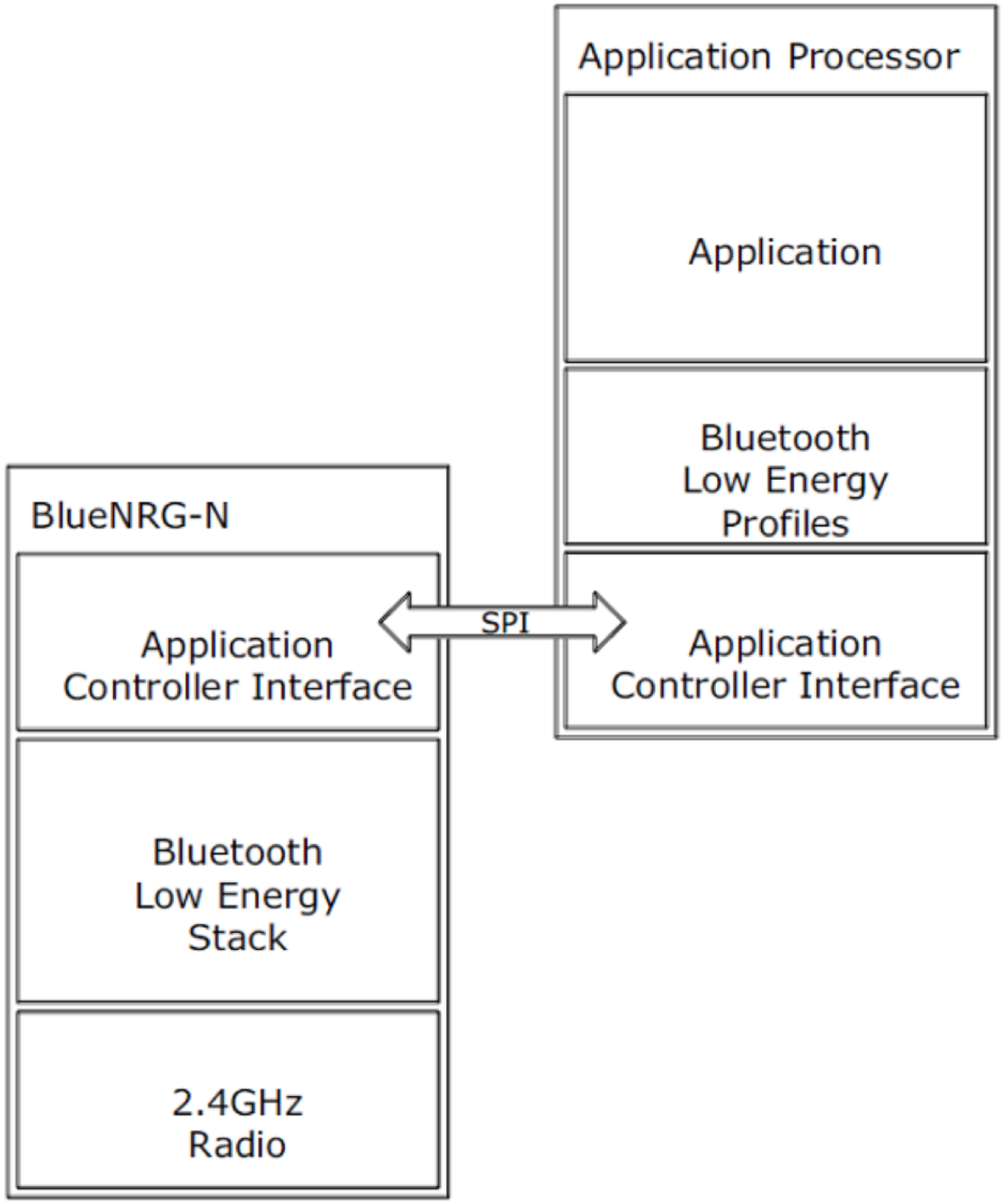
Features

- Bluetooth v4.1 compliant
  - Supports master and slave modes
  - Multiple roles supported simultaneously
- Embedded Bluetooth low energy protocol stack
  - GAP, GATT, SM, L2CAP, LL, RFPHY
- Bluetooth low energy profiles provided separately
- Bluetooth radio performance:
  - Embedded ST BlueNRG-MS
  - Tx power: + 4 dBm
  - Rx sensitivity: - 88 dBm
  - Provides up to 92 dB link budget with excellent link reliability
- Host interface
  - SPI, IRQ, and RESET
  - On-field stack upgrading available via SPI
- AES security co-processor
- Certification
  - CE qualified
  - FCC, IC modular approval certified
  - TELEC

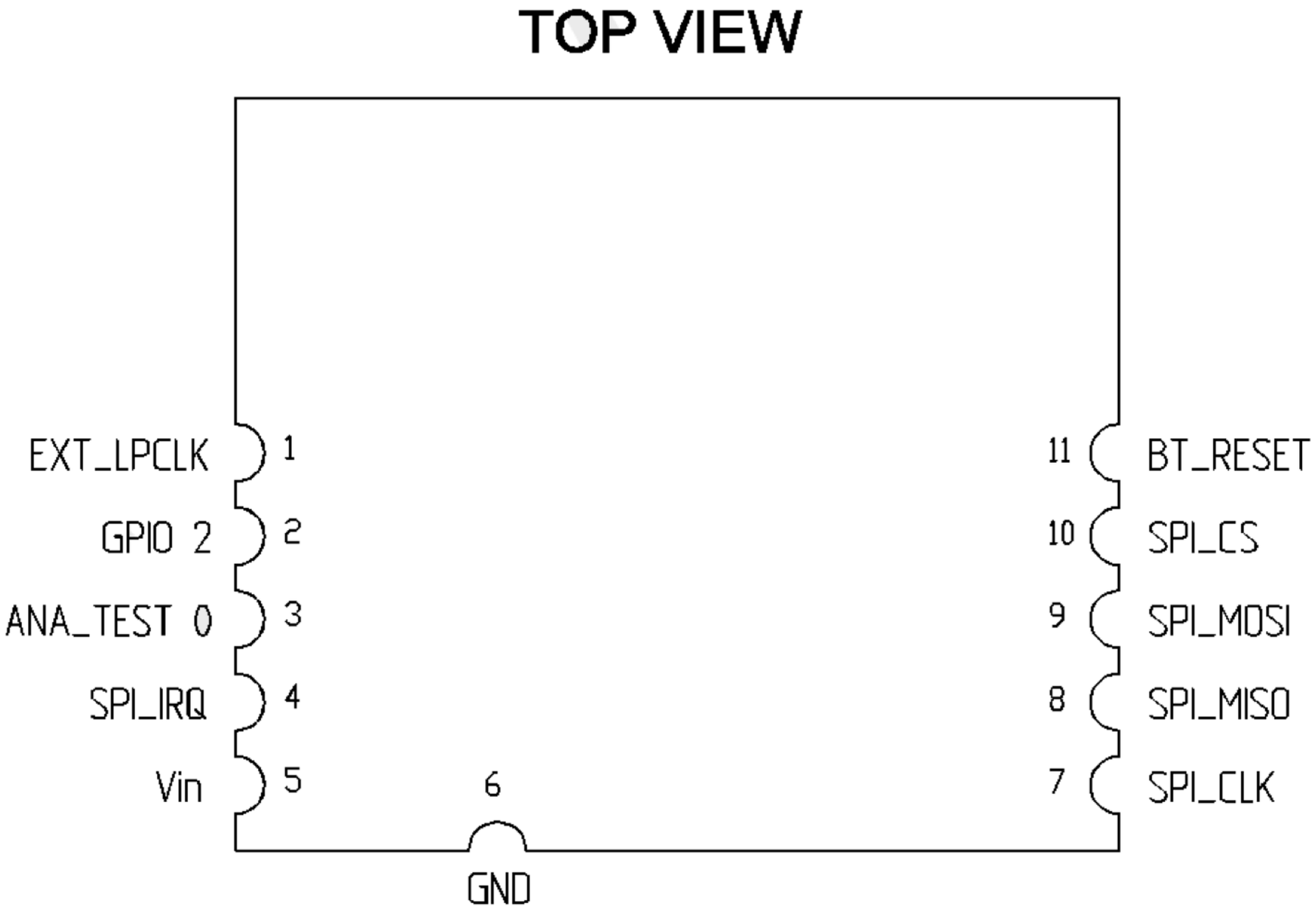
Block Diagram - View 1



Block Diagram - View 2



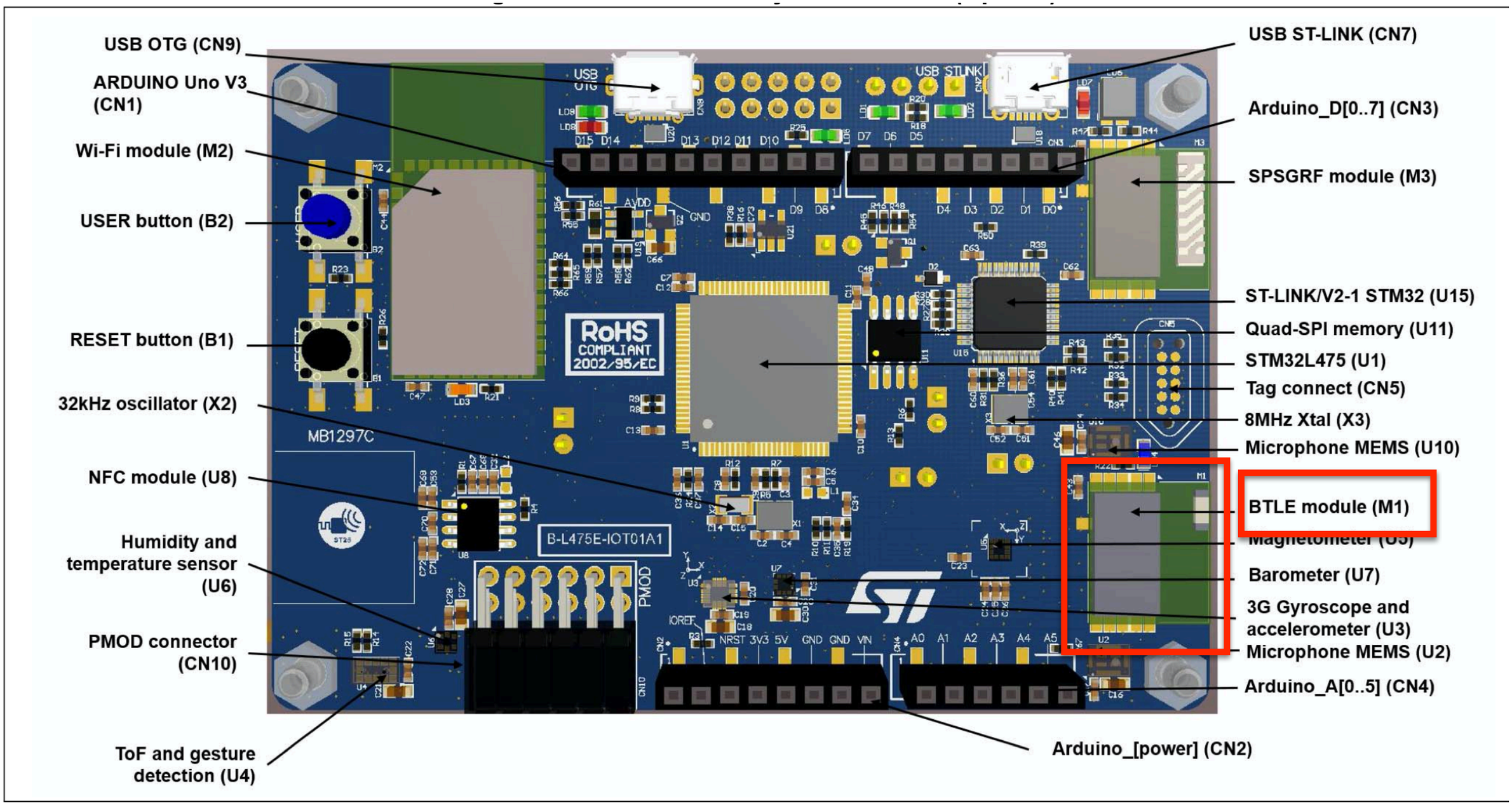
Pin Connection



User Manual

STM32L Discovery Kit IoT Node

Use of BTLE



SPBTLE-RF Module

Figure 13. SPBTLE-RF module

User Manual

7.11.1 Bluetooth (V4.1 compliant) SPBTLE-RF module

The ST SPBTLE-RF module (M1) is implemented on top side of the STM32L4 Discovery kit for IoT node board.

The SPBTLE-RF is an easy to use Bluetooth smart master/slave network processor module, compliant with Bluetooth V4.1. The SPBTLE-RF B-Smart module supports multiple roles simultaneously, and it can act at the same time as Bluetooth Smart sensor and hub device.

The entire Bluetooth Smart stack and protocol are embedded into the SPBTLE-RF B-Smart module. The external host application processor, where the application resides, is connected to the SPBTLE-RF B-Smart module through a standard SPI interface (SPI3 of STM32L475VGT6).

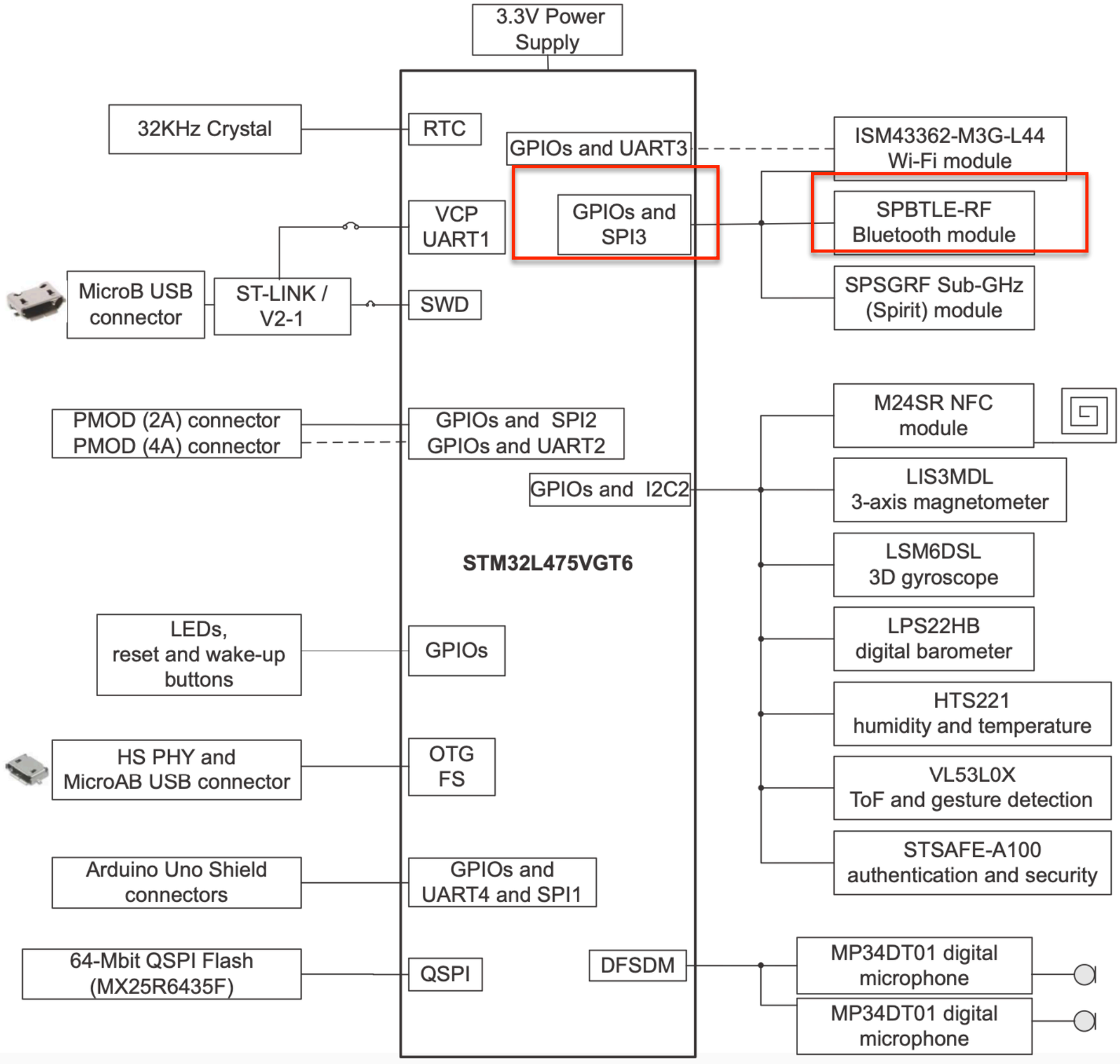
SPBTLE-RF Features

The main features of the ST SPBTLE-RF module are listed below.

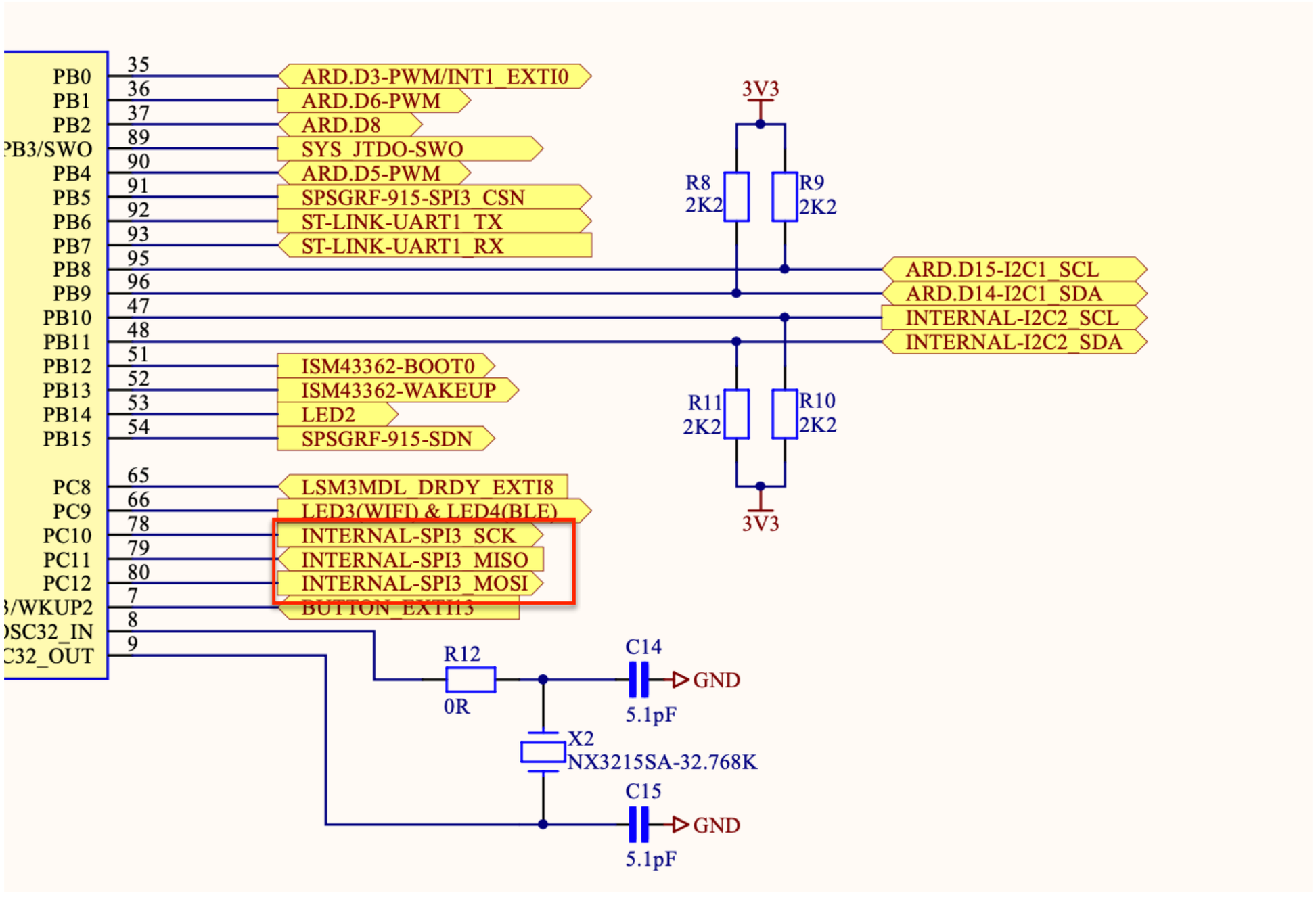
- Bluetooth V4.1 compliant (supports master and slave modes, multiple roles supported simultaneously
- Embedded Bluetooth low-energy protocol stack (GAP, GATT, SM, L2CAP, LL, RFPHY)
- Bluetooth low-energy profiles provided separately
- Bluetooth radio performance:
- Embedded ST BlueNRG-MS
- Tx power: + 4 dBm
- Host interface SPI, IRQ, and RESET On-field stack upgrading available via SPI.
- Certification: CE qualified, FCC, IC modular approval certified, BQE qualified
- On-board chip antenna

Schematics

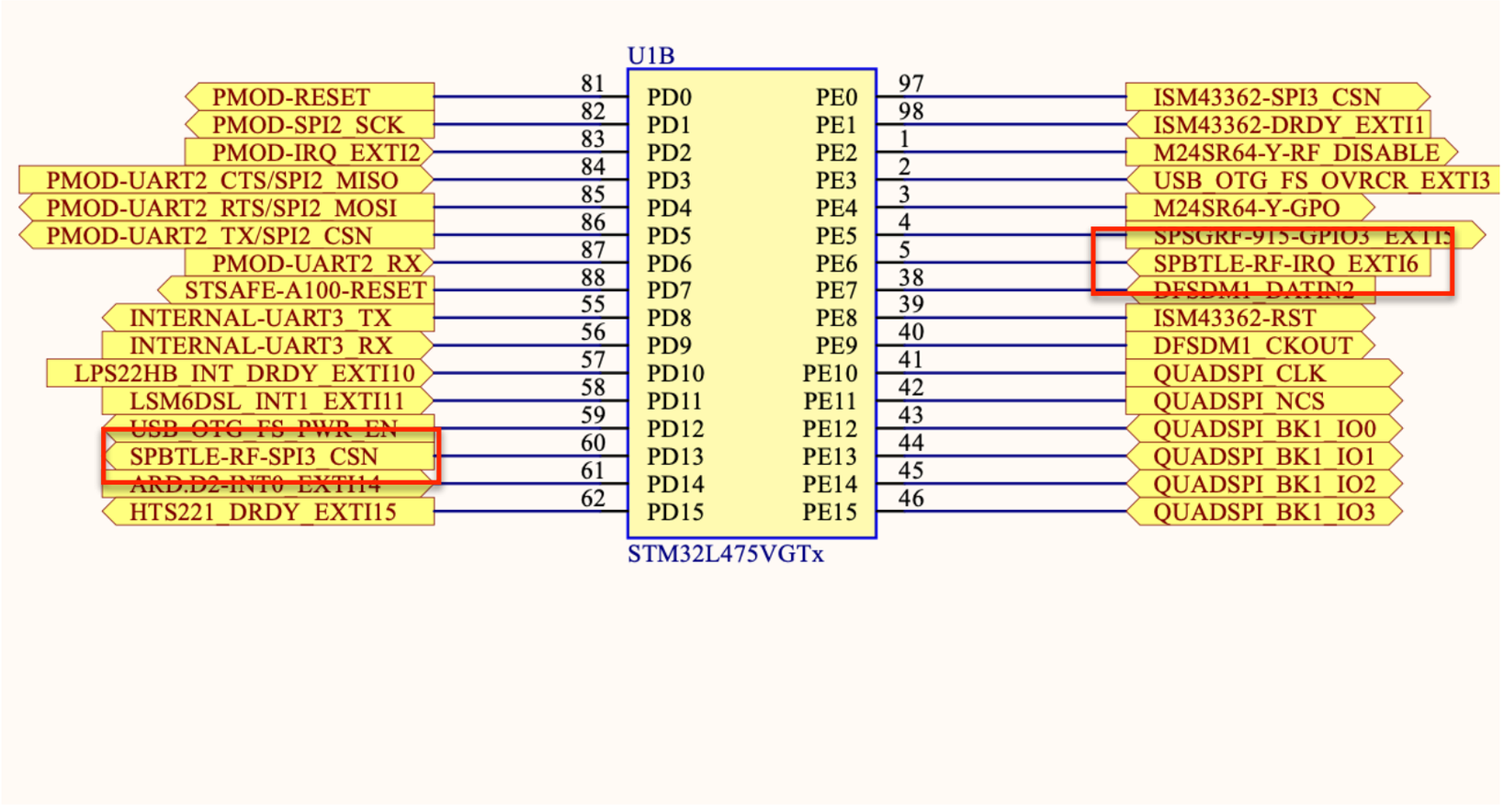
STM324L Discovery Kit IoT Node



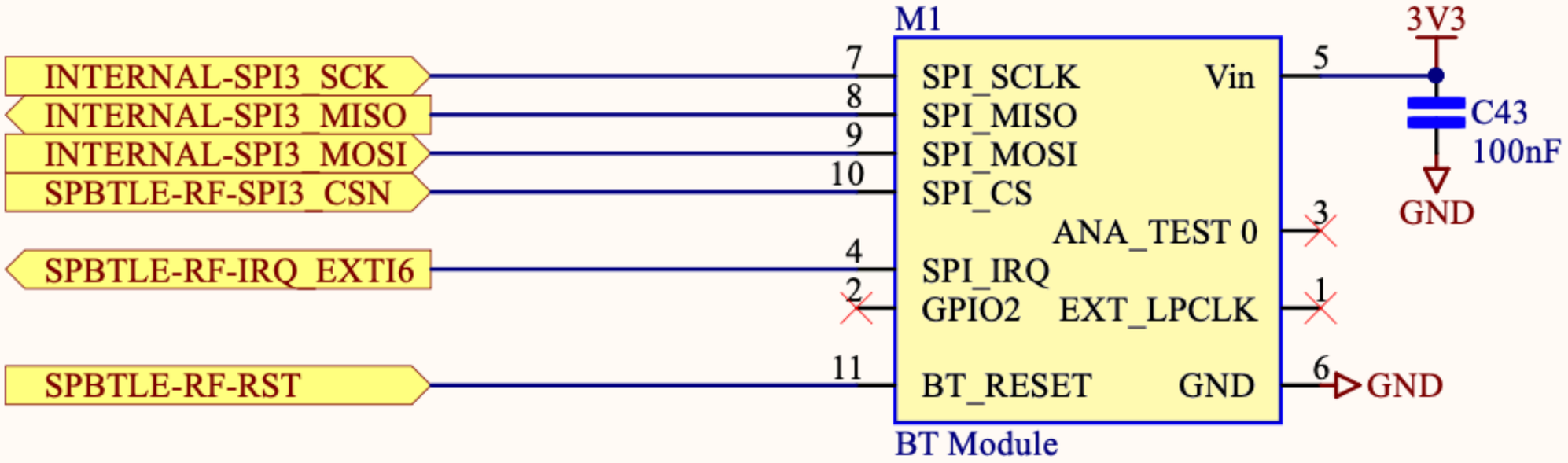
STM32L475



STM32L475



SPBT-RF



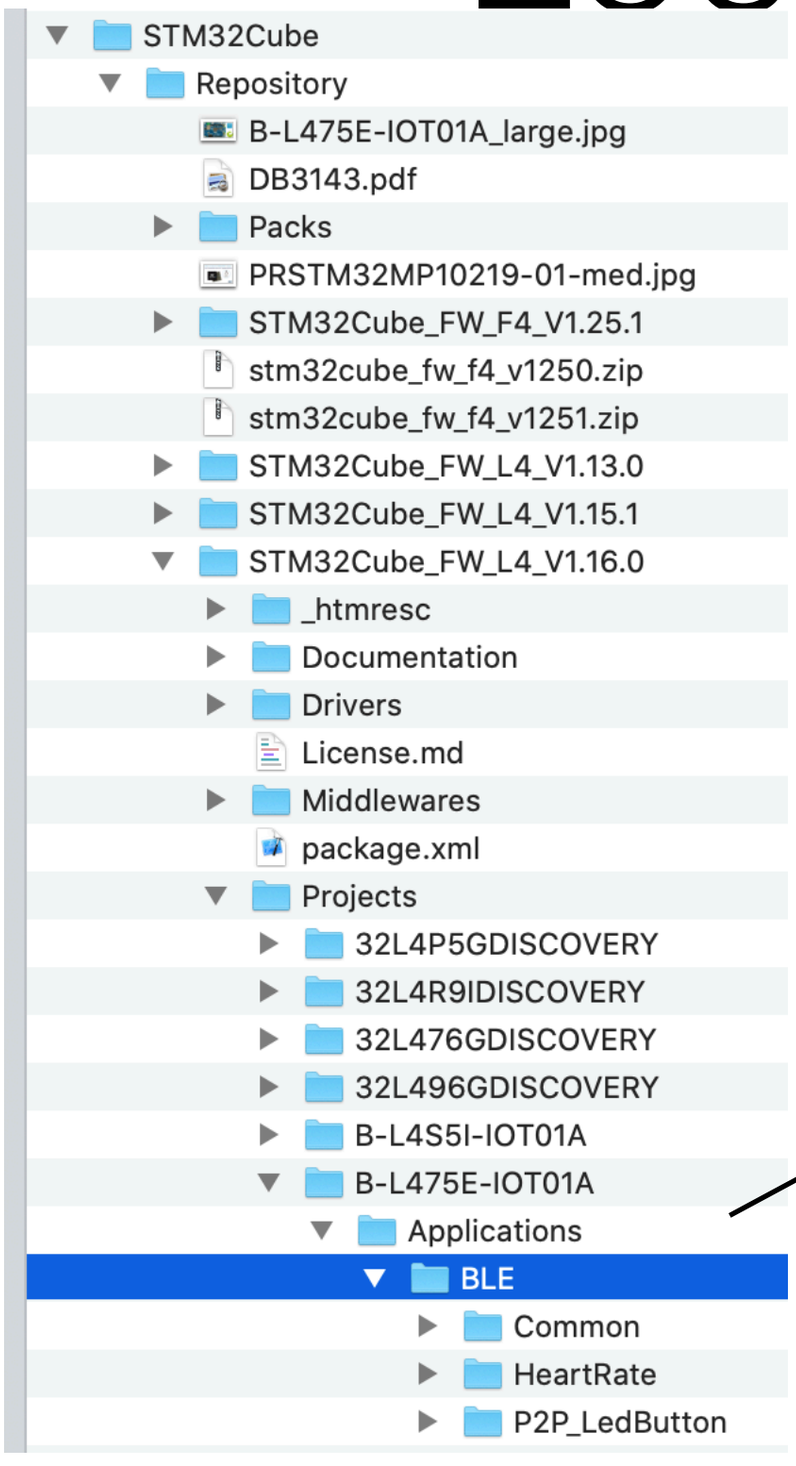
BLE

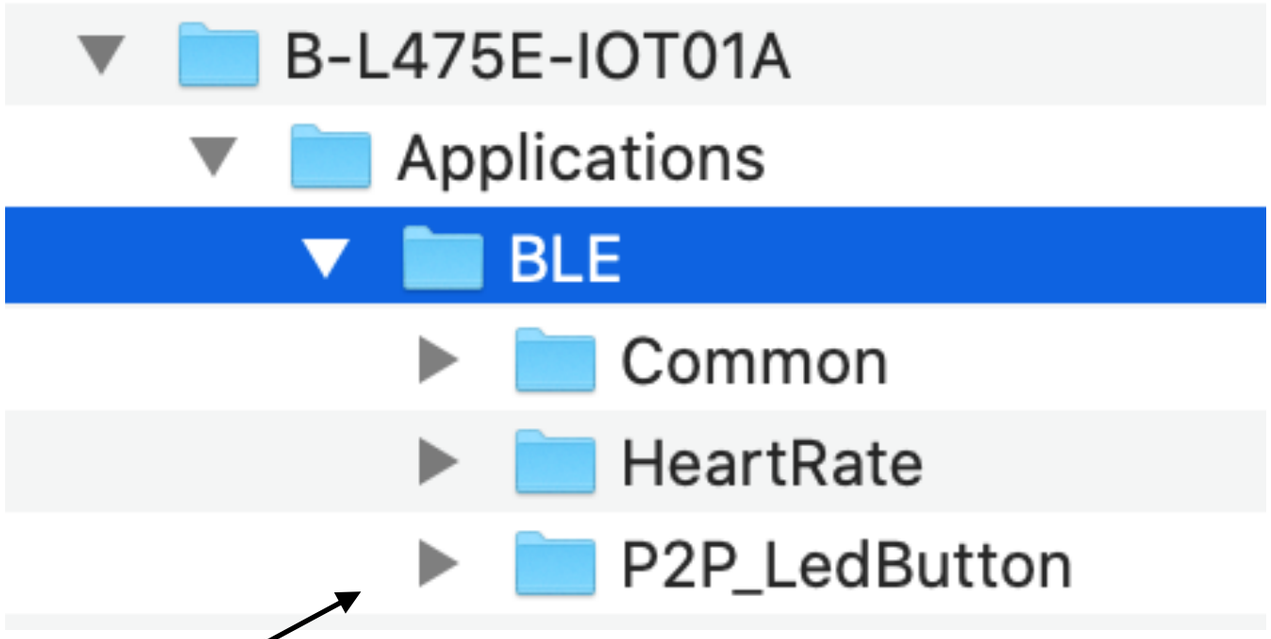
Hands-On Project

BLE Hands-On Project Overview

- The goal of this project is to give you hands-on experience with adding BLE to your device
  - Use the Middleware included with STMCubeIDE
- To confirm your experience, you will create a **PDF document** that you will submit for grading
  - The PDF document will capture the major steps you perform to complete this project
  - See example PDF posted with assignment for example PDF format

Location of File





P2P_LedButton README

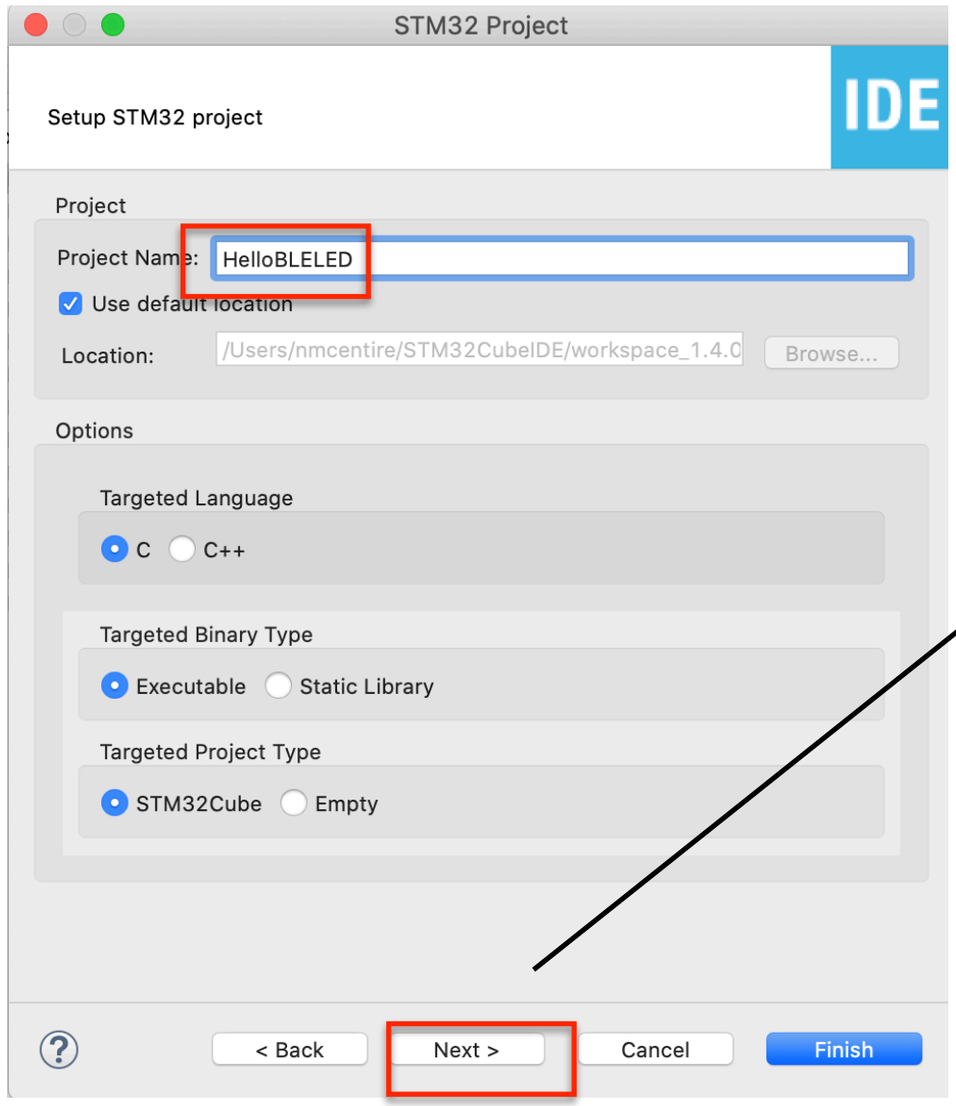
```
This example aims at demonstrating point-to-point communications using the BLE component.

Two STM32 B-L475E-IOT01A Discovery boards are used: one acting as GATT client,
the other as GATT server.
The two boards needs to be compiled with different code by changing the #definitions in config.h
  #define LB_CLIENT  0/1    /*1 = Device is GAP Central & GATT Client */
  #define LB_SERVER  1/0    /*1 = Device is GAP Peripheral & GATT Server */

Once the code is downloaded on the two STM32 B-L475E-IOT01A Discovery boards and executed,
the modules are initialized.  The slave device (GAP Peripheral) starts advertising,
the master device (GAP Central) scans and automatically connects to the slave at power up.
ST proprietary Led Button service is implemented on the slave device with Led Characteristics
& Button Characteristics (GATT Server).
Once connected, the Master Device(GATT Client) start to discover the remote services and Characteristics
The above phase takes some seconds, after that period when pressing the User button
on one board the service allows toggling the Led on the other board.
The User button can be pressed independently on the GATT Client or on the GATT Server.

To summarise:
  *1*  User presses User Button on GATT Server
  *2*  Server  ------------ GATT Notification ------>   Client
  *3*    LED LD1 Toggles on GATT Client
or
  *1*  User presses User Button on GATT Client
  *2*  Client  ------------ GATT Write command ------>   Server
  *3*    LED LD1 Toggles on GATT Server
```

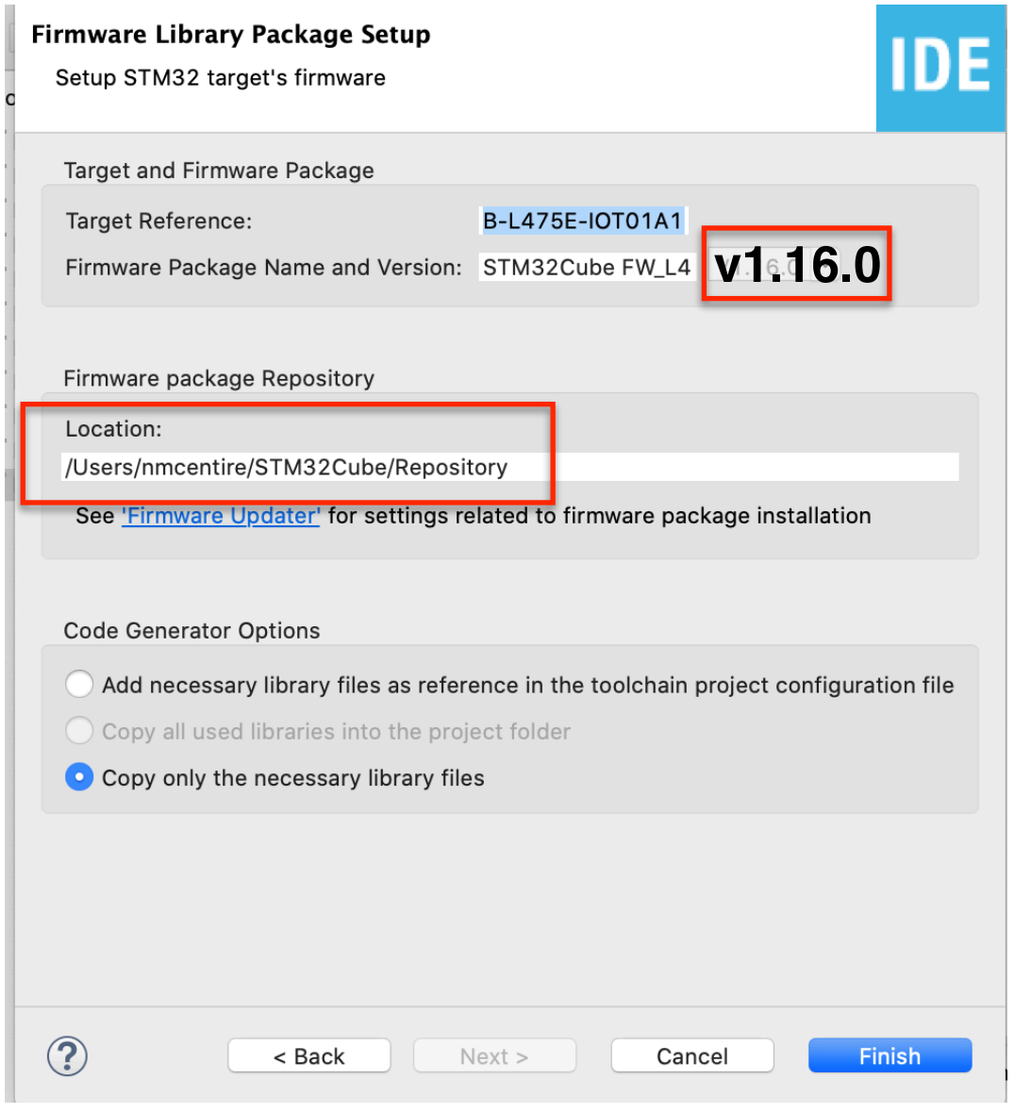
NOTE: We will build GATT Server (Central)

P2P_LedButton README Part 2

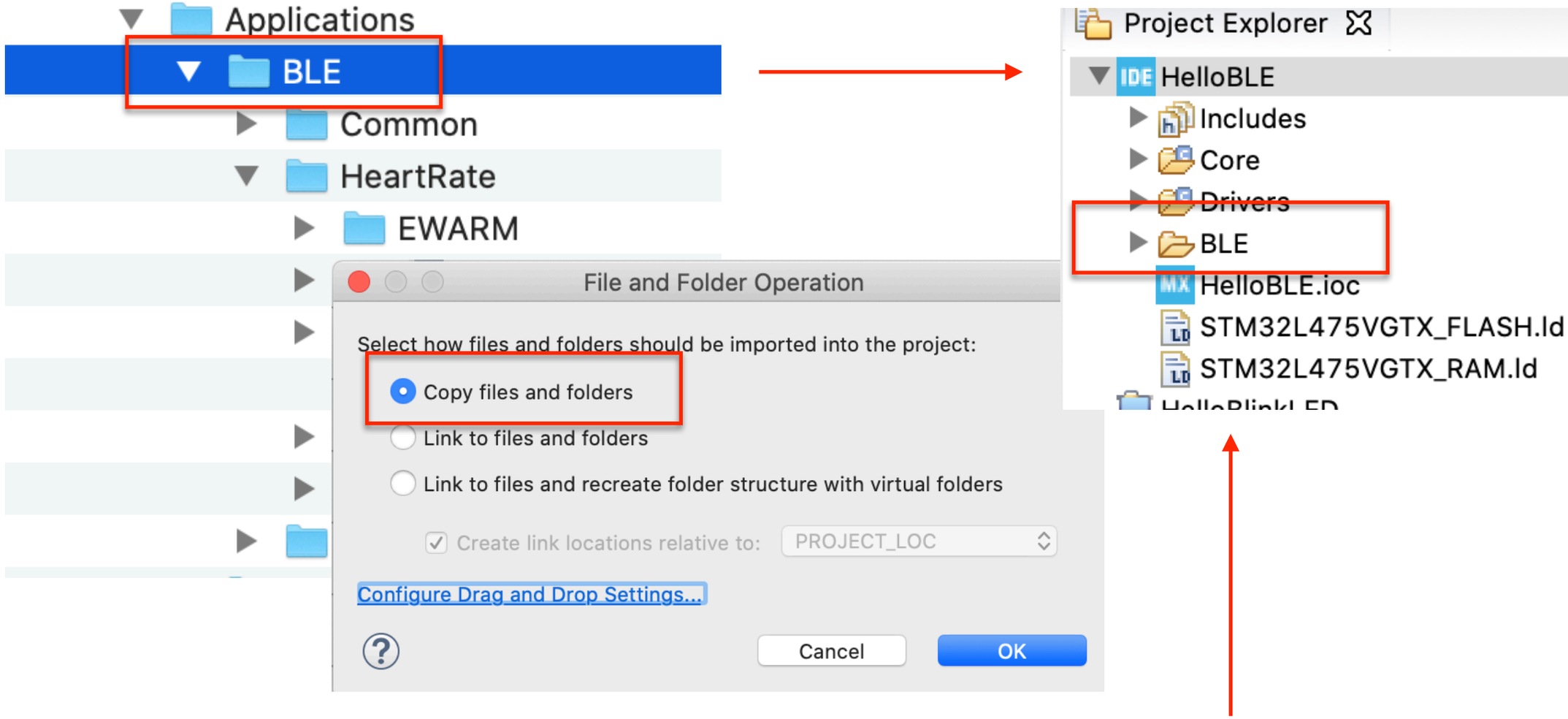
```
- BLE/P2P_LedButton/Src/main.c                  Main Program
- BLE/P2P_LedButton/Src/system_stm32l4xx.c      STM32L4xx system clock configuration file
- BLE/P2P_LedButton/Src/stm32l4xx_it.c          STM32 interrupt handlers
- BLE/P2P_LedButton/Src/lb_demo.c               P2P main Led Button application
- BLE/P2P_LedButton/Src/lb_client_app.c         P2P Client Led Button application
- BLE/P2P_LedButton/Src/lb_server_app.c         P2P Server Led Button application
- BLE/P2P_LedButton/Inc/config.h                Application configuration file
- BLE/P2P_LedButton/Inc/stm32l4xx_hal_conf.h    HAL configuration file
- BLE/P2P_LedButton/Inc/stm32l4xx_it.h          STM32 interrupt handlers header file
- BLE/P2P_LedButton/Inc/lb_demo.h               Exported files and function of lb_demo.c
- BLE/P2P_LedButton/Inc/lb_client_app.h         Exported files and function of lb_client_app.c
- BLE/P2P_LedButton/Inc/lb_server_app.h         Exported files and function of lb_server_app.c
- BLE/Common/                                   These files are Common also to other applic/examples then P2P_LedButton (e.g. to Heart
- BLE/Common/ble_core/*.*                       BlueNRG-MS Bluetooth Low Energy device driver
- BLE/Common/ble_services/*.*                   GATT services according to BLE spec
- BLE/Common/debug/*.*                          Code usefull for debugging (DBG should be activated in config.h)
- BLE/Common/tl/*.*                             HCI layer and SPI protocol
- BLE/Common/hw/*.*                             HW board and device dependencies (SPI pins, timeserver, low power)
- BLE/Common/utilities/*.*                      Scheduler, memory/queue/fifo/list management, otp, etc
```

Create New Project
(And Find Location of Repository)



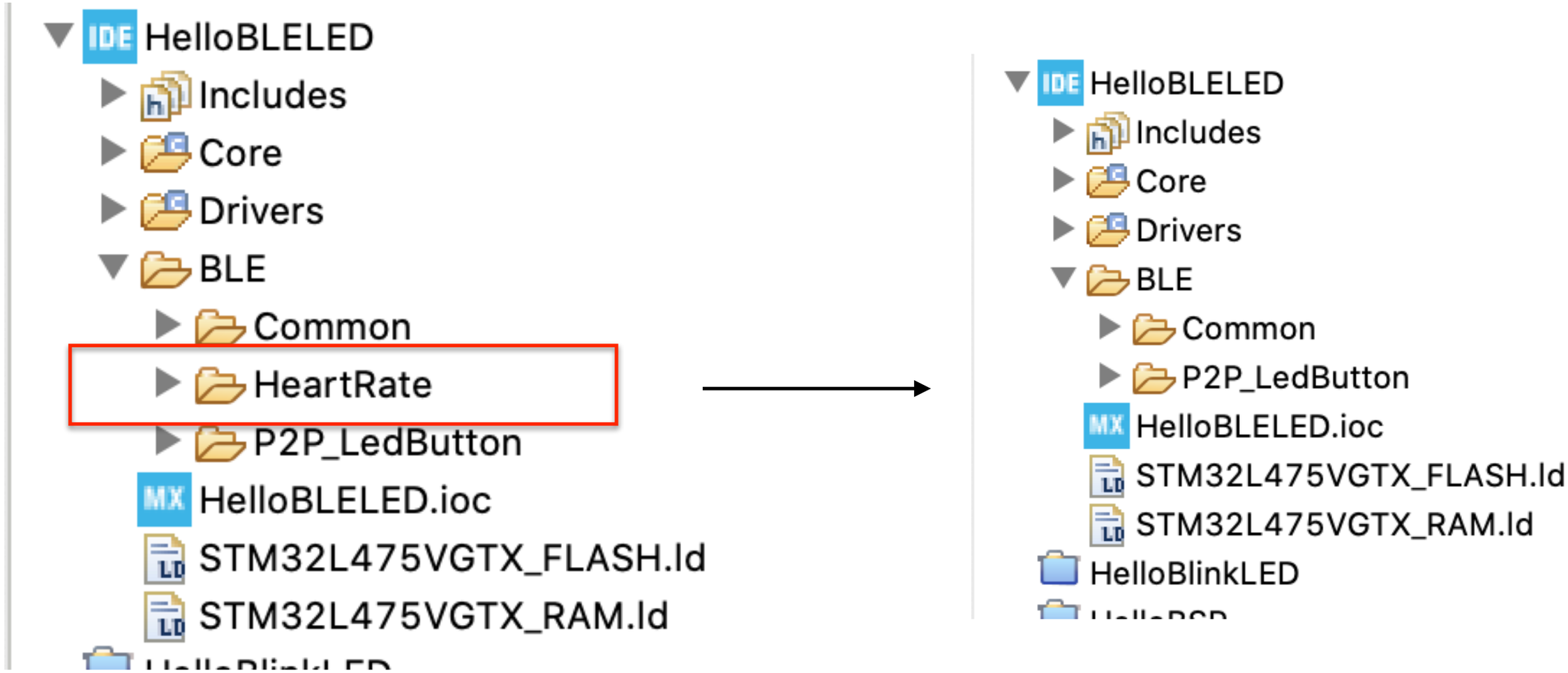


BLE Folder Drag/Drop (COPY FILES)

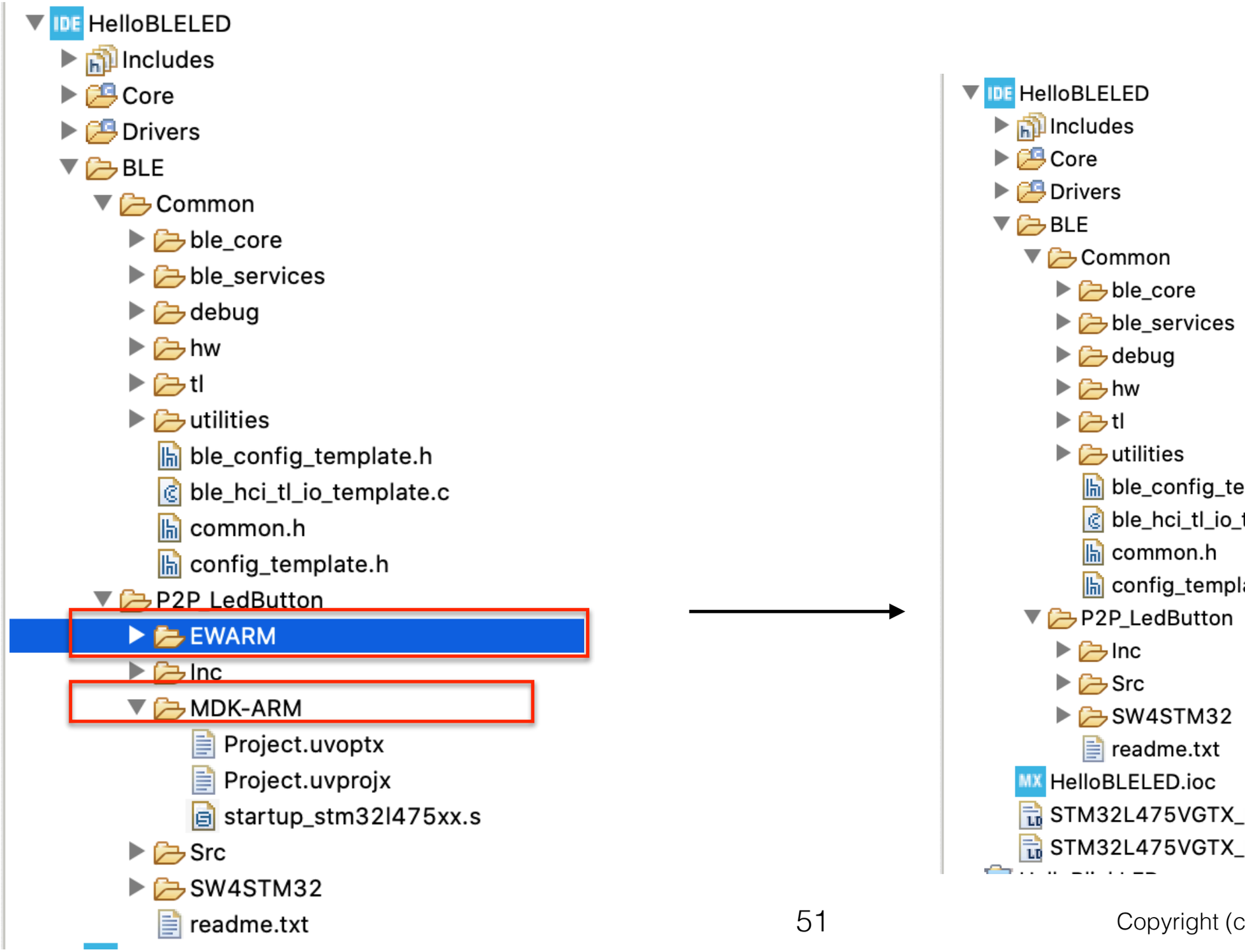


NOTE: Notice BLE Folder at top level with Core and Drivers

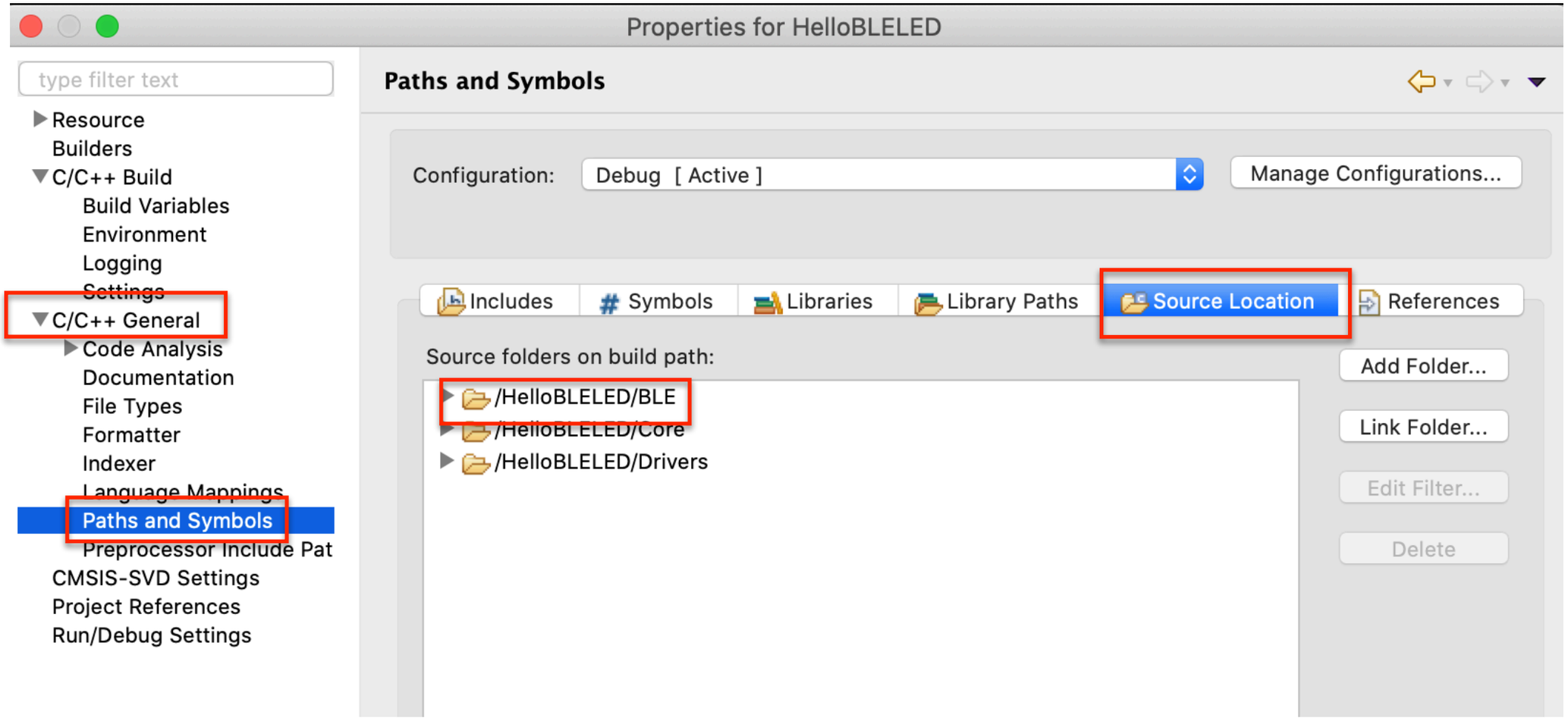
Delete HeartRate Folder



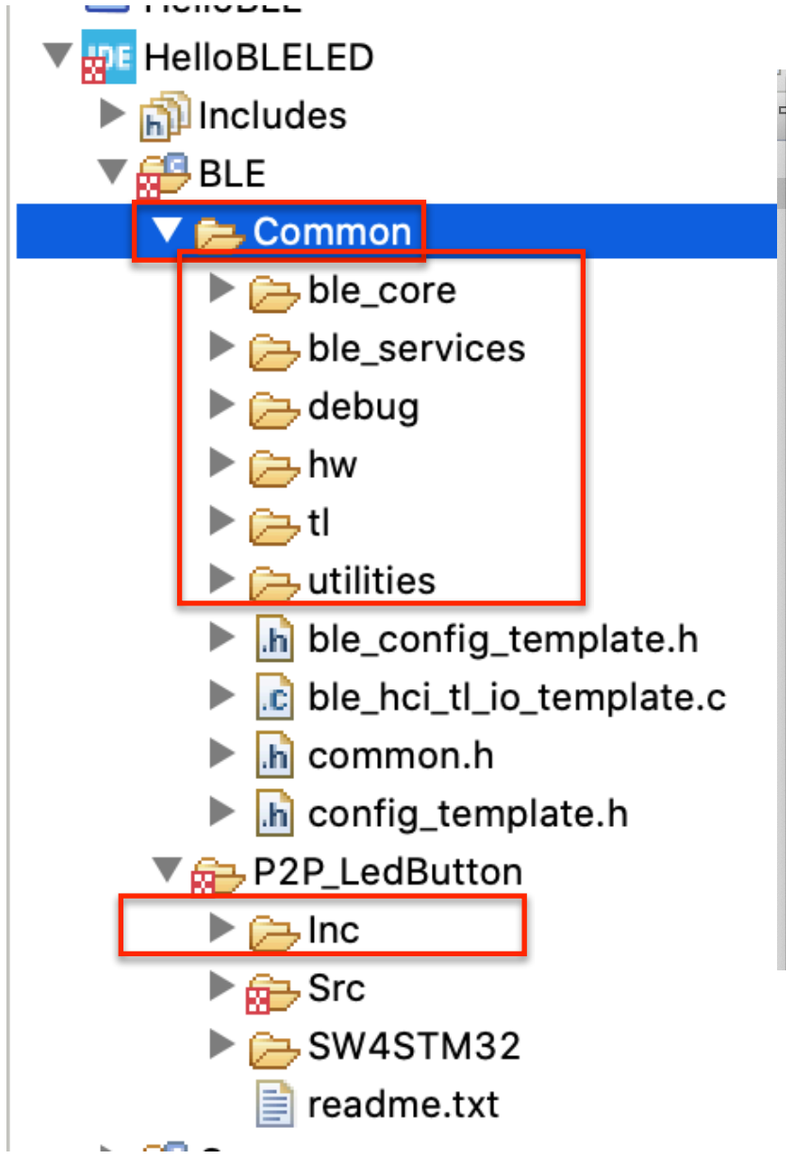
Delete EWARM Folder and MDK-ARM Folder

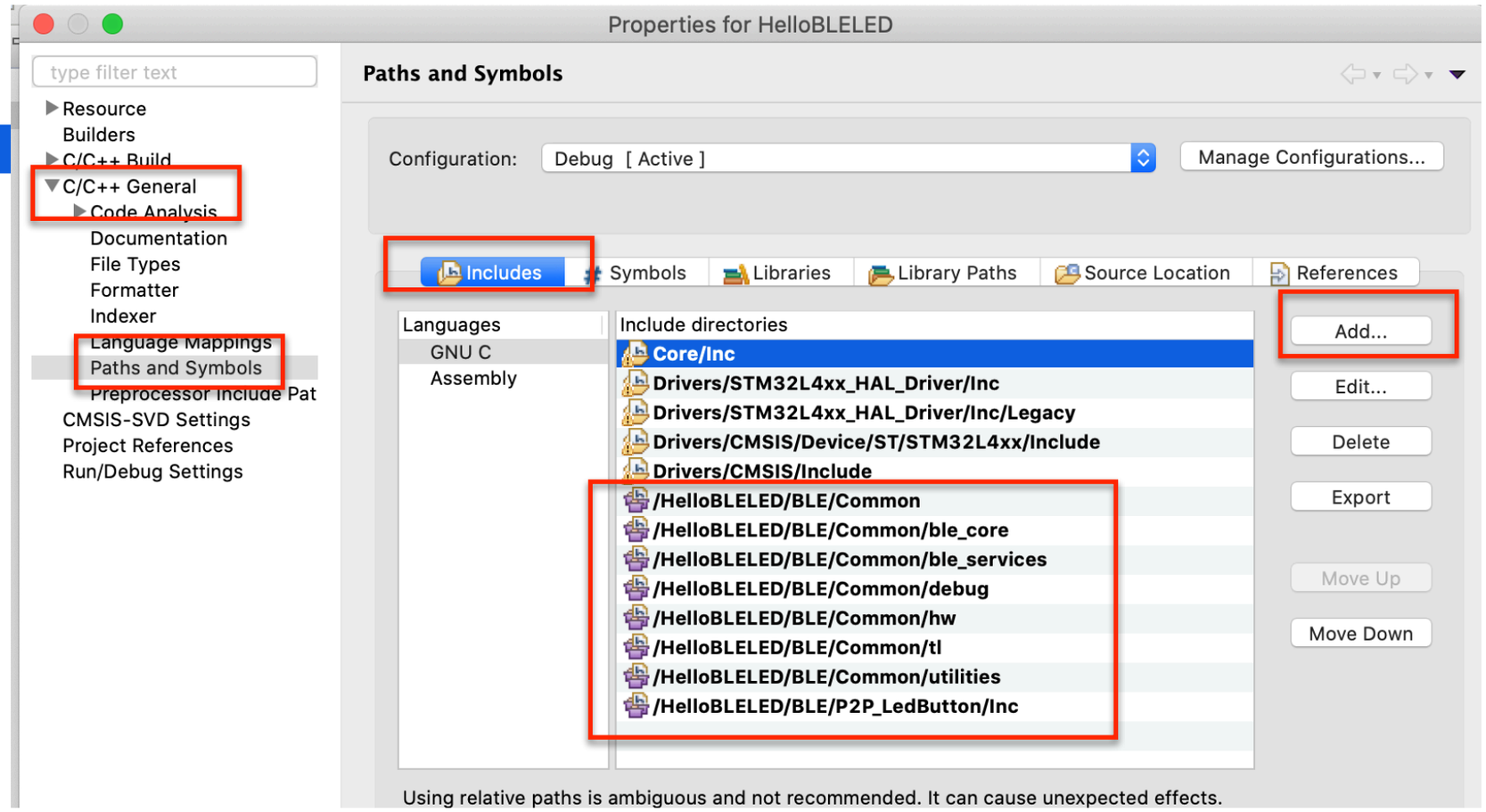


Add BLE to Source Path



Add Include Paths To Project Properties

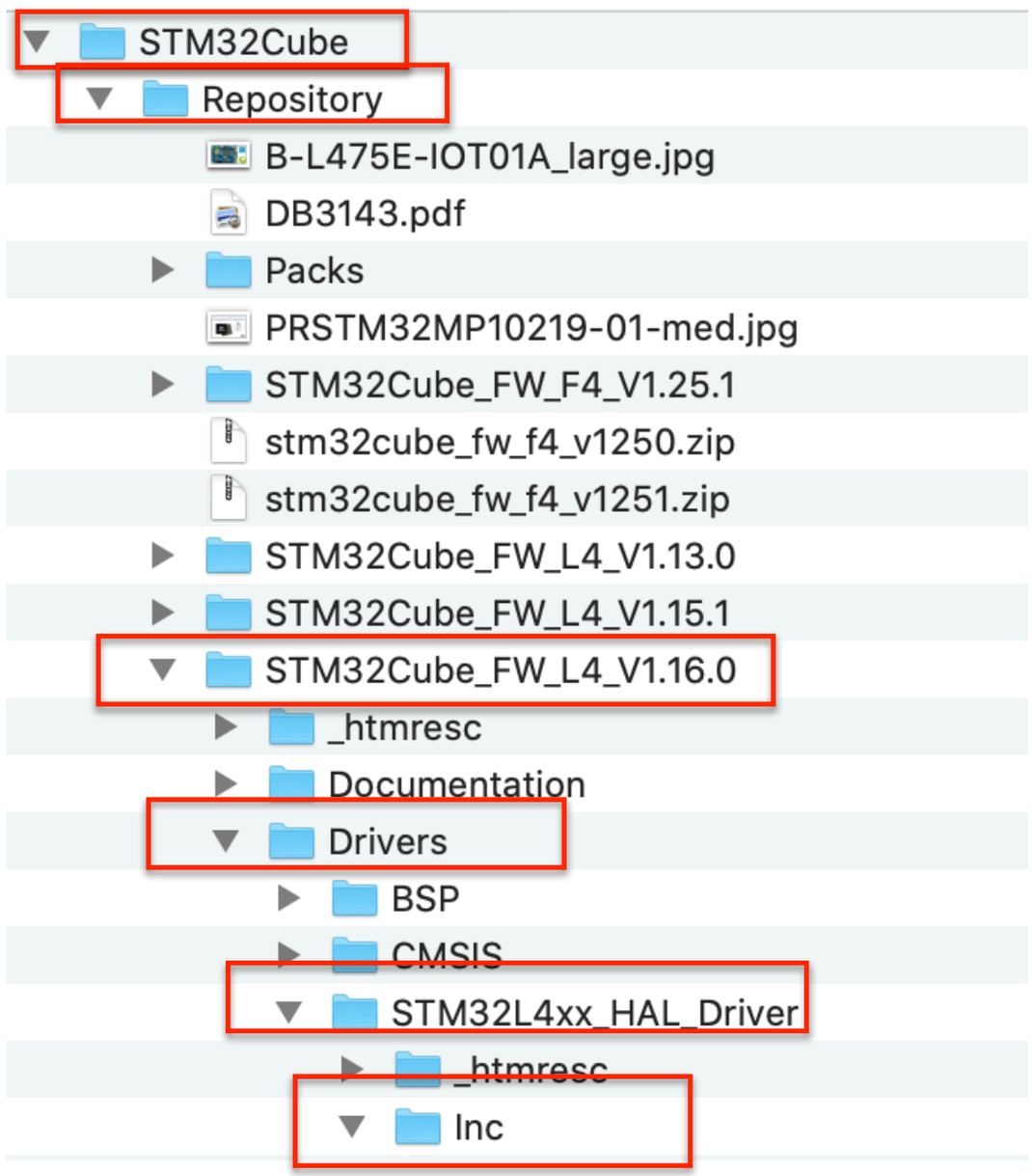




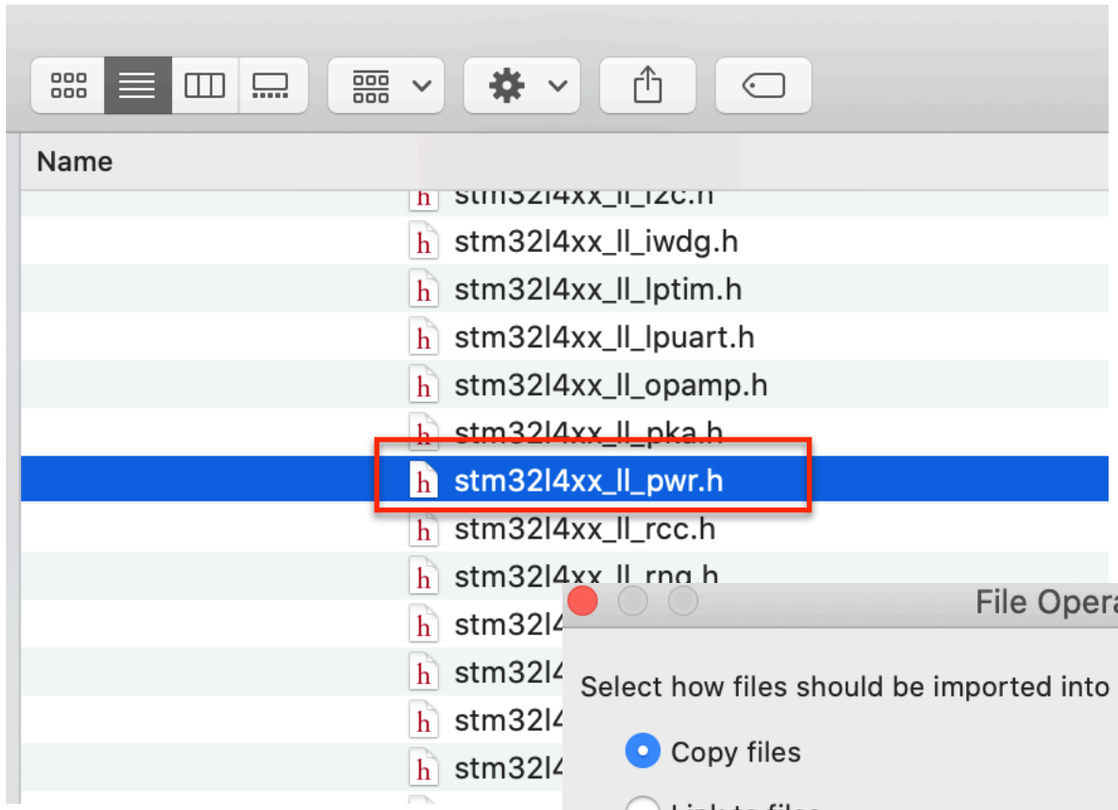
Attempt to Build Missing Header File stm32l4xx_ll_pwr.h

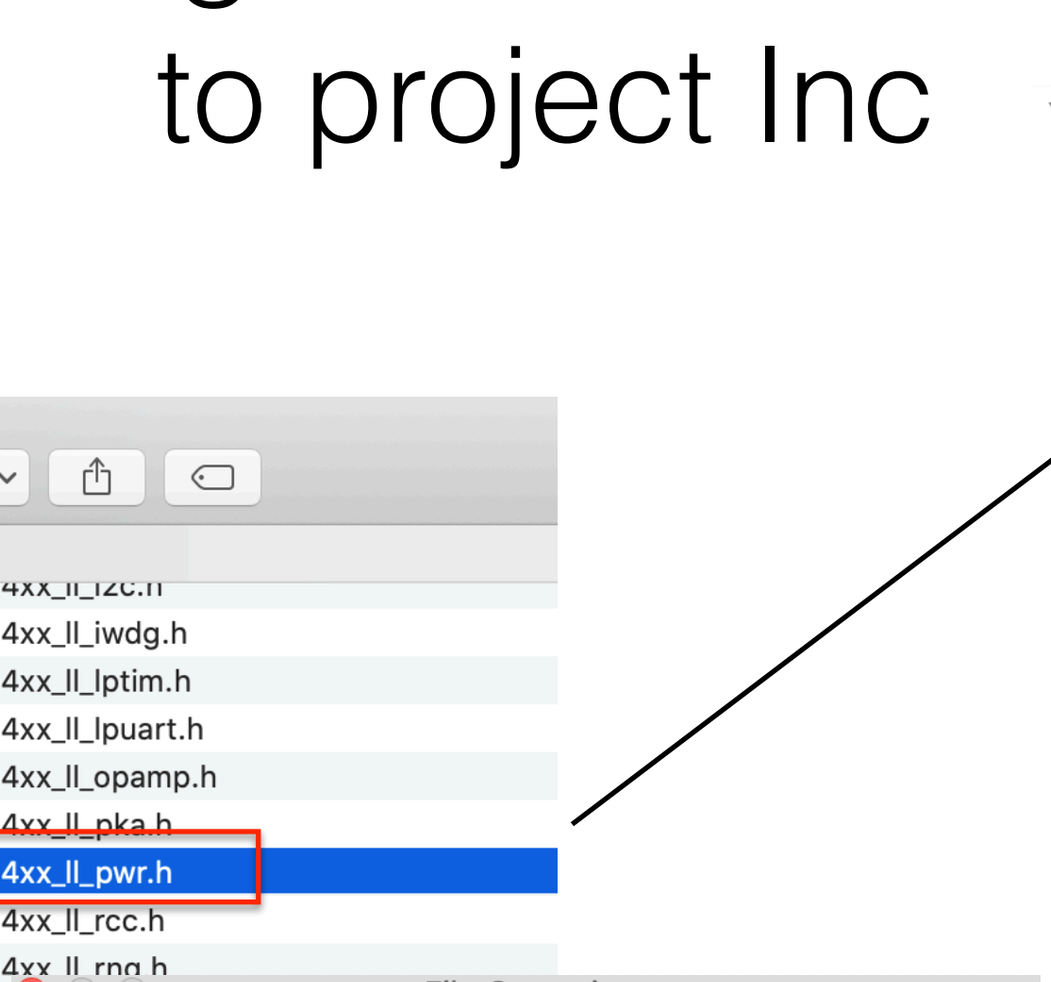
```
arm-none-eabi-gcc "../Core/Src/system_stm32l4xx.c" -mcpu=cortex-m4 -std=gnu11 -g3 -DUSE_HAL_DRIVER -DDEBUG -DSTM32L475xx -c -I../Core/Inc -I../D
arm-none-eabi-gcc "../BLE/P2P_LedButton/Src/lb_client_app.c" -mcpu=cortex-m4 -std=gnu11 -g3 -DUSE_HAL_DRIVER -DDEBUG -DSTM32L475xx -c -I../Core/
In file included from /Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/BLE/P2P_LedButton/Inc/config.h:28:0,
                 from /Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/BLE/Common/common.h:35,
                 from ../BLE/P2P_LedButton/Src/lb_client_app.c:22:
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/BLE/Common/hw/hw.h:30:10: fatal error: stm32l4xx_ll_pwr.h: No such file or directory
 #include "stm32l4xx_ll_pwr.h"
          ^~~~~~~~~~~~~~~~~~~~
compilation terminated.
make: *** [BLE/P2P_LedButton/Src/subdir.mk:33: BLE/P2P_LedButton/Src/lb_client_app.o] Error 1
make: *** Waiting for unfinished jobs....
"make -j3 all" terminated with exit code 2. Build might be incomplete.
```

Where to find needed header files



Copy Missing stm32l4xx_ll_pwr.h file to project Inc

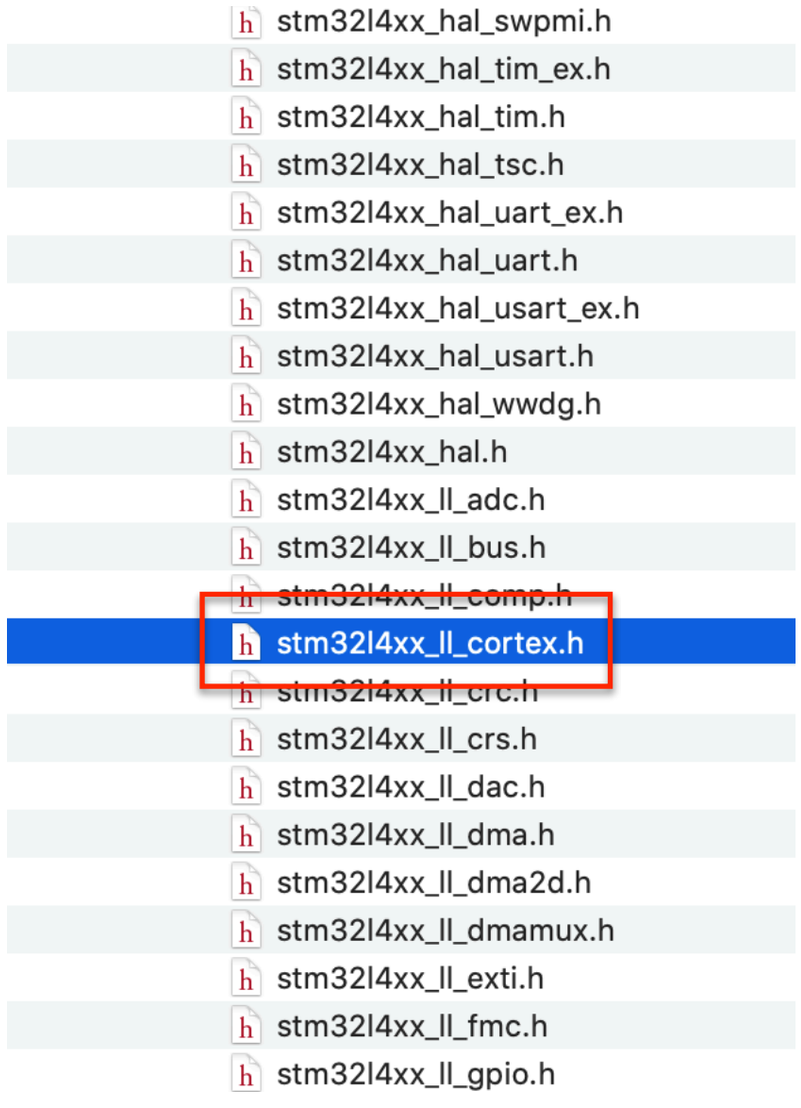


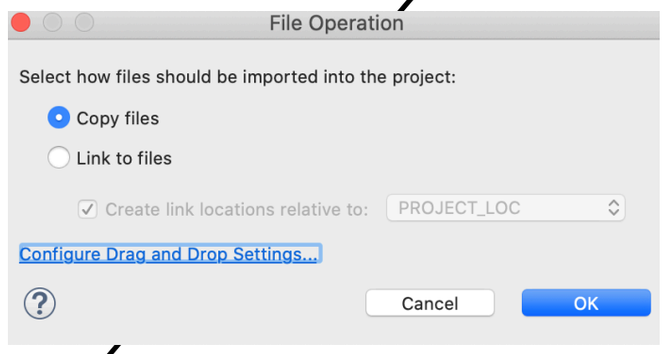


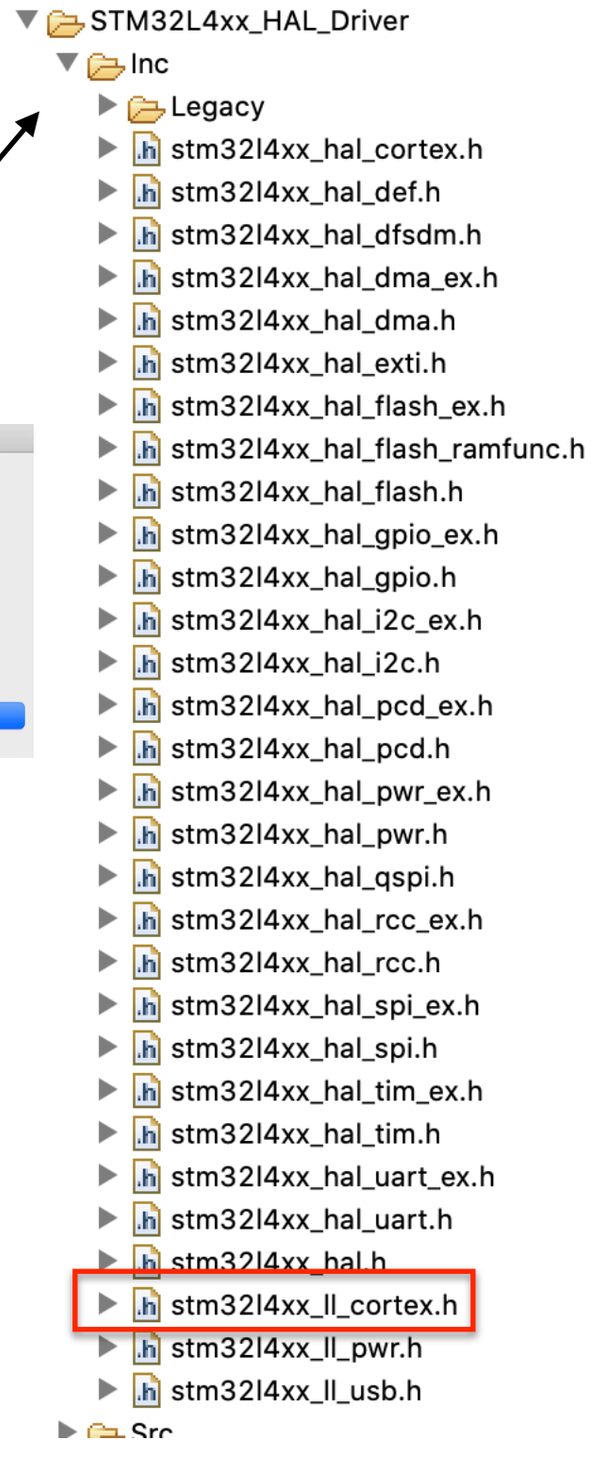
Attempt to Build Missing Header File stm32l4xx_ll_cortex.h

```
CDT Build Console [HelloBLELED]
06:58:38 **** Incremental Build of configuration Debug
make -j3 all
arm-none-eabi-gcc "../BLE/P2P_LedButton/Src/lb_client_a
arm-none-eabi-gcc "../BLE/P2P_LedButton/Src/lb_demo.c"
arm-none-eabi-gcc "../BLE/P2P_LedButton/Src/lb_server_a
In file included from /Users/nmcentire/STM32CubeIDE/wor
                 from /Users/nmcentire/STM32CubeIDE/wor
                 from ../BLE/P2P_LedButton/Src/lb_clien
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLEL
 #include "stm32l4xx_ll_cortex.h"
          ^~~~~~~~~~~~~~~~~~~~~~~
compilation terminated.
In file included from /Users/nmcentire/STM32CubeIDE/wor
                 from /Users/nmcentire/STM32CubeIDE/wor
```

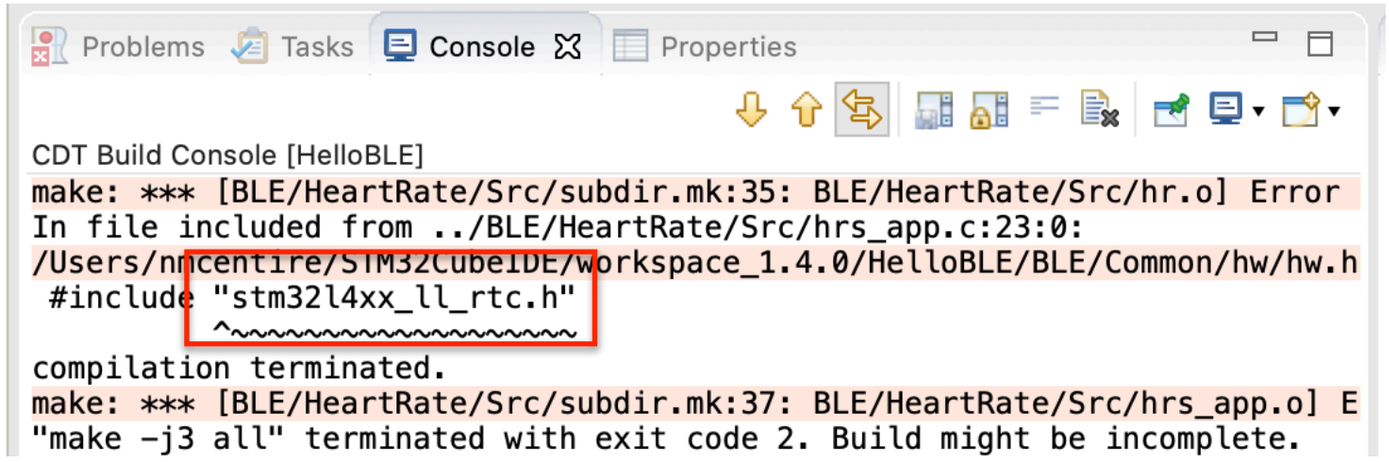
Copy Missing stm32l4xx_ll_cortex.h file to project Inc



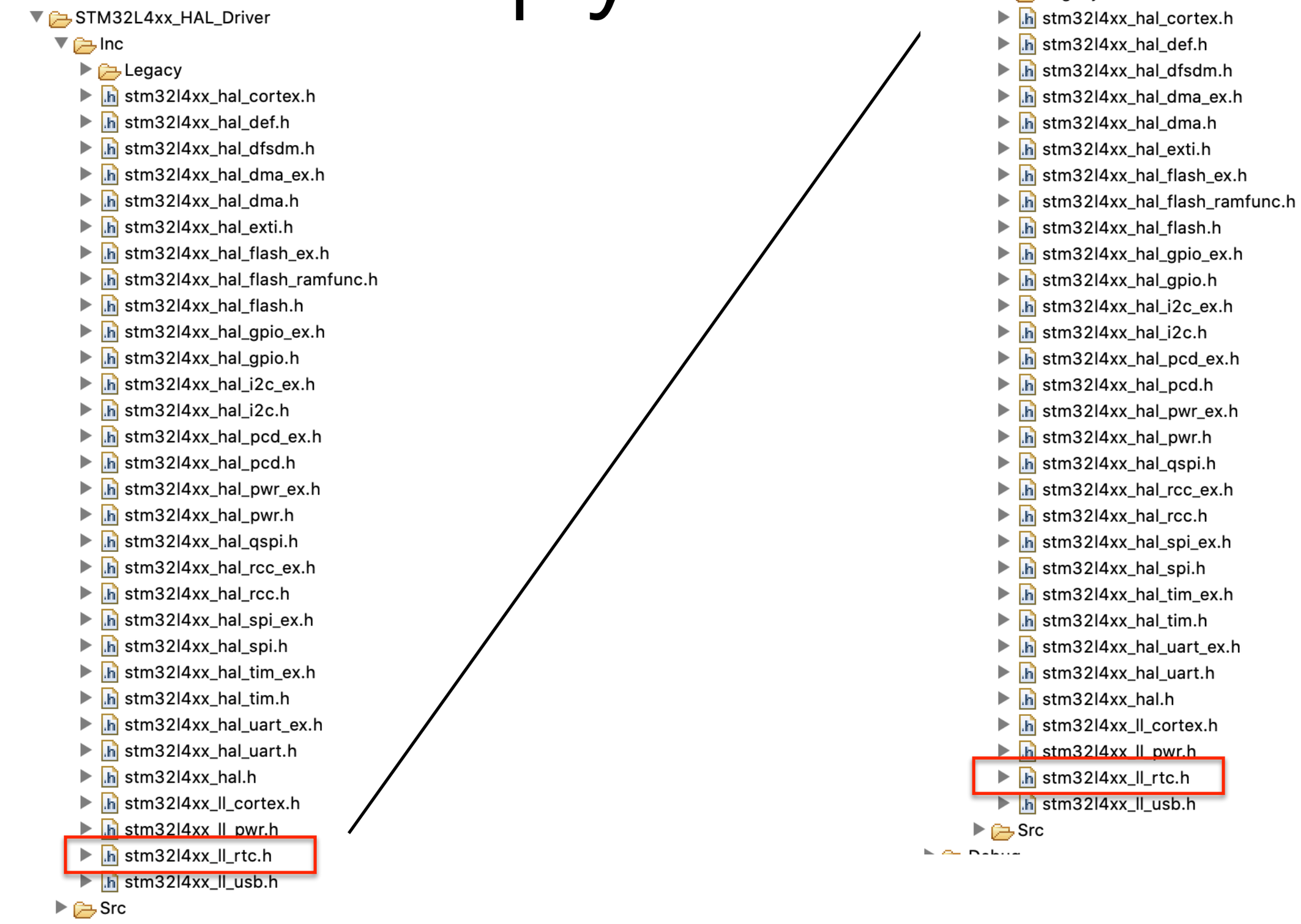




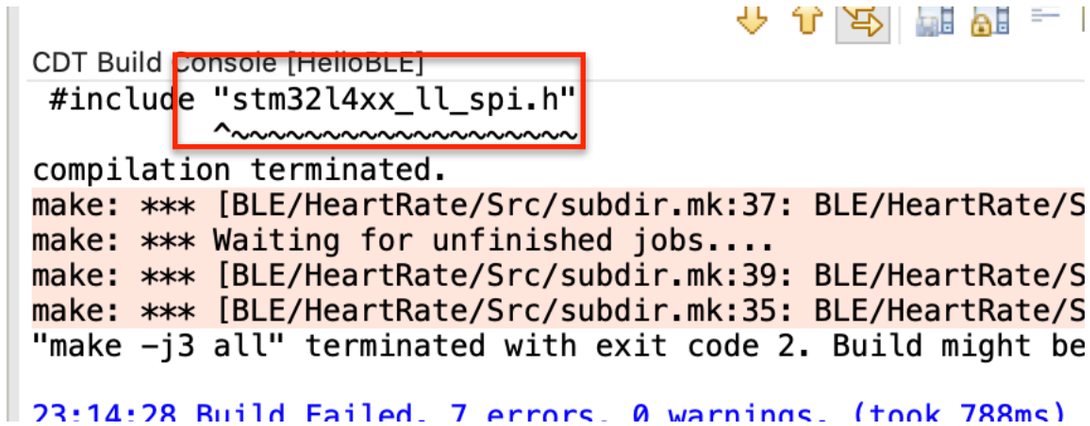
Attempt to build



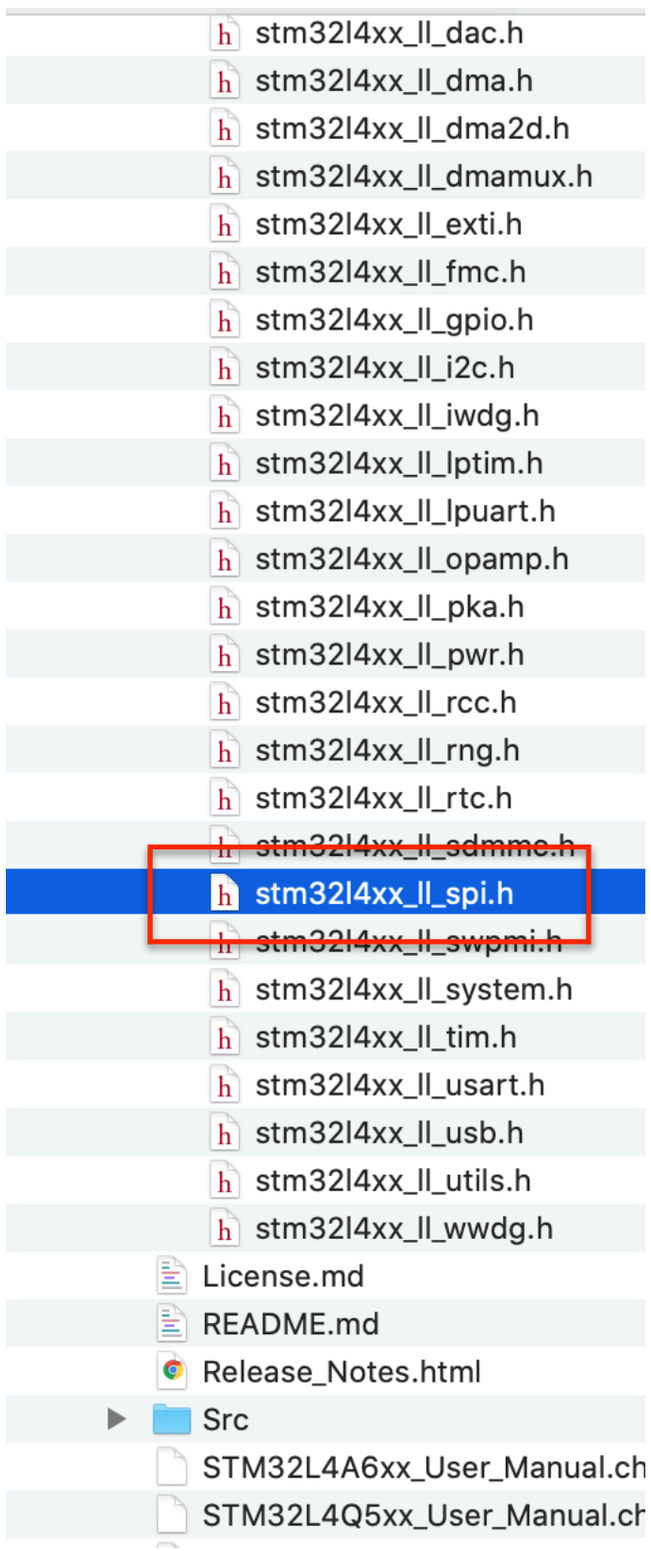
Copy File

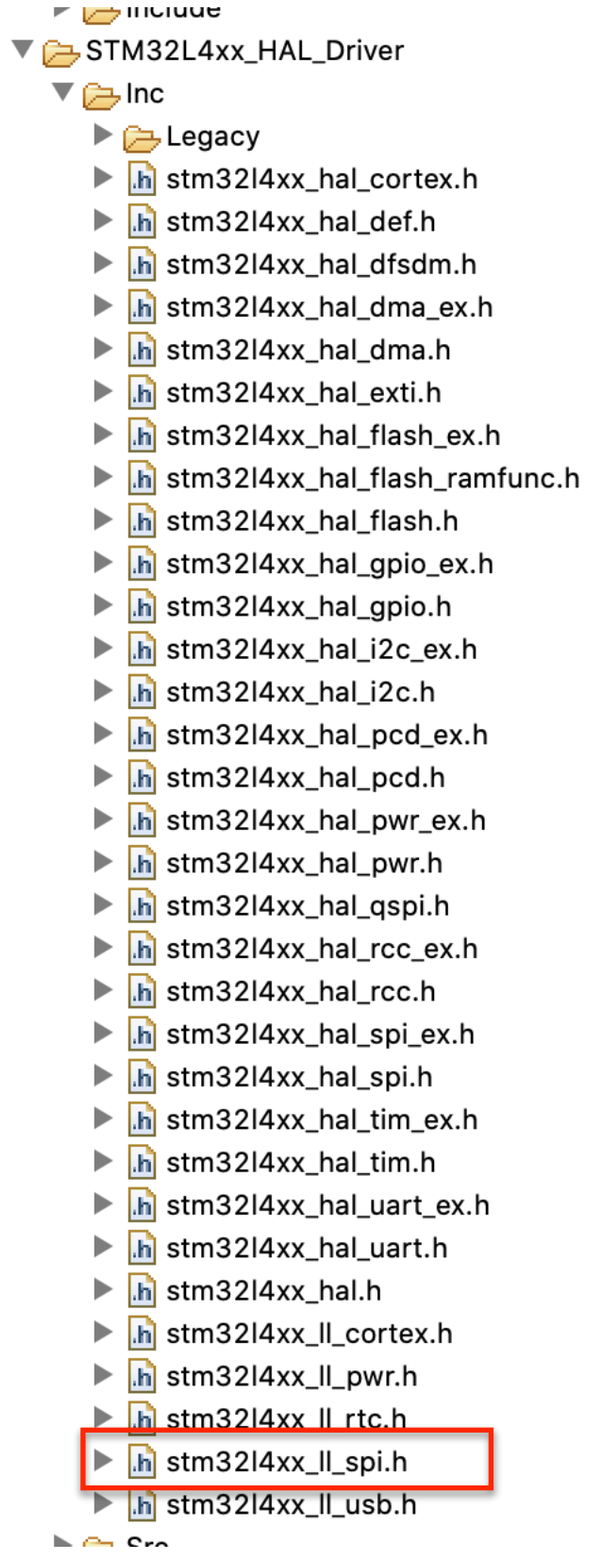


Attempt to build



Copy File



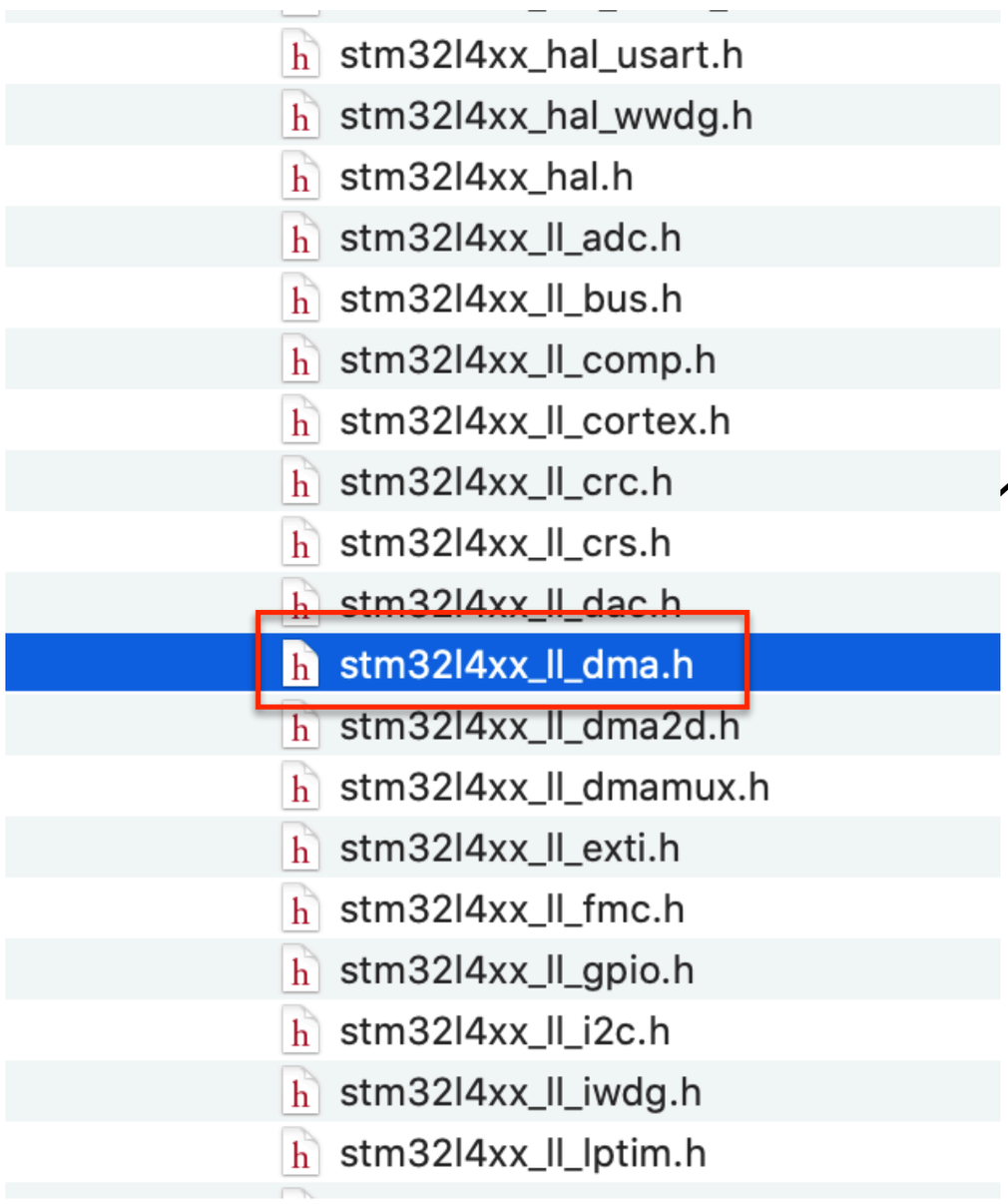


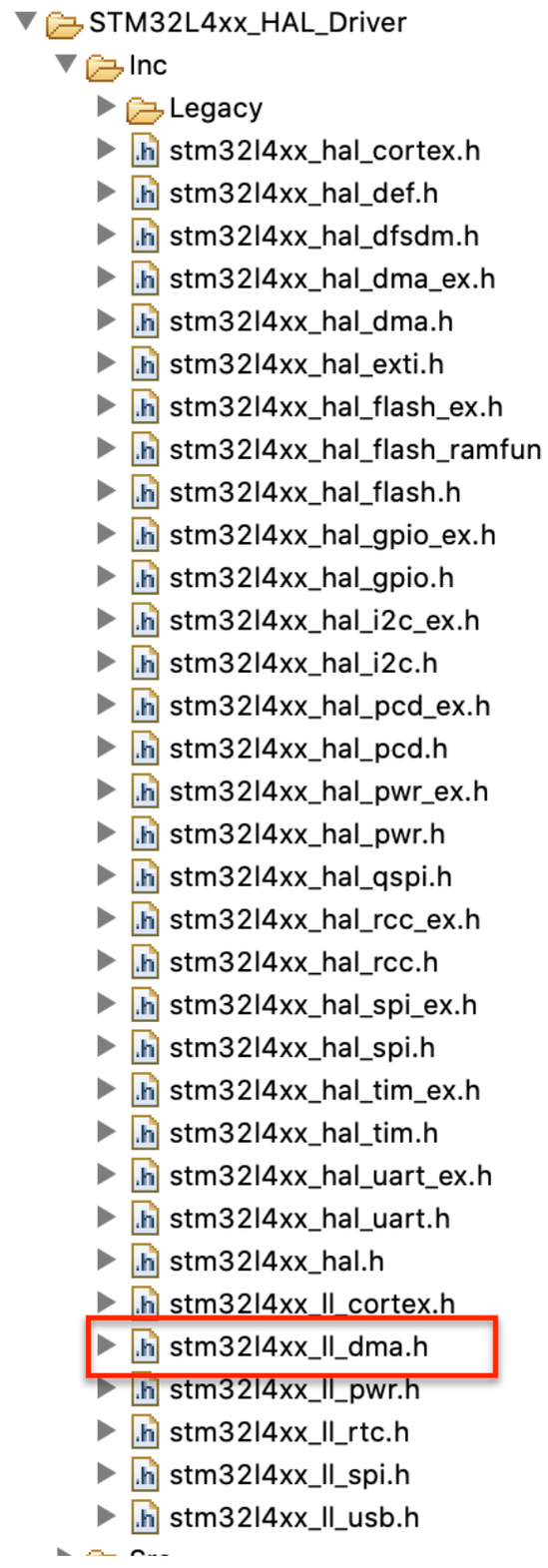
Attempt to build

CDT Build Console [HelloBLELED]

```
07:08:05 **** Incremental Build of configuration Debug
make -j3 all
arm-none-eabi-gcc "../BLE/P2P_LedButton/Src/lb_client_a
arm-none-eabi-gcc "../BLE/P2P_LedButton/Src/lb_demo.c"
arm-none-eabi-gcc "../BLE/P2P_LedButton/Src/lb_server_a
In file included from /Users/nmcentire/STM32CubeIDE/wor
                 from /Users/nmcentire/STM32CubeIDE/wor
                 from ../BLE/P2P_LedButton/Src/lb_clien
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLEL
 #include "stm32l4xx_ll_dma.h"
          ^~~~~~~~~~~~~~~~~~~~
compilation terminated.
In file included from /Users/nmcentire/STM32CubeIDE/wor
                 from /Users/nmcentire/STM32CubeIDE/wor
```

Copy File

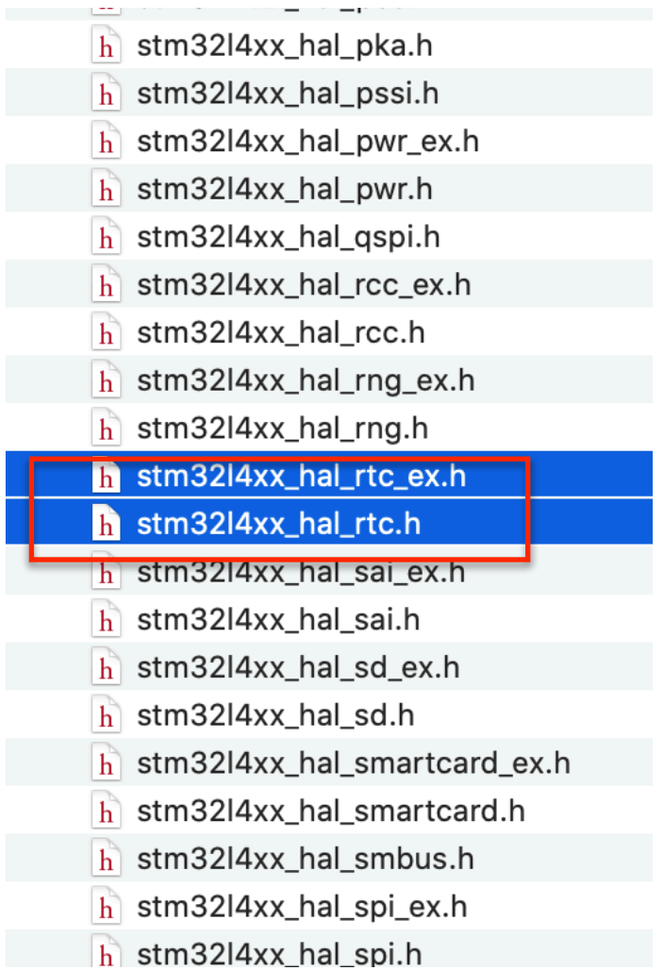


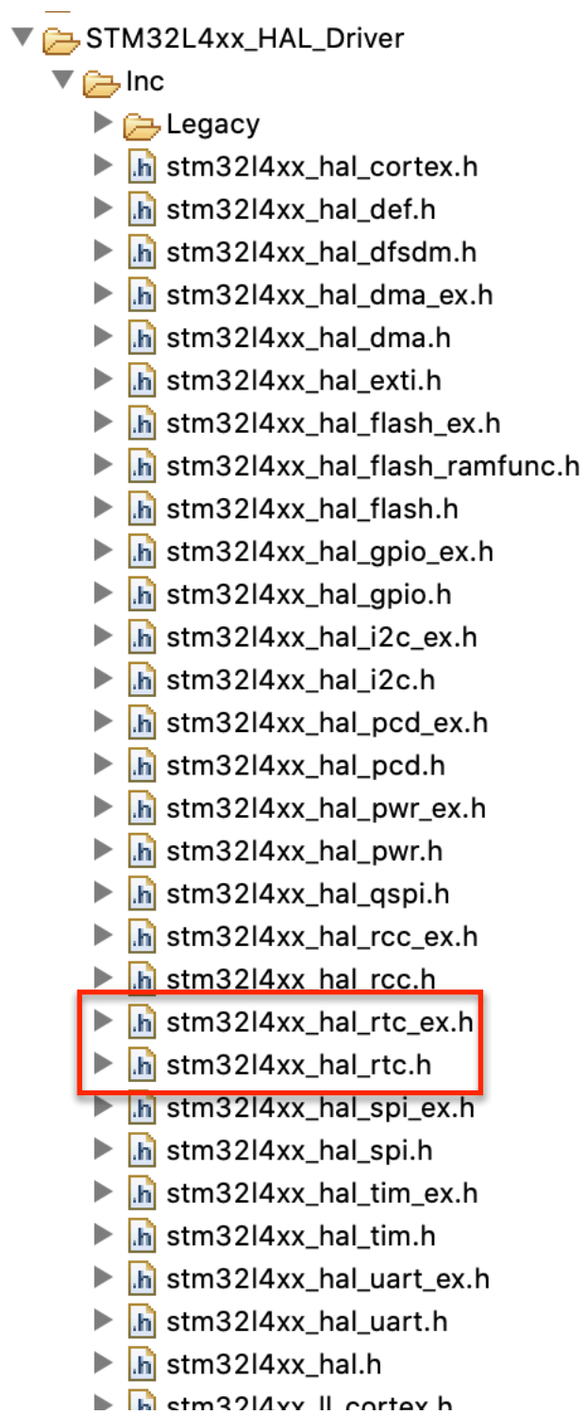


Attempt Build

```
CDT Build Console [HelloBLE]
23:39:07 **** Incremental Build of configuration Debug for project HelloBLE ****
make -j3 all
arm-none-eabi-gcc "../BLE/HeartRate/Src/hr.c" -mcpu=cortex-m4 -std=gnu11 -g3 -DUSE_HAL_DRIVER -DDEBUG -DSTM32L475xx -c -I../Core/
arm-none-eabi-gcc "../BLE/HeartRate/Src/hrs_app.c" -mcpu=cortex-m4 -std=gnu11 -g3 -DUSE_HAL_DRIVER -DDEBUG -DSTM32L475xx -c -I../
arm-none-eabi-gcc "../BLE/HeartRate/Src/main.c" -mcpu=cortex-m4 -std=gnu11 -g3 -DUSE_HAL_DRIVER -DDEBUG -DSTM32L475xx -c -I../Cor
In file included from ../BLE/HeartRate/Src/hrs_app.c:23:0:
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLE/BLE/Common/hw/hw.h:97:51: error: unknown type name 'RTC_HandleTypeDef'; di
   void HW_TS_Init(HW_TS_InitMode_t TimerInitMode, RTC_HandleTypeDef *hrtc);
                                                   ^~~~~~~~~~~~~~~~~
                                                   I2C_HandleTypeDef
In file included from ../BLE/HeartRate/Src/main.c:22:0:
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLE/BLE/Common/hw/hw.h:97:51: error: unknown type name 'RTC_HandleTypeDef'; di
   void HW_TS_Init(HW_TS_InitMode_t TimerInitMode, RTC_HandleTypeDef *hrtc);
                                                   ^~~~~~~~~~~~~~~~~
                                                   I2C_HandleTypeDef
../BLE/HeartRate/Src/main.c:47:8: error: unknown type name 'RTC_HandleTypeDef'
 static RTC_HandleTypeDef hrtc; /**< RTC handler declaration */
```

Copy TWO Files

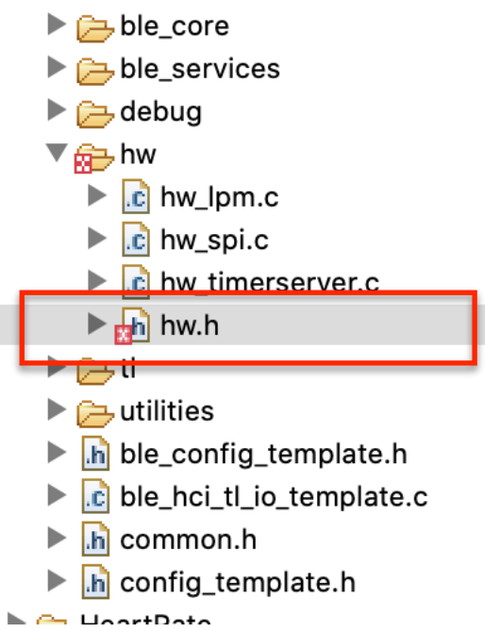




Attempt Build

```
CDT Build Console [HelloBLE]
23:39:07 **** Incremental Build of configuration Debug for project HelloBLE ****
make -j3 all
arm-none-eabi-gcc "../BLE/HeartRate/Src/hr.c" -mcpu=cortex-m4 -std=gnu11 -g3 -DUSE_HAL_DRIVER -DDEBUG -DSTM32L475xx -c -I../Core/
arm-none-eabi-gcc "../BLE/HeartRate/Src/hrs_app.c" -mcpu=cortex-m4 -std=gnu11 -g3 -DUSE_HAL_DRIVER -DDEBUG -DSTM32L475xx -c -I../
arm-none-eabi-gcc "../BLE/HeartRate/Src/main.c" -mcpu=cortex-m4 -std=gnu11 -g3 -DUSE_HAL_DRIVER -DDEBUG -DSTM32L475xx -c -I../Cor
In file included from ../BLE/HeartRate/Src/hrs_app.c:23:0:
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLE/BLE/Common/hw/hw.h:97:51: error: unknown type name 'RTC_HandleTypeDef'; di
   void HW_TS_Init(HW_TS_InitMode_t TimerInitMode, RTC_HandleTypeDef *hrtc);
                                                   ^~~~~~~~~~~~~~~~~
                                                   I2C_HandleTypeDef
In file included from ../BLE/HeartRate/Src/main.c:22:0:
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLE/BLE/Common/hw/hw.h:97:51: error: unknown type name 'RTC_HandleTypeDef'; di
   void HW_TS_Init(HW_TS_InitMode_t TimerInitMode, RTC_HandleTypeDef *hrtc);
                                                   ^~~~~~~~~~~~~~~~~
                                                   I2C_HandleTypeDef
../BLE/HeartRate/Src/main.c:47:8: error: unknown type name 'RTC_HandleTypeDef'
 static RTC_HandleTypeDef hrtc; /**< RTC handler declaration */
```

Edit Header file to add HAL RTC



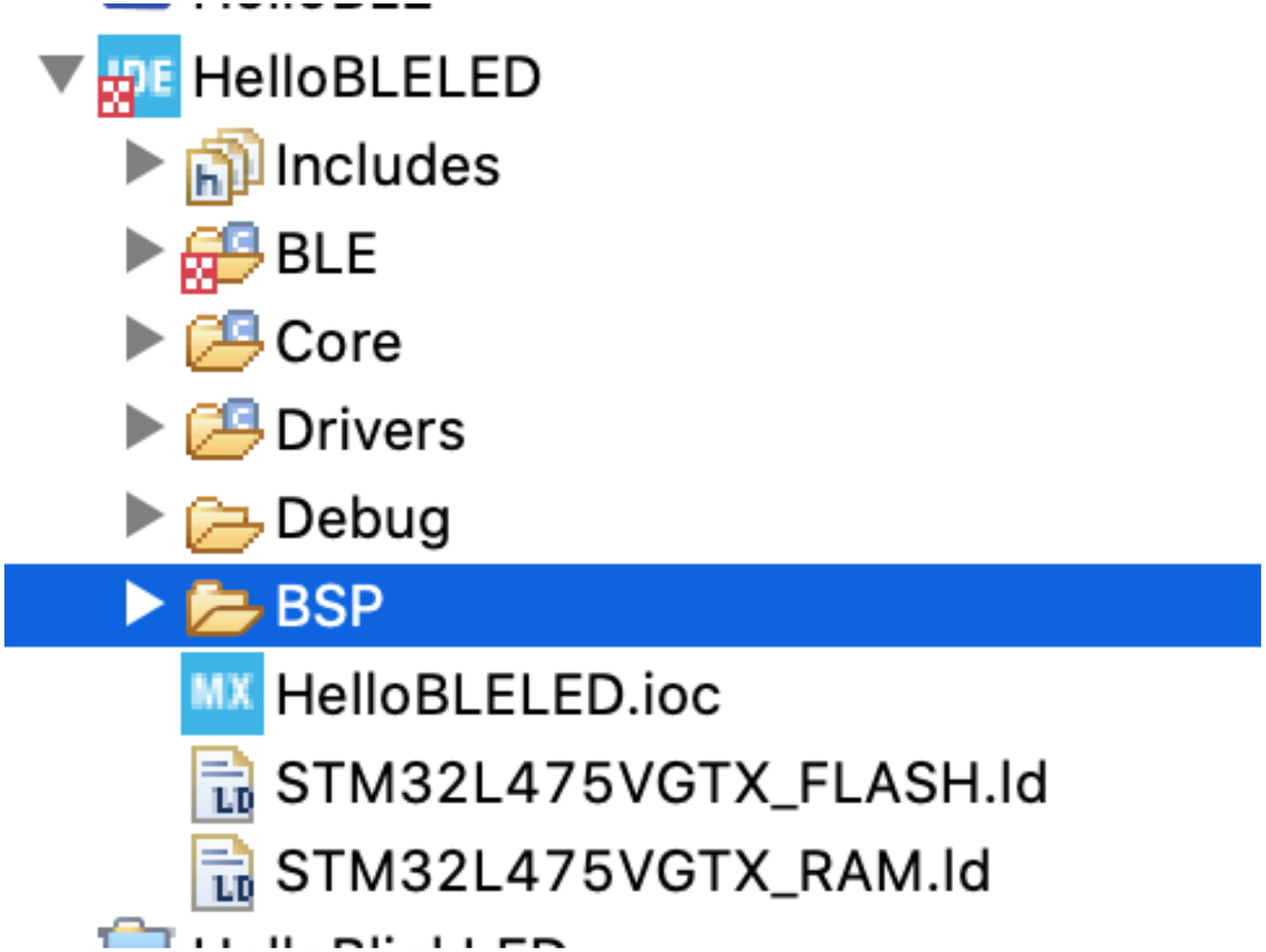

```
23
24  #ifdef __cplusplus
25  extern "C" {
26  #endif
27
28    /* Includes ------------------------------------------------------------------
29  #include "stm32l4xx.h"
30  #include "stm32l4xx_ll_pwr.h"
31  #include "stm32l4xx_ll_cortex.h"
32  #include "stm32l4xx_ll_rtc.h"
33  #include "stm32l4xx_ll_spi.h"
34  #include "stm32l4xx_ll_dma.h"
35
36  #include "stm32l4xx_hal_rtc.h" //For RTC_HandleTypeDef
37
38
39
```

Attempt Build

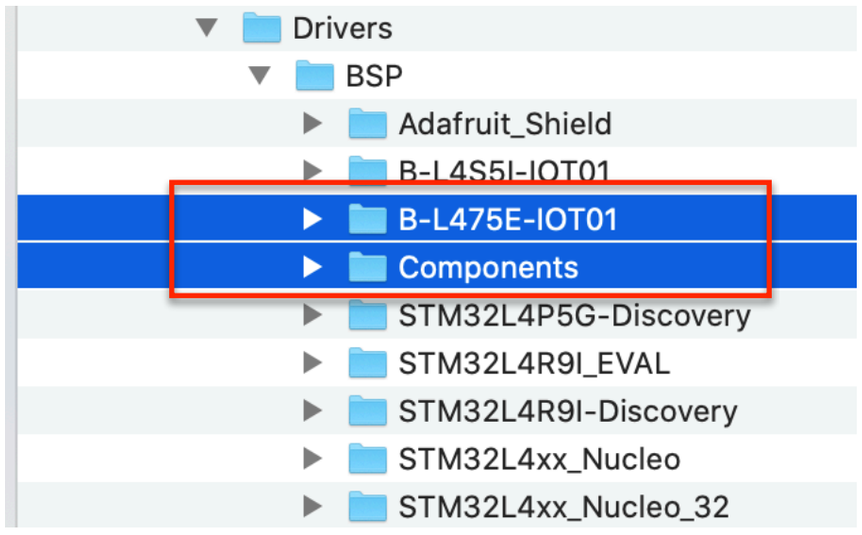
```
arm-none-eabi-gcc "../BLE/P2P_LedButton/Src/lb_client_app.c" -mcpu=cortex-m4 -std=gnu11 -g3 -DUSE_HAL_DRIVER -D
arm-none-eabi-gcc "../BLE/P2P_LedButton/Src/lb_demo.c" -mcpu=cortex-m4 -std=gnu11 -g3 -DUSE_HAL_DRIVER -DDEBUG
arm-none-eabi-gcc "../BLE/P2P_LedButton/Src/lb_server_app.c" -mcpu=cortex-m4 -std=gnu11 -g3 -DUSE_HAL_DRIVER -D
../BLE/P2P_LedButton/Src/lb_demo.c:36:10: fatal error: stm32l475e_iot01.h: No such file or directory
 #include "stm32l475e_iot01.h"
          ^~~~~~~~~~~~~~~~~~~~
compilation terminated.
make: *** [BLE/P2P_LedButton/Src/subdir.mk:35: BLE/P2P_LedButton/Src/lb_demo.o] Error 1
make: *** Waiting for unfinished jobs....
../BLE/P2P_LedButton/Src/lb_server_app.c:30:10: fatal error: stm32l475e_iot01.h: No such file or directory
 #include "stm32l475e_iot01.h"
          ^~~~~~~~~~~~~~~~~~~~
compilation terminated.
../BLE/P2P_LedButton/Src/lb_client_app.c:31:10: fatal error: stm32l475e_iot01.h: No such file or directory
 #include "stm32l475e_iot01.h"
          ^~~~~~~~~~~~~~~~~~~~
compilation terminated.
make: *** [BLE/P2P_LedButton/Src/subdir.mk:37: BLE/P2P_LedButton/Src/lb_server_app.o] Error 1
make: *** [BLE/P2P_LedButton/Src/subdir.mk:33: BLE/P2P_LedButton/Src/lb_client_app.o] Error 1
"make -j3 all" terminated with exit code 2. Build might be incomplete.
```

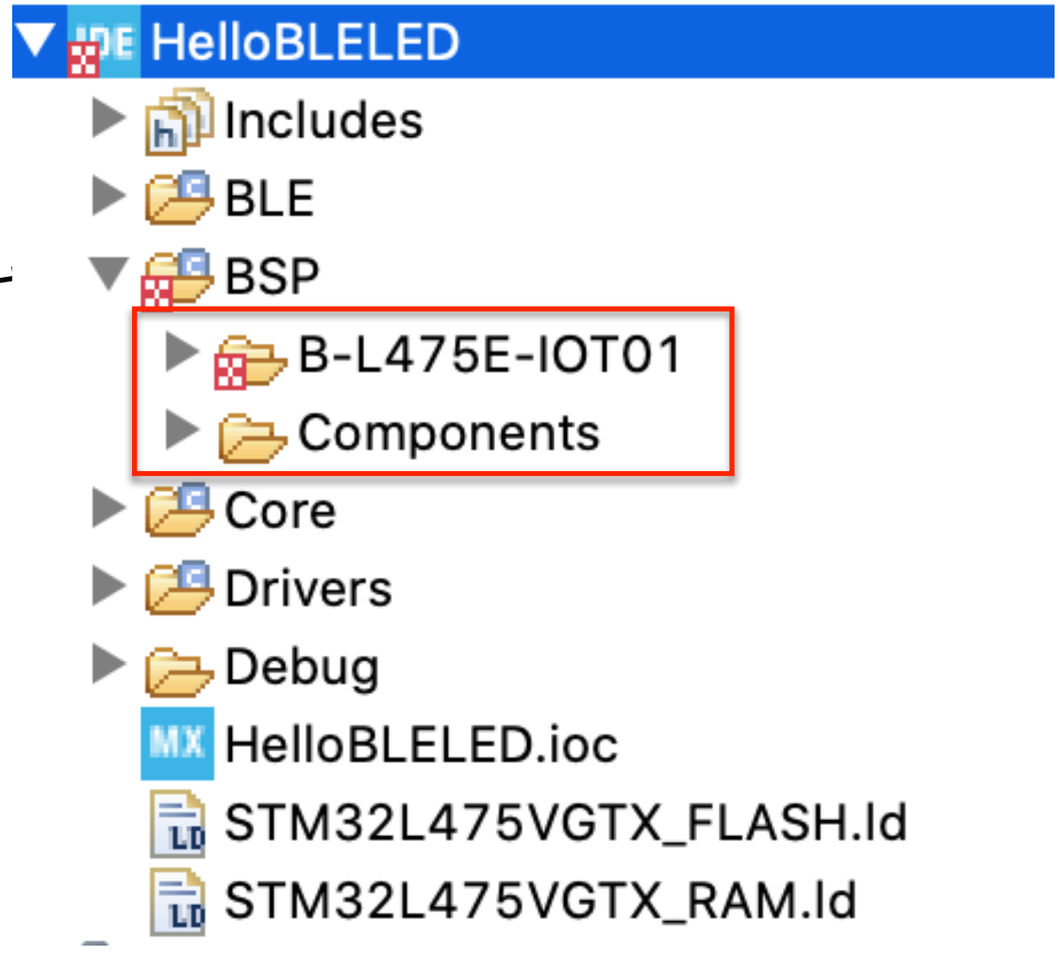
From the board support package

Add BSP Folder To Project

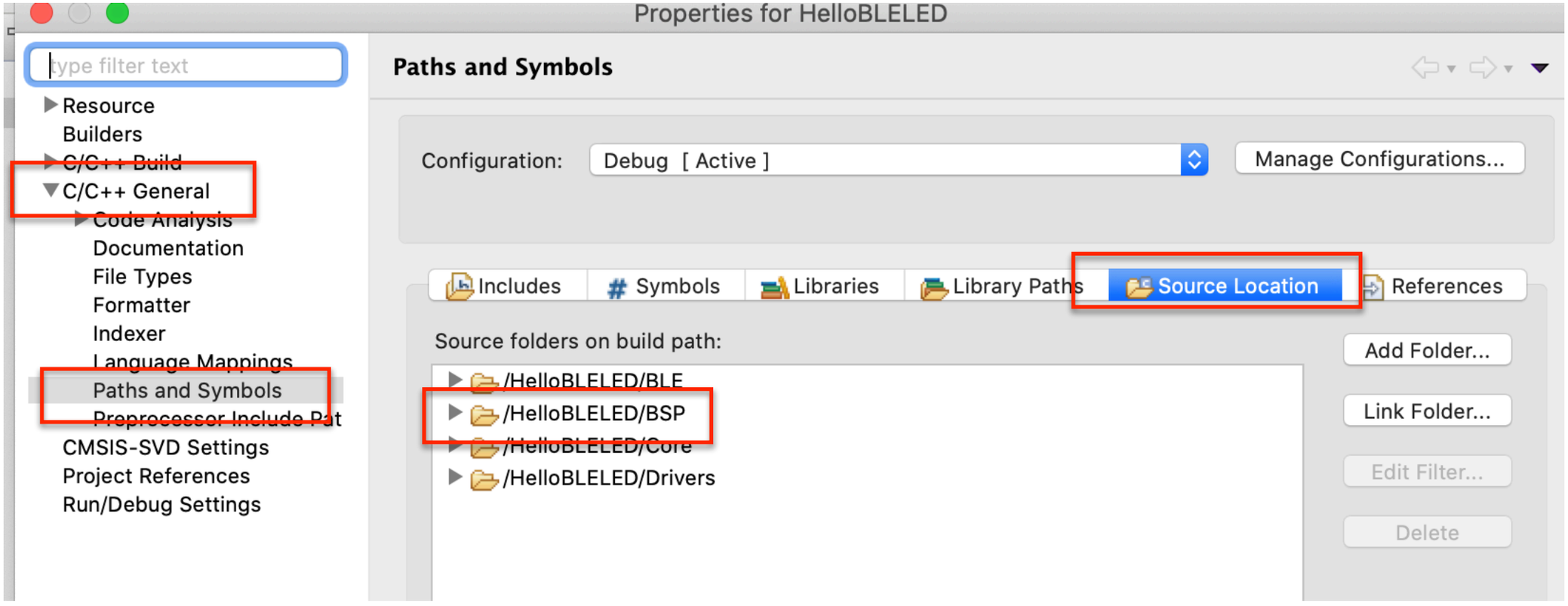


Copy TWO Folder Contents to Project

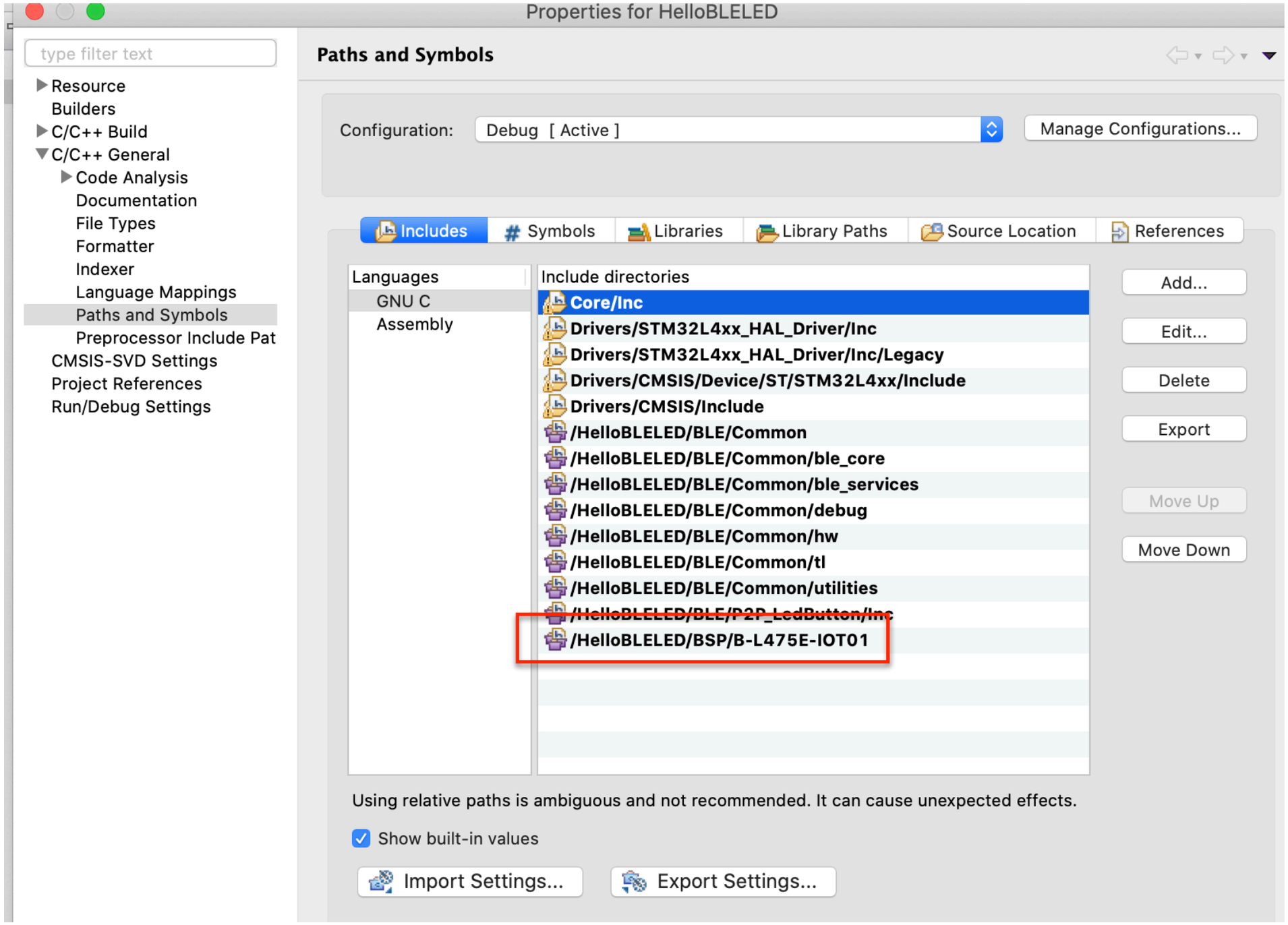




Add Source Location



Add Include Path



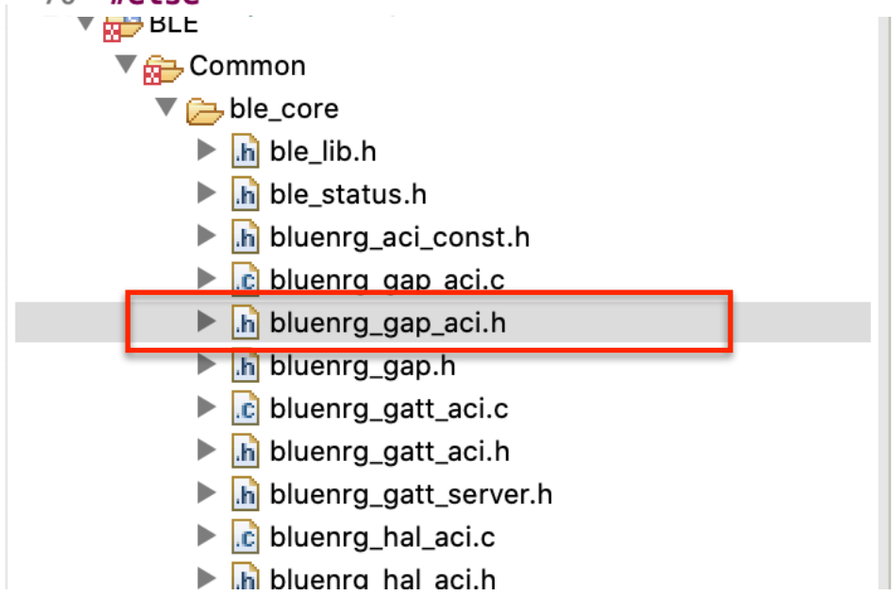
Attempt Build

```
                                                                ^
../BLE/Common/ble_services/svc_ctl.c:154:18: note: in expansion of macro 'SVCCTL_GAP_DEVICE_NAME_LENGTH'
                  SVCCTL_GAP_DEVICE_NAME_LENGTH,
                  ^~~~~~~~~~~~~~~~~~~~~~~~~~~~~
In file included from /Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/BLE/Common/ble_core/ble_lib.h:35:0,
                 from ../BLE/Common/ble_services/svc_ctl.c:28:
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/BLE/Common/ble_core/bluenrg_gap_aci.h:103:12: note: expected 'uint1
 tBleStatus aci_gap_init(uint8_t role,
            ^~~~~~~~~~~~
../BLE/Common/ble_services/svc_ctl.c:152:5: error: too many arguments to function 'aci_gap_init'
     aci_gap_init(role,
     ^~~~~~~~~~~~
In file included from /Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/BLE/Common/ble_core/ble_lib.h:35:0,
                 from ../BLE/Common/ble_services/svc_ctl.c:28:
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/BLE/Common/ble_core/bluenrg_gap_aci.h:103:12: note: declared here
 tBleStatus aci_gap_init(uint8_t role,
            ^~~~~~~~~~~~
make: *** [BLE/Common/ble_services/subdir.mk:33: BLE/Common/ble_services/svc_ctl.o] Error 1
make: *** Waiting for unfinished jobs....
"make -j2 all" terminated with exit code 2. Build might be incomplete.
```

Notice Function Prototype is inside #ifdef

```
#if BLUENRG_MS
///@cond BLUENRG_MS
/**
  * @brief  Initialize the GAP layer.
  * @note   Register the GAP service with the GATT.
  *         All the standard GAP characteristics will also be added:
  *         @li Device Name
  *         @li Appearance
  *         @li Peripheral Preferred Connection Parameters (peripheral role only)
  *         @code
  * @param       role     Bitmap of allowed roles: see @ref gap_roles "GAP roles".
  * @param       privacy_enabled     Enable (1) or disable (0) privacy.
  * @param       device_name_char_len Length of the device name characteristic
  * @param[out]  service_handle  Handle of the GAP service.
  * @param[out]  dev_name_char_handle  Device Name Characteristic handle
  * @param[out]  appearance_char_handle Appearance Characteristic handle
  * @retval tBleStatus Value indicating success or error code.
  */
tBleStatus aci_gap_init(uint8_t role, uint8_t privacy_enabled,
                        uint8_t device_name_char_len,
                        uint16_t* service_handle,
                        uint16_t* dev_name_char_handle,
                        uint16_t* appearance_char_handle);
///@endcond
#else
```

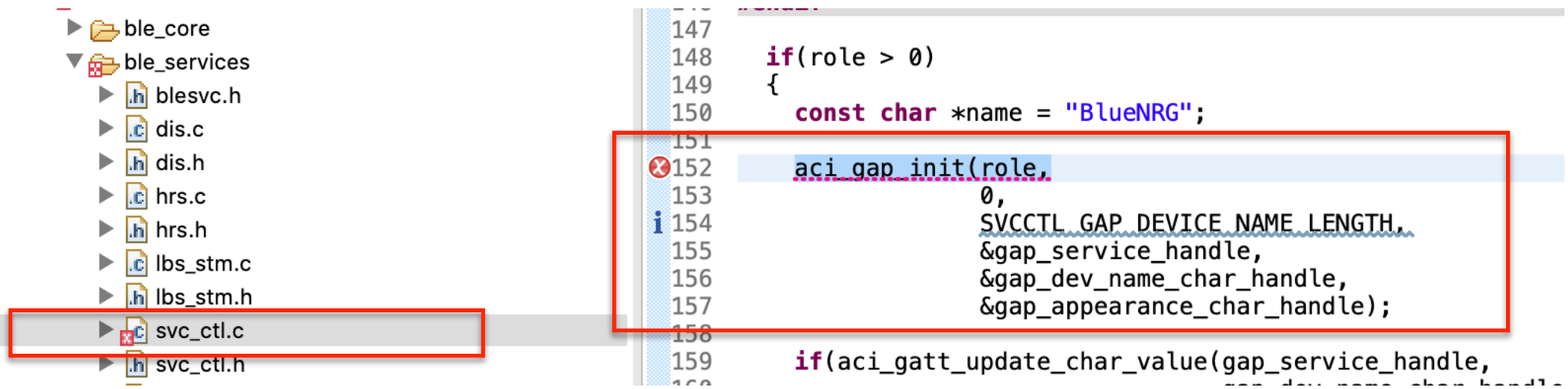
5-Params



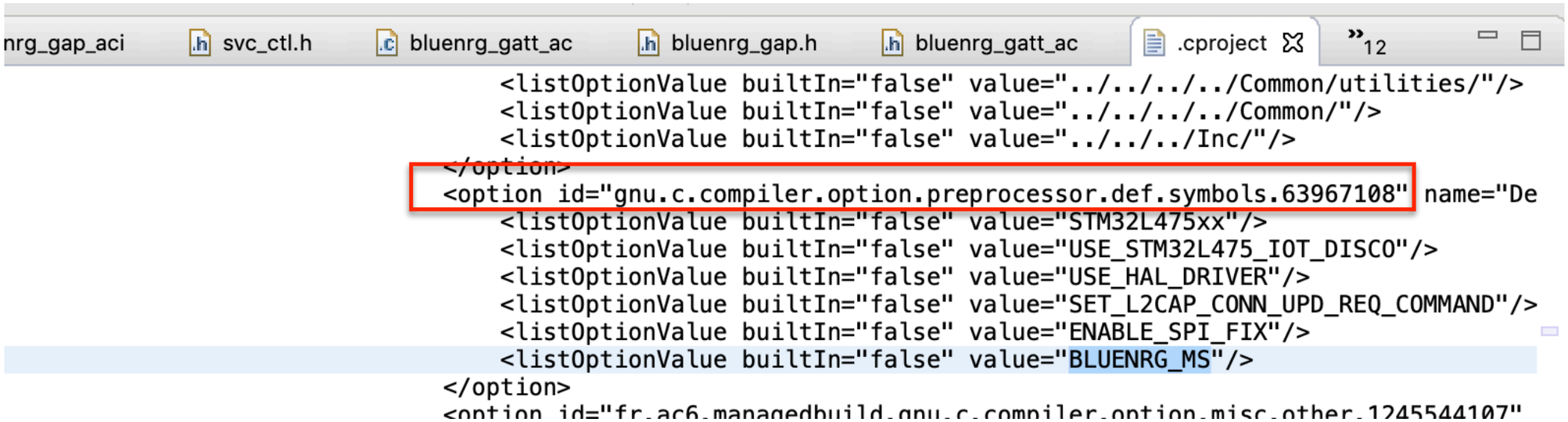

```
  *           if(ret){
  *             PRINTF("aci_gatt_update_char_value failed.\n");
  *           }
  *         @endcode
  * @param       role     One of the allowed roles: @ref GAP_PERIPHERAL_ROLE
  * @param[out]  service_handle  Handle of the GAP service.
  * @param[out]  dev_name_char_handle  Device Name Characteristic handle
  * @param[out]  appearance_char_handle Appearance Characteristic handle
  * @retval tBleStatus Value indicating success or error code.
  */
BleStatus aci_gap_init(uint8_t role,
                       uint16_t* service_handle,
                       uint16_t* dev_name_char_handle,
                       uint16_t* appearance_char_handle);
//@endcond
endif
```

4-Params

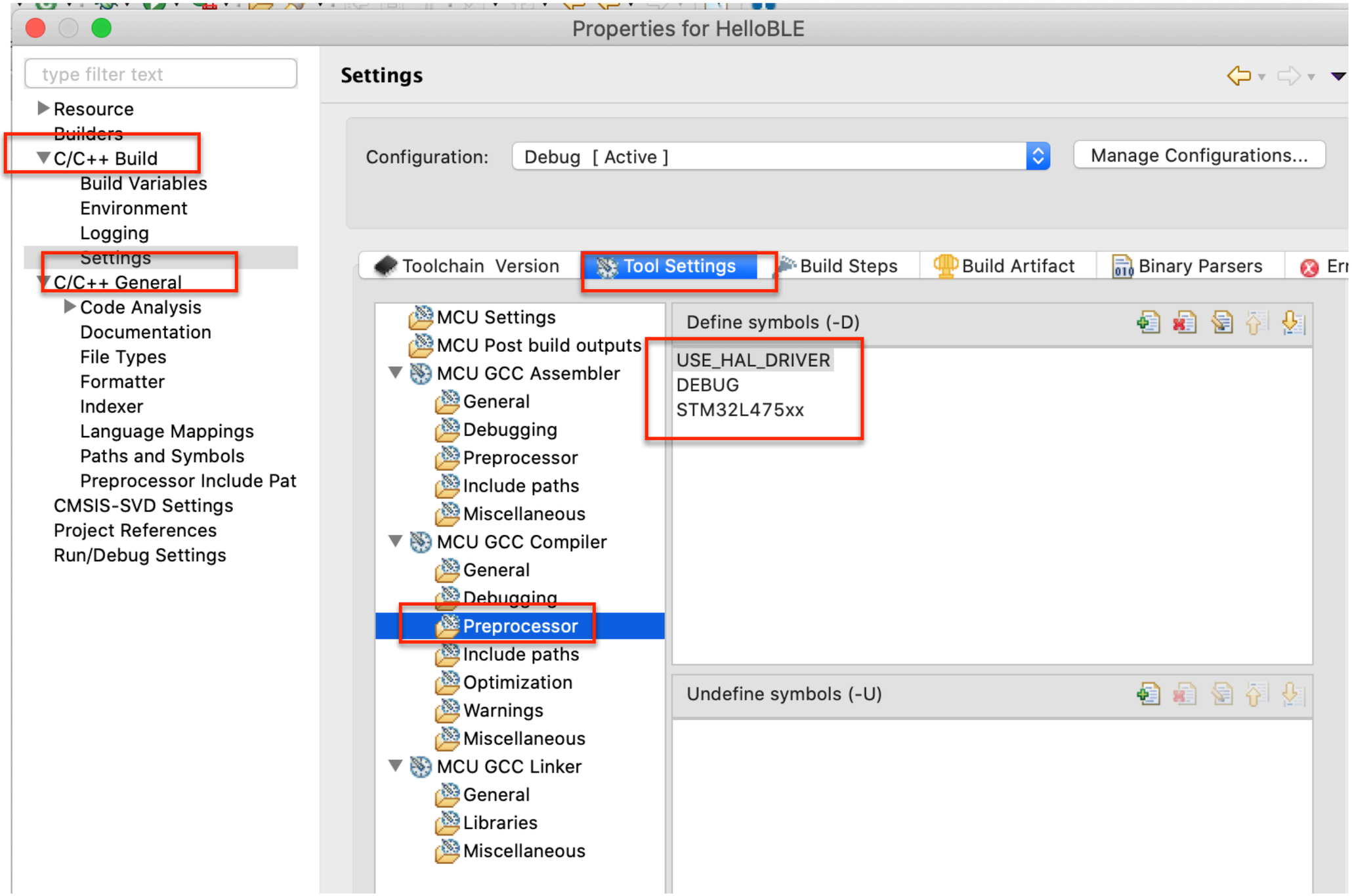
5-Param Version Used By Code



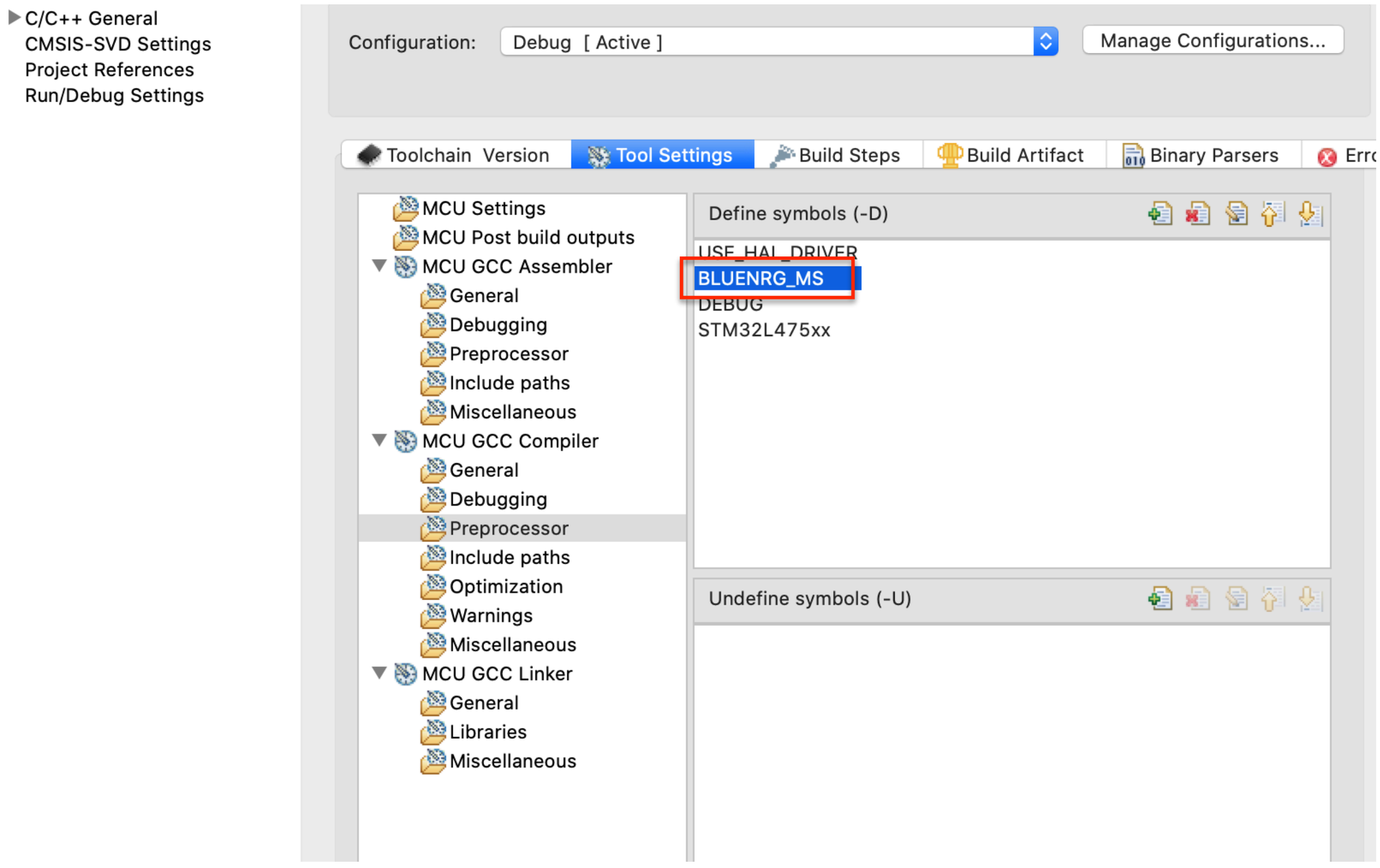
Value of BLUENRG_MS set to false



Original Values



Add Value



Attempt Build

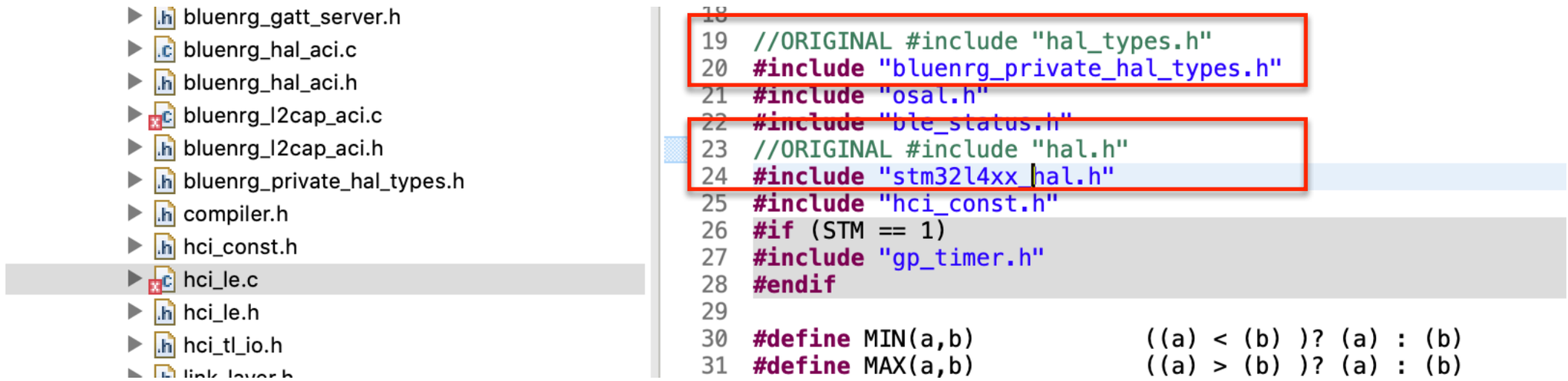
```
arm-none-eabi-gcc "../BLE/Common/ble_core/hci_le.c" -mcpu=cortex-m4 -std=gnu11 -g3 -DUSE_HAL_DRIVER -DBLUENRG_
../BLE/Common/ble_core/bluenrg_l2cap_aci.c:16:10: fatal error: hal_types.h: No such file or directory
 #include "hal_types.h"
          ^~~~~~~~~~~~~
compilation terminated.
make: *** [BLE/Common/ble_core/subdir.mk:39: BLE/Common/ble_core/bluenrg_l2cap_aci.o] Error 1
make: *** Waiting for unfinished jobs....
../BLE/Common/ble_core/hci_le.c:19:10: fatal error: hal_types.h: No such file or directory
 #include "hal_types.h"
          ^~~~~~~~~~~~~
compilation terminated.
make: *** [BLE/Common/ble_core/subdir.mk:41: BLE/Common/ble_core/hci_le.o] Error 1
"make -j3 all" terminated with exit code 2. Build might be incomplete.
```

Look for hal_types.h

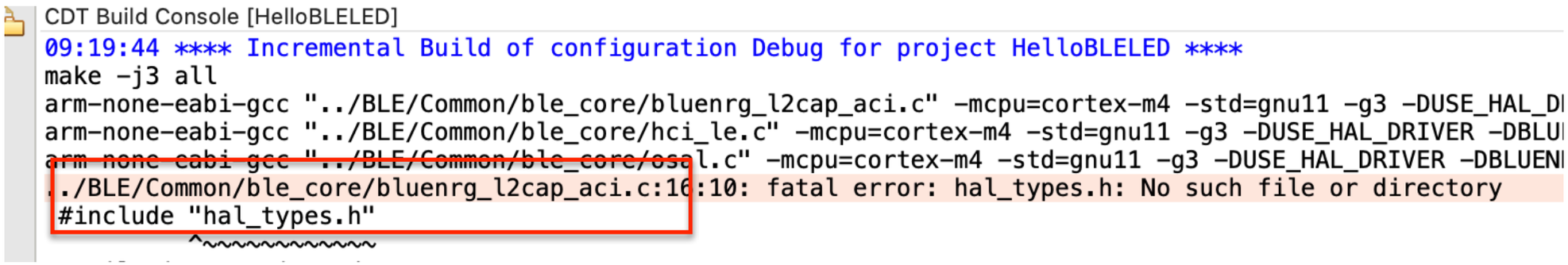
```
Normans-MacBook-Air-674:workspace_1.4.0 nmcentire$ find . | grep hal_types
./HelloBLE/BLE/Common/ble_core/bluenrg_private_hal_types.h
```

NOTE: Did not find hal_types.h but did find bluenrg_private_hal_types.h

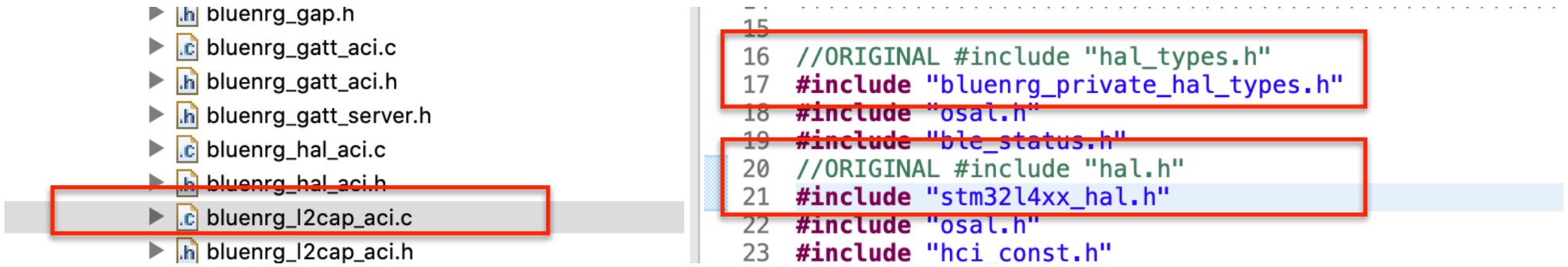
Edit include files



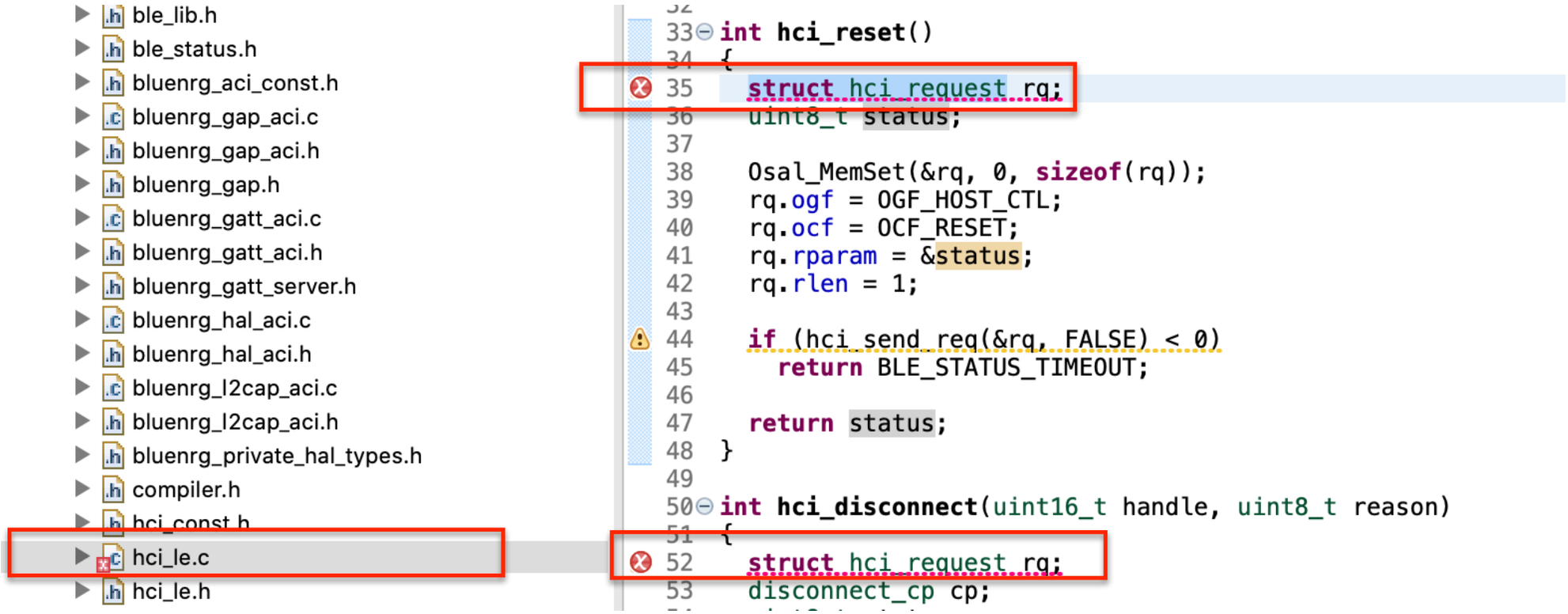
Attempt Build



Edit Include Files



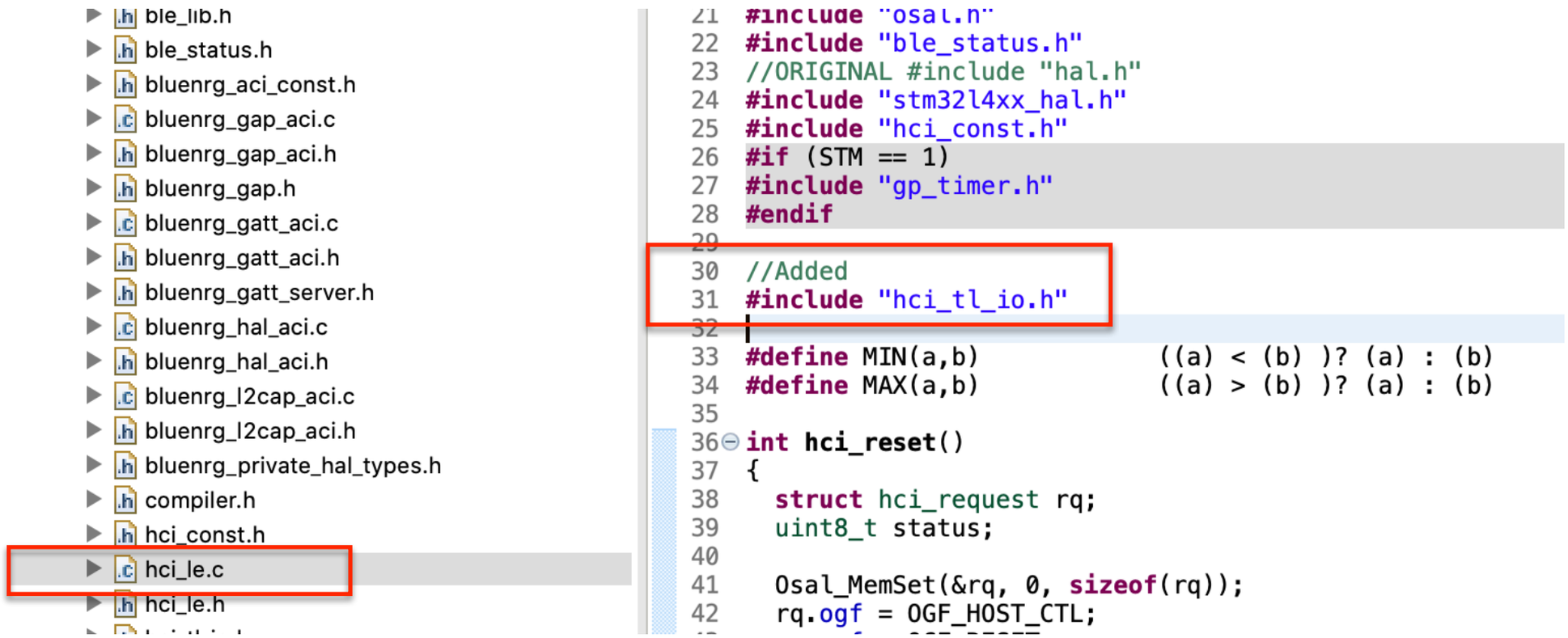
Attempt Build



Find where struct hci_request defined

```
./HelloBLELED//BLE/Common/ble_core/bluenrg_hal_aci.c:  struct hci_request rq;
./HelloBLELED//BLE/Common/ble_core/bluenrg_hal_aci.c:  struct hci_request rq;
./HelloBLELED//BLE/Common/ble_core/bluenrg_hal_aci.c:  struct hci_request rq;
./HelloBLELED//BLE/Common/ble_core/bluenrg_hal_aci.c:  struct hci_request rq;
./HelloBLELED//BLE/Common/ble_core/bluenrg_hal_aci.c:  struct hci_request rq;
./HelloBLELED//BLE/Common/ble_core/bluenrg_hal_aci.c:  struct hci_request rq;
./HelloBLELED//BLE/Common/ble_core/bluenrg_hal_aci.c:  struct hci_request rq;
./HelloBLELED//BLE/Common/ble_core/bluenrg_hal_aci.c:  struct hci_request rq;
./HelloBLELED//BLE/Common/ble_core/bluenrg_hal_aci.c:  struct hci_request rq;
./HelloBLELED//BLE/Common/ble_core/hci_tl_io.h:struct hci_request {
./HelloBLELED//BLE/Common/ble_core/hci_tl_io.h:int32_t hci_send_req(struct hci_request *r, uint8_t async);
./HelloBLELED//BLE/Common/ble_core/bluenrg_l2cap_aci.c:  struct hci_request rq;
./HelloBLELED//BLE/Common/ble_core/bluenrg_l2cap_aci.c:  struct hci_request rq;
```

Add Header File



Attempt Build

CDT Build Console [HelloBLELED]

```
09:29:51 **** Incremental Build of configuration Debug for project HelloBLELED ****
make -j3 all
arm-none-eabi-gcc "../BLE/Common/ble_core/hci_le.c" -mcpu=cortex-m4 -std=gnu11 -g3 -DUSE_HA
arm-none-eabi-gcc "../BLE/Common/ble_hci_tl_io_template.c" -mcpu=cortex-m4 -std=gnu11 -g3 -
../BLE/Common/ble_hci_tl_io_template.c:25:1: error: unknown type name 'int32_t'
 int32_t hci_send_req(struct hci_request *r, uint8_t async)
 ^~~~~~
../BLE/Common/ble_hci_tl_io_template.c:25:45: error: unknown type name 'uint8_t'
 int32_t hci_send_req(struct hci_request *r, uint8_t async)
                                             ^~~~~~
make: *** [BLE/Common/subdir.mk:18: BLE/Common/ble_hci_tl_io_template.o] Error 1
make: *** Waiting for unfinished jobs....
"make -j3 all" terminated with exit code 2. Build might be incomplete.
```

Add Include File

```
 3  * @file    hci_tl_io_template.c
 4  * @author  MCD Application Team
 5  * @brief   This lower API is imposed by the MW
 7  * @attention
 8  *
 9  * <h2><center>&copy; Copyright (c) 2017 STMic
10  * All rights reserved.</center></h2>
11  *
12  * This software component is licensed by ST u
13  * the "License"; You may not use this file ex
14  * License. You may obtain a copy of the Licen
15  *                        http://www.st.com/SL
16  *
18  */
19
20  // Added
21  #include <stdint.h>
22
23  /* Function prototypes -----------------------
24
25  /* HCI send request: generic API imposed by MW
26  /*   transport layer depends by the applic, e.
27
28  int32_t hci_send_req(struct hci_request *r, ui
29  {
30    return 0;
31  }
```

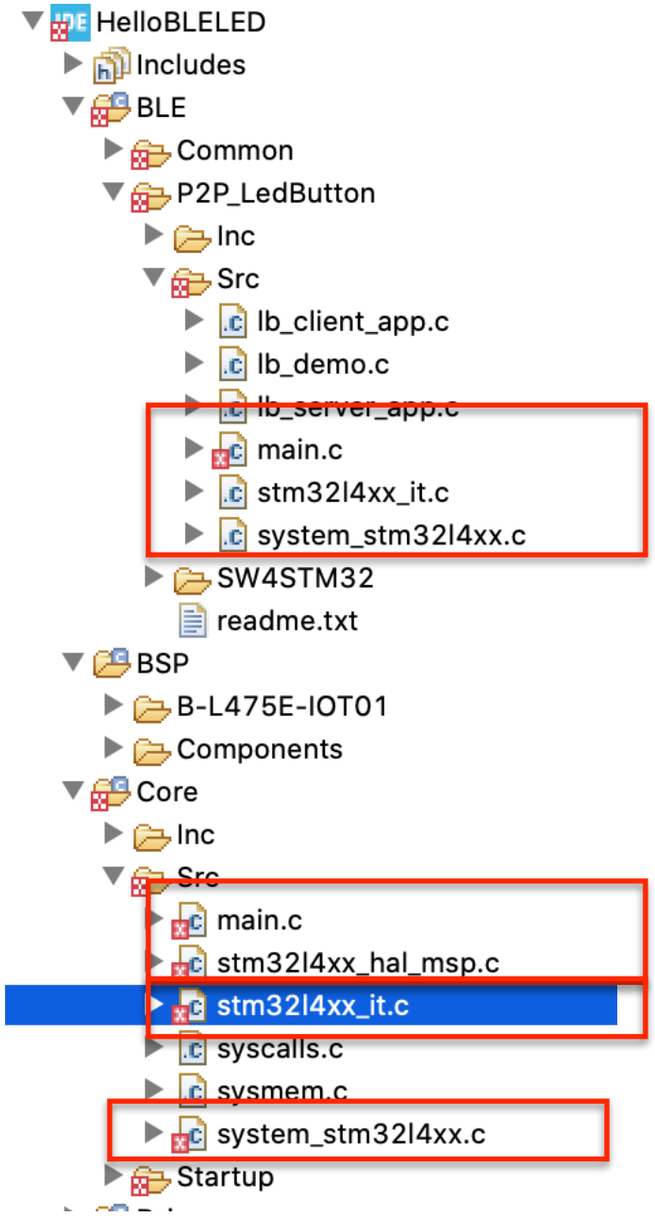
Attempt Build Multiple Definitions

```
CDT Build Console [HelloBLELED]
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../Core/Src/stm32l4xx_it.c:183: multiple definition of `SysTick_Handler'
BLE/P2P_LedButton/Src/stm32l4xx_it.o:/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/P2P_LedButton/Src/stm32l4xx_it.c:138: first defined here
Core/Src/stm32l4xx_it.o: In function `EXTI9_5_IRQHandler':
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../Core/Src/stm32l4xx_it.c:204: multiple definition of `EXTI9_5_IRQHandler'
BLE/P2P_LedButton/Src/stm32l4xx_it.o:/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/P2P_LedButton/Src/stm32l4xx_it.c:166: first defined here
Core/Src/stm32l4xx_it.o: In function `EXTI15_10_IRQHandler':
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../Core/Src/stm32l4xx_it.c:221: multiple definition of `EXTI15_10_IRQHandler'
BLE/P2P_LedButton/Src/stm32l4xx_it.o:/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/P2P_LedButton/Src/stm32l4xx_it.c:177: first defined here
Core/Src/system_stm32l4xx.o:/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../Drivers/CMSIS/Device/ST/STM32L4xx/Include/system_stm32l4xx.h:58: multiple d
BLE/P2P_LedButton/Src/system_stm32l4xx.o:/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../Drivers/CMSIS/Device/ST/STM32L4xx/Include/system_stm32l4xx.h:5
Core/Src/system_stm32l4xx.o:(.rodata.AHBPrescTable+0x0): multiple definition of `AHBPrescTable'
```

Note: stm32l4xx_it.c appears two Places. This is source of error

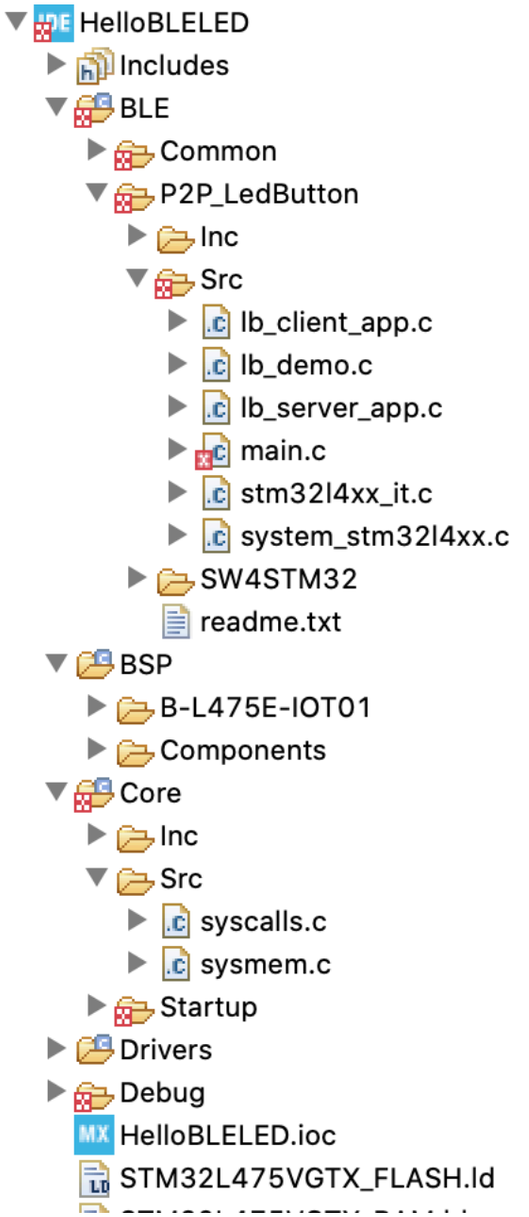
it = interrupt

Remove Duplicates



Keep These

Remove These

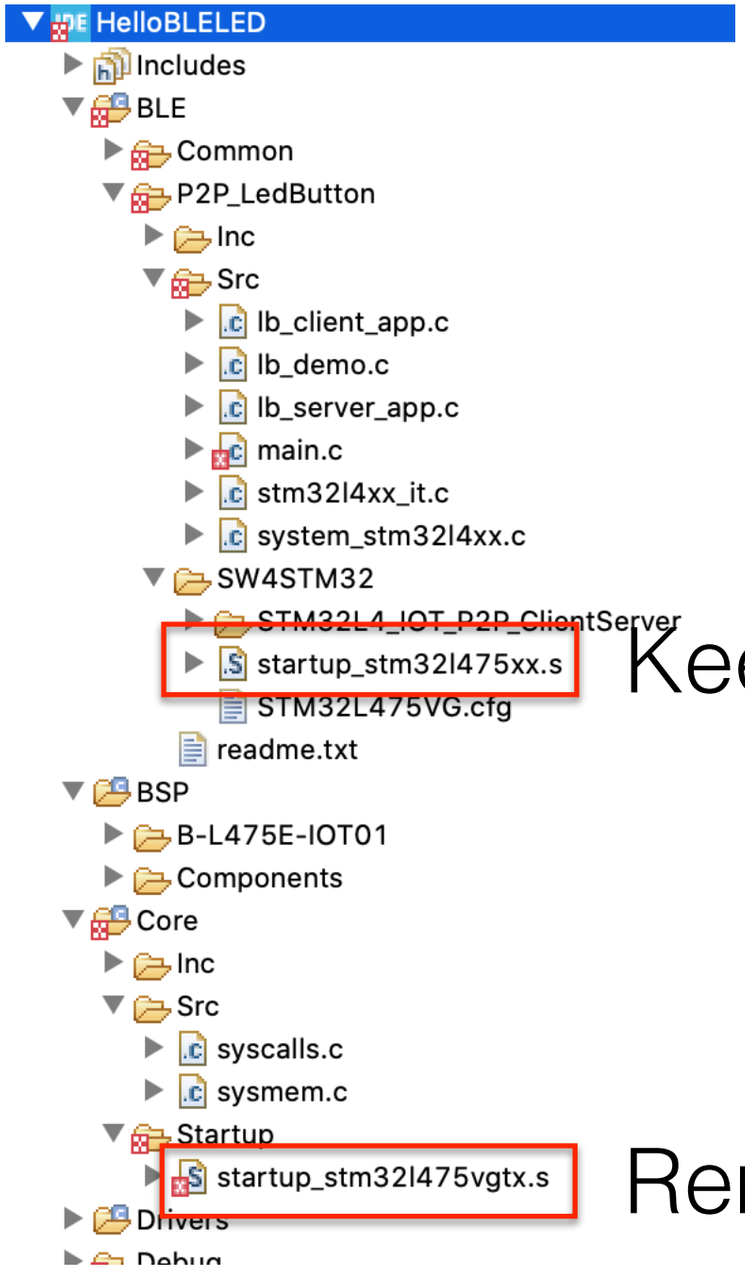


Attempt Build

```
09:40:57 **** Incremental Build of configuration Debug for project HelloBLELED ****
make -j3 all
arm-none-eabi-gcc -o "HelloBLELED.elf" @"objects.list"   -mcpu=cortex-m4 -T"/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/STM32L475VGTX_FLASH.ld" --sp
BLE/Common/tl/tl_ble_hci.o: In function `hci_send_req':
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/Common/tl/tl_ble_hci.c:268: multiple definition of `hci_send_req'
BLE/Common/ble_hci_tl_io_template.o:/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/Common/ble_hci_tl_io_template.c:29: first defined here
Core/Startup/startup_stm32l475vgtx.o:(.isr_vector+0x0): multiple definition of `g_pfnVectors'
BLE/P2P_LedButton/SW4STM32/startup_stm32l475xx.o:(.isr_vector+0x0): first defined here
Core/Startup/startup_stm32l475vgtx.o: In function `FPU_IRQHandler':
```

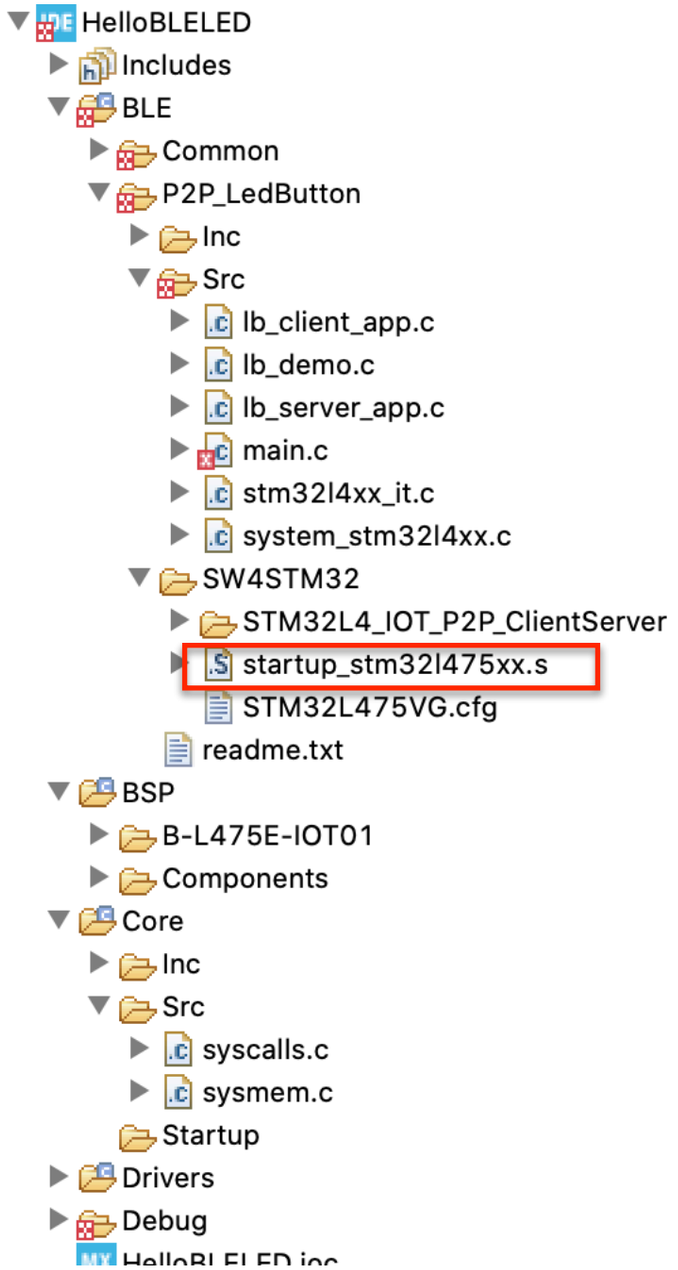
NOTE: Need to remove multiple copies of startup code

Remove Multiple Versions of Startup Code



Keep This file

Remove This file



Attempt Build

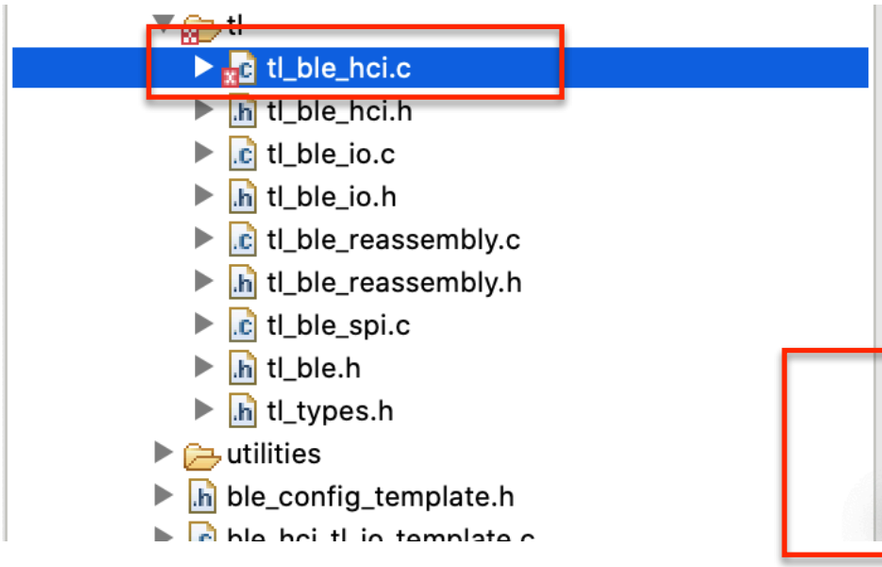
```
09:46:43 **** Incremental Build of configuration Debug for project HelloBLELED ****
make -j3 all
arm-none-eabi-gcc -o "HelloBLELED.elf" @"objects.list"   -mcpu=cortex-m4 -T"/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/STM32L475VGTX_FLASH.ld" --s
BLE/Common/tl/tl_ble_hci.o: In function `hci_send_req':
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/Common/tl/tl_ble_hci.c:268: multiple definition of `hci_send_req'
BLE/Common/ble_hci_tl_io_template.o:/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/Common/ble_hci_tl_io_template.c:29: first defined here
BLE/Common/ble_services/hrs.o: In function `HearRate_Event_Handler':
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/Common/ble_services/hrs.c:123: undefined reference to `HRS_Notification'
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/Common/ble_services/hrs.c:155: undefined reference to `HRS_Notification'
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/Common/ble_services/hrs.c:160: undefined reference to `HRS_Notification'
BLE/Common/hw/hw_timerserver.o: In function `HW_TS_Init':
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/Common/hw/hw_timerserver.c:600: undefined reference to `LL_EXTI_EnableRisingTrig_0_31'
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/Common/hw/hw_timerserver.c:601: undefined reference to `LL_EXTI_EnableIT_0_31'
BLE/P2P_LedButton/Src/main.o: In function `main':
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/P2P_LedButton/Src/main.c:92: undefined reference to `LL_RCC_IsActiveFlag_PINRST'
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/P2P_LedButton/Src/main.c:104: undefined reference to `LL_RCC_ForceBackupDomainReset'
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/P2P_LedButton/Src/main.c:106: undefined reference to `LL_RCC_ReleaseBackupDomainReset'
BLE/P2P_LedButton/Src/main.o: In function `Init_RTC':
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/P2P_LedButton/Src/main.c:204: undefined reference to `HAL_RTCEx_EnableBypassShadow'
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/P2P_LedButton/Src/main.c:214: undefined reference to `HAL_RTC_Init'
collect2: error: ld returned 1 exit status
make: *** [makefile:84: HelloBLELED.elf] Error 1
"make -j3 all" terminated with exit code 2. Build might be incomplete.
```

Issue 1: Multiple definitions of hci_send_req

Issue 2: undefined references

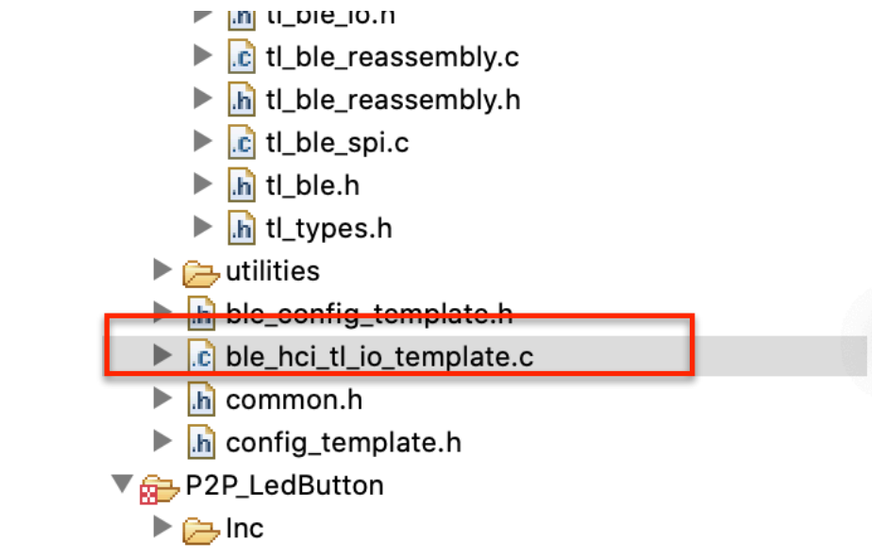
Multiple Definitions Issue

```
:t HelloBLELED ****

ortex-m4 -T"/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/STM32L475VGTX_FLASH.ld" --

../BLE/Common/tl/tl_ble_hci.c:268: multiple definition of `hci_send_req'
E/workspace_1.4.0/HelloBLELED/Debug/../BLE/Common/ble_hci_tl_io_template.c:29: first defined here
```




```
256    pCmdBuffer->cmdserial.cmd.plen = plen;
257    memcpy( pCmdBuffer->cmdserial.cmd.payload, param, plen );
258
259    TL_BLE_SendCmd();
260
261    return;
262  }
263
264
265
266  /* This API is imposed by the MW */
267  int32_t hci_send_req(struct hci_request *r, uint8_t async)
268  {
269    return ( TL_BLE_HCI_SendCmd( (TL_BLE_HCI_Cmd_t *)r ) );
```

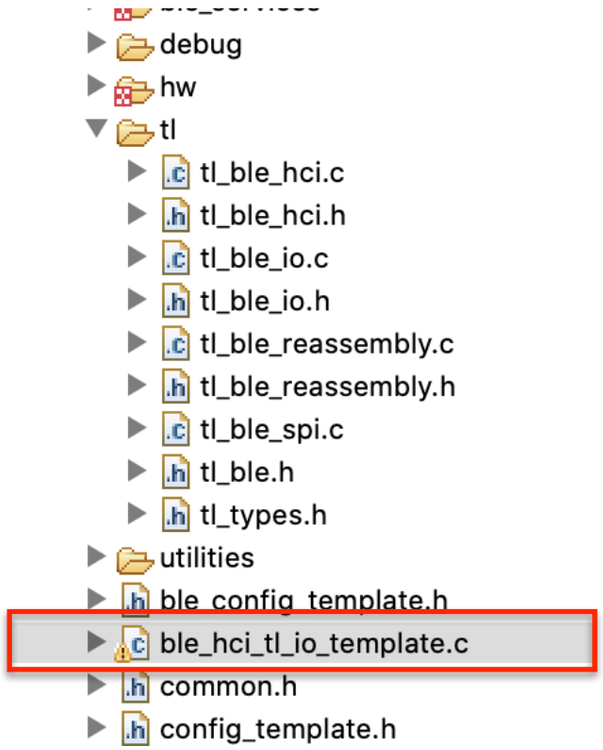
multiple definition of `hci_send_req'




```
18   */
19
20  // Added
21  #include <stdint.h>
22
23  /* Function prototypes -----------------------------------------
24
25  /* HCI send request: generic API imposed by MW to the lower layers
    depends by the applic, e.g.: spi, ipcc, etc
27
28  int32_t hci_send_req(struct hci_request *r, uint8_t async)
29  {
30    return 0;
31  }
```

multiple definition of `hci_send_req'

Remove Template File



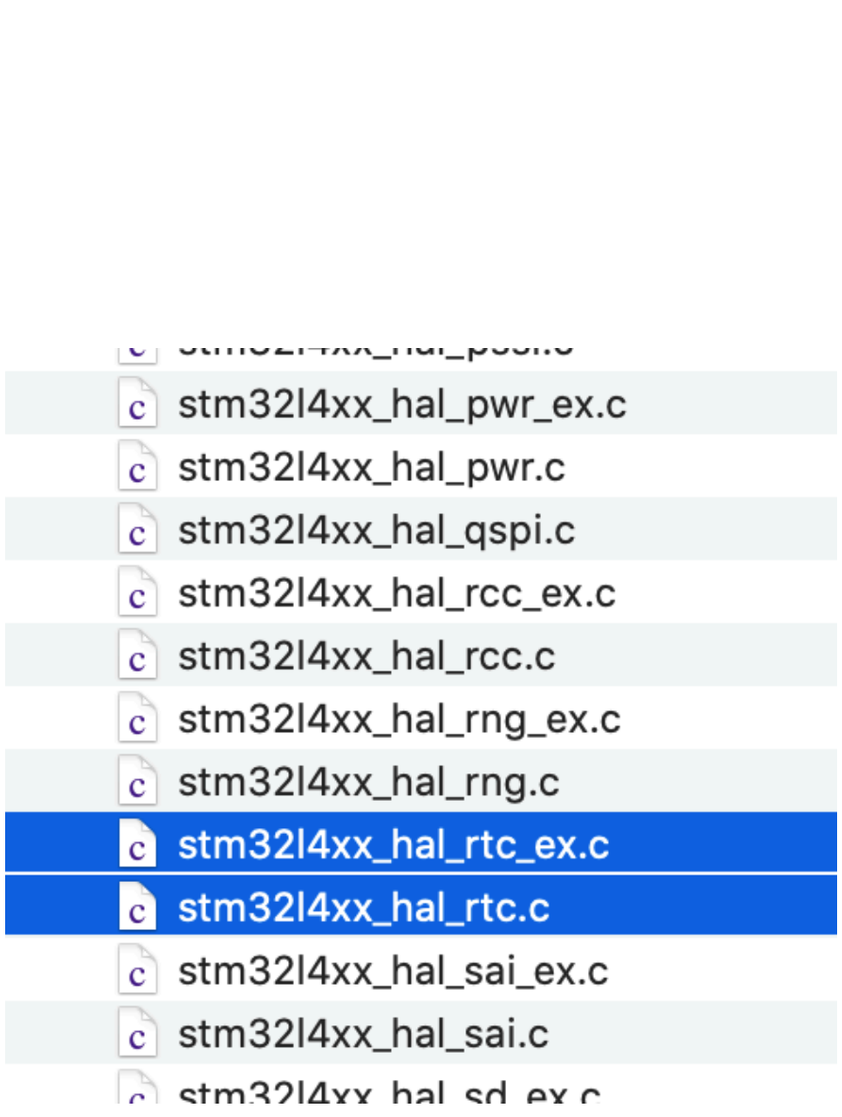
Delete this file

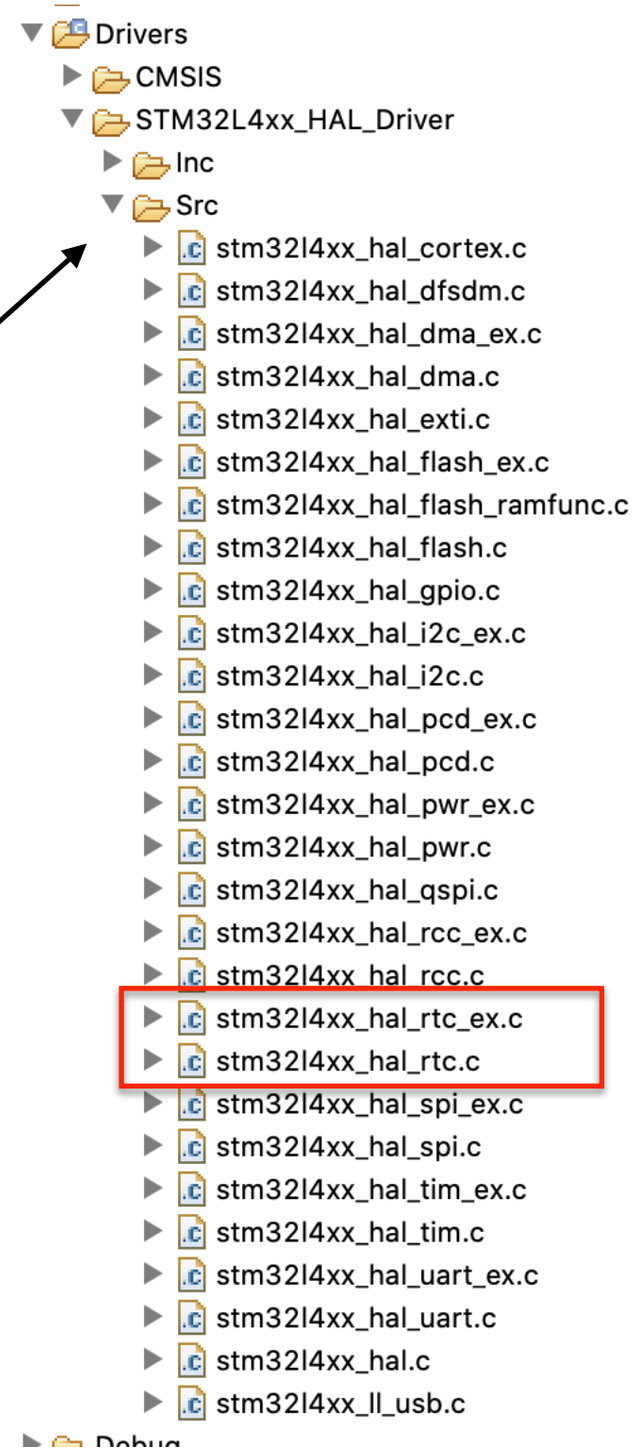
Linking Errors

```
tion `HearRate_Event_Handler':
e_1.4.0/HelloBLELED/Debug/../BLE/Common/ble_services/hrs.c:123: undefined reference to `HRS_Notification'
e_1.4.0/HelloBLELED/Debug/../BLE/Common/ble_services/hrs.c:155: undefined reference to `HRS_Notification'
e_1.4.0/HelloBLELED/Debug/../BLE/Common/ble_services/hrs.c:160: undefined reference to `HRS_Notification'
ction `HW_TS_Init':
e_1.4.0/HelloBLELED/Debug/../BLE/Common/hw/hw_timerserver.c:600: undefined reference to `LL_EXTI_EnableRisingTrig_0_31'
e_1.4.0/HelloBLELED/Debug/../BLE/Common/hw/hw_timerserver.c:601: undefined reference to `LL_EXTI_EnableIT_0_31'
ion `main':
e_1.4.0/HelloBLELED/Debug/../BLE/P2P_LedButton/Src/main.c:92: undefined reference to `LL_RCC_IsActiveFlag_PINRST'
e_1.4.0/HelloBLELED/Debug/../BLE/P2P_LedButton/Src/main.c:104: undefined reference to `LL_RCC_ForceBackupDomainReset'
e_1.4.0/HelloBLELED/Debug/../BLE/P2P_LedButton/Src/main.c:106: undefined reference to `LL_RCC_ReleaseBackupDomainReset'
ion `Init_RTC':
e_1.4.0/HelloBLELED/Debug/../BLE/P2P_LedButton/Src/main.c:204: undefined reference to `HAL_RTCEx_EnableBypassShadow'
e_1.4.0/HelloBLELED/Debug/../BLE/P2P_LedButton/Src/main.c:214: undefined reference to `HAL_RTC_Init'
atus
f] Error 1
de 2. Build might be incomplete.
```

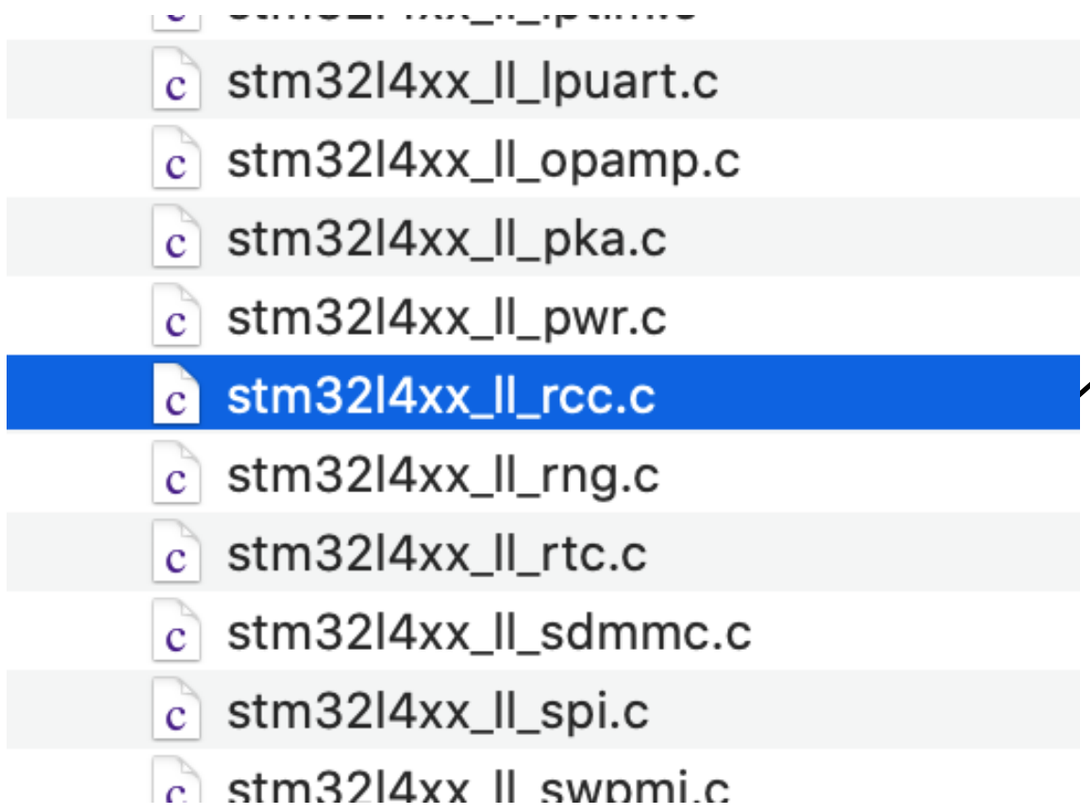
Missing HAL_RTC and LL_RCC .c files
(we added .h files but not .c files)

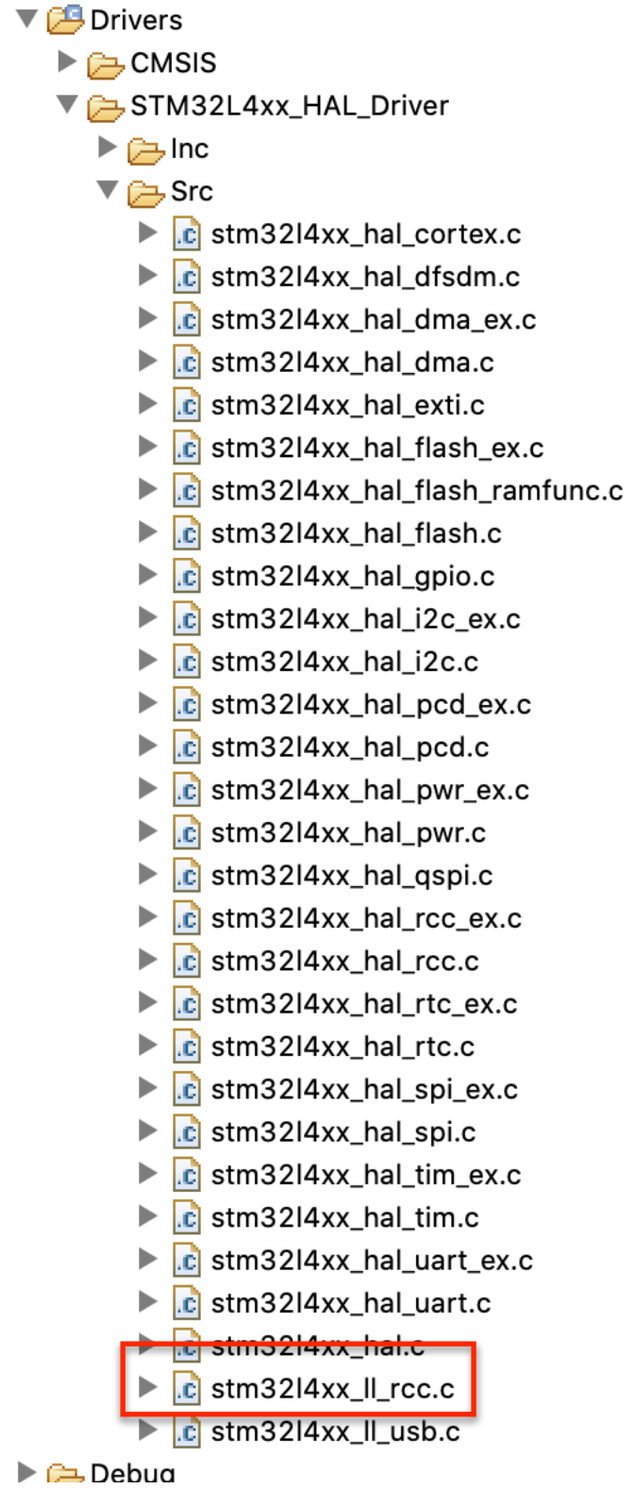
Copy Files


stm32l4xx_hal_pwr_ex.c
stm32l4xx_hal_pwr.c
stm32l4xx_hal_qspi.c
stm32l4xx_hal_rcc_ex.c
stm32l4xx_hal_rcc.c
stm32l4xx_hal_rng_ex.c
stm32l4xx_hal_rng.c
stm32l4xx_hal_rtc_ex.c
stm32l4xx_hal_rtc.c
stm32l4xx_hal_sai_ex.c
stm32l4xx_hal_sai.c


Drivers
CMSIS
STM32L4xx_HAL_Driver
Inc
Src
stm32l4xx_hal_cortex.c
stm32l4xx_hal_dfsdm.c
stm32l4xx_hal_dma_ex.c
stm32l4xx_hal_dma.c
stm32l4xx_hal_exti.c
stm32l4xx_hal_flash_ex.c
stm32l4xx_hal_flash_ramfunc.c
stm32l4xx_hal_flash.c
stm32l4xx_hal_gpio.c
stm32l4xx_hal_i2c_ex.c
stm32l4xx_hal_i2c.c
stm32l4xx_hal_pcd_ex.c
stm32l4xx_hal_pcd.c
stm32l4xx_hal_pwr_ex.c
stm32l4xx_hal_pwr.c
stm32l4xx_hal_qspi.c
stm32l4xx_hal_rcc_ex.c
stm32l4xx_hal_rcc.c
stm32l4xx_hal_rtc_ex.c
stm32l4xx_hal_rtc.c
stm32l4xx_hal_spi_ex.c
stm32l4xx_hal_spi.c
stm32l4xx_hal_tim_ex.c
stm32l4xx_hal_tim.c
stm32l4xx_hal_uart_ex.c
stm32l4xx_hal_uart.c
stm32l4xx_hal.c
stm32l4xx_ll_usb.c

Copy Files

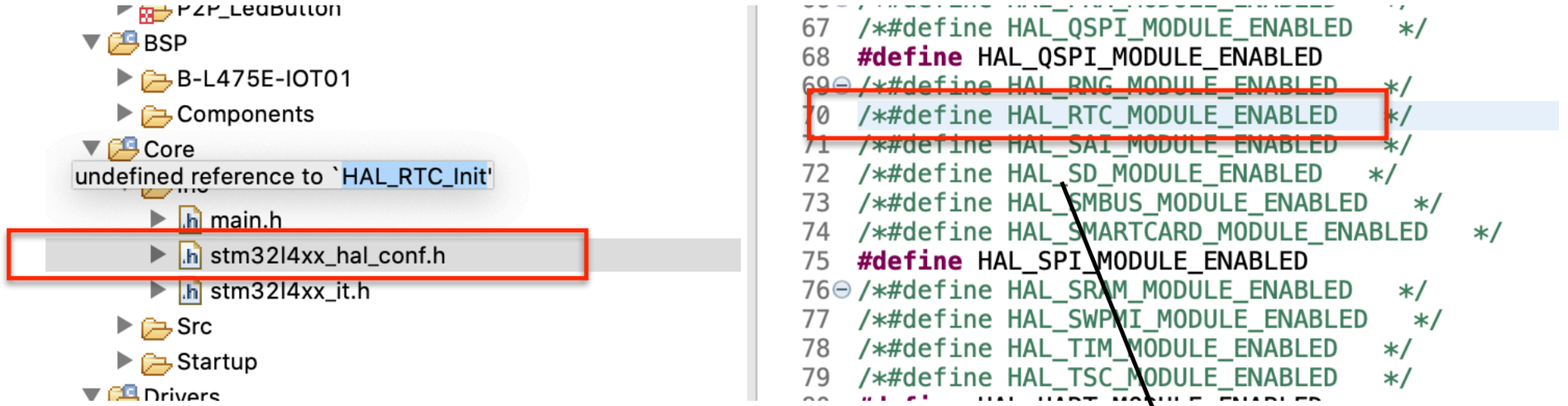




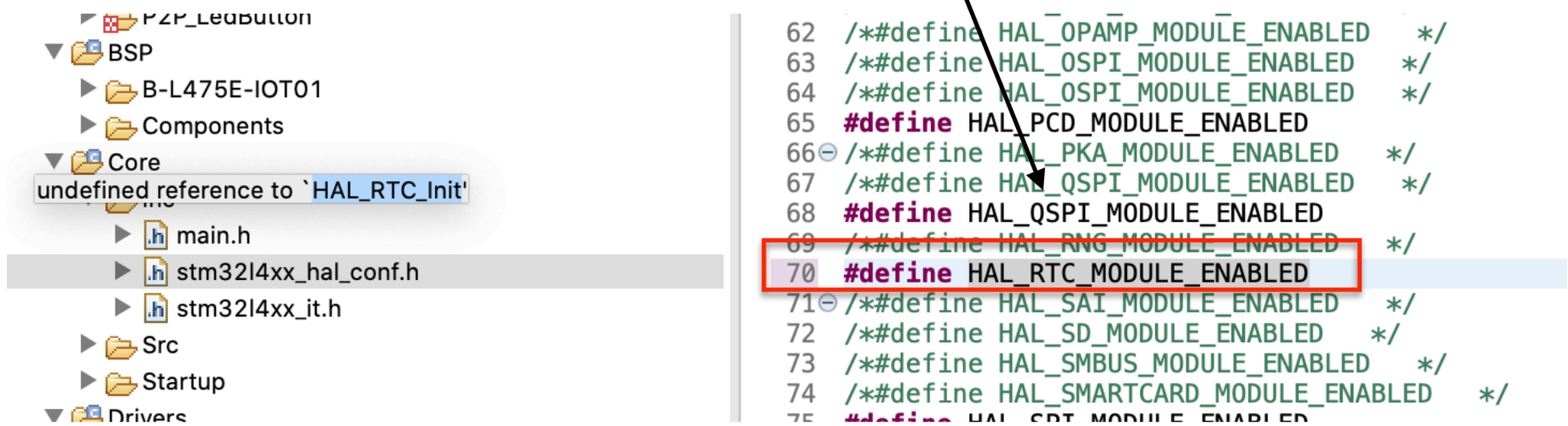
Search for HAL_RTC_Init

```
grep: HelloBLELED.: No such file or directory
Normans-MacBook-Air-674:workspace_1.4.0 nmcentire$ grep -r HAL_RTC_Init HelloBLELED/
HelloBLELED//Drivers/STM32L4xx_HAL_Driver/Inc/stm32l4xx_hal_rtc.h:HAL_StatusTypeDef HAL_RTC_Init(RTC_
HelloBLELED//Drivers/STM32L4xx_HAL_Driver/Src/stm32l4xx_hal_rtc.c:        format using the HAL_RTC_Ir
HelloBLELED//Drivers/STM32L4xx_HAL_Driver/Src/stm32l4xx_hal_rtc.c:  By default, after the @ref HAL_RT
state is HAL_RTC_STATE_RESET,
HelloBLELED//Drivers/STM32L4xx_HAL_Driver/Src/stm32l4xx_hal_rtc.c:  in the @ref HAL_RTC_Init()/@ref H
hen these cal multiple definition of `hci_send_req'
HelloBLELED//Drivers/STM32L4xx_HAL_Driver/Src/stm32l4xx_hal_rtc.c:  If not, MspInit or MspDeInit are
_Init()/@ref HAL_RTC_DeInit()
HelloBLELED//Drivers/STM32L4xx_HAL_Driver/Src/stm32l4xx_hal_rtc.c:  or @ref HAL_RTC_Init() function.
HelloBLELED//Drivers/STM32L4xx_HAL_Driver/Src/stm32l4xx_hal_rtc.c:HAL_StatusTypeDef HAL_RTC_Init(RTC_
HelloBLELED//Drivers/STM32L4xx_HAL_Driver/Src/stm32l4xx_hal_rtc_ex.c:        format using the HAL_RTC
HelloBLELED//Drivers/STM32L4xx_HAL_Driver/Src/stm32l4xx_hal_rtc_ex.c:        To output the selected R
_RTC_Init() function.
HelloBLELED//Drivers/STM32L4xx_HAL_Driver/Src/stm32l4xx_hal_rtc_ex.c:     (+) STM32L412xx and STM32L4
TC tamper configuration, you have to call HAL_RTC_Init() in order to
HelloBLELED//Drivers/STM32L4xx_HAL_Driver/Src/stm32l4xx_hal_rtc_ex.c:     (+) STM32L412xx and STM32L4
ling these functions you have to call HAL_RTC_Init() in order to
HelloBLELED//Drivers/STM32L4xx_HAL_Driver/Src/stm32l4xx_hal_rtc_ex.c:       HAL_RTC_Init() function.
HelloBLELED//Drivers/STM32L4xx_HAL_Driver/Src/stm32l4xx_hal_rtc_ex.c:       HAL_RTC_Init() function.
HelloBLELED//BLE/P2P_LedButton/Src/main.c:  HAL_RTC_Init(&hrtc);
Binary file HelloBLELED//Debug/BLE/P2P_LedButton/Src/main.o matches
Normans-MacBook-Air-674:workspace_1.4.0 nmcentire$
```

RTC Module Not Enabled



Change to this.

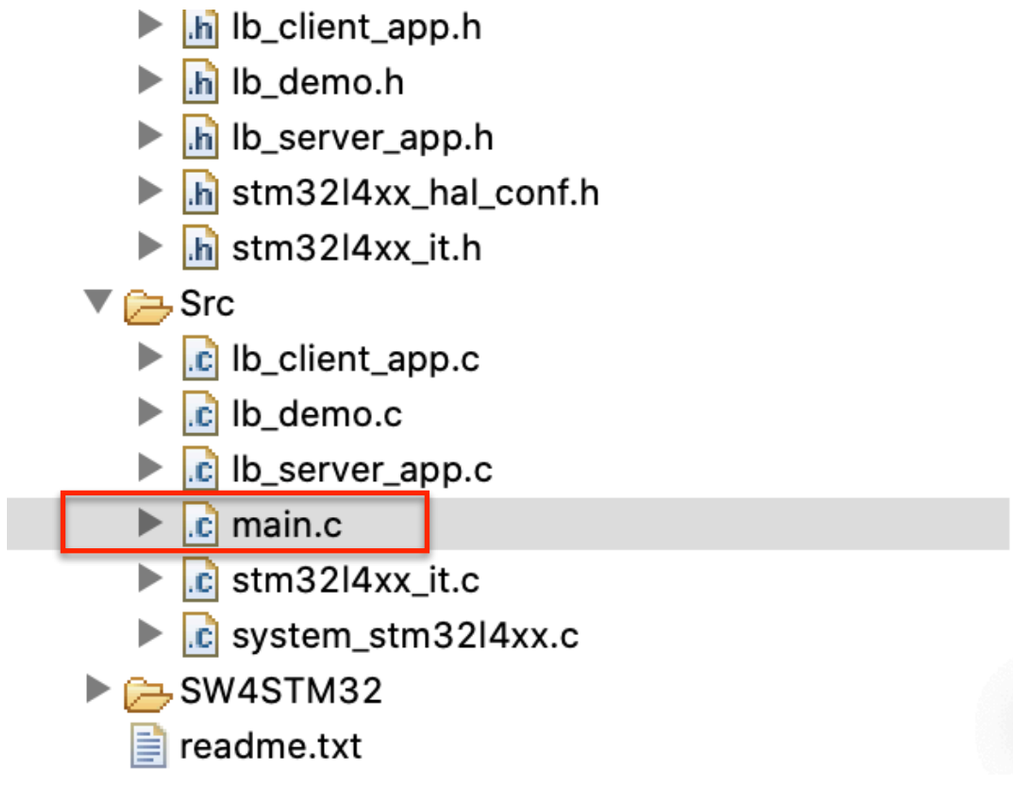


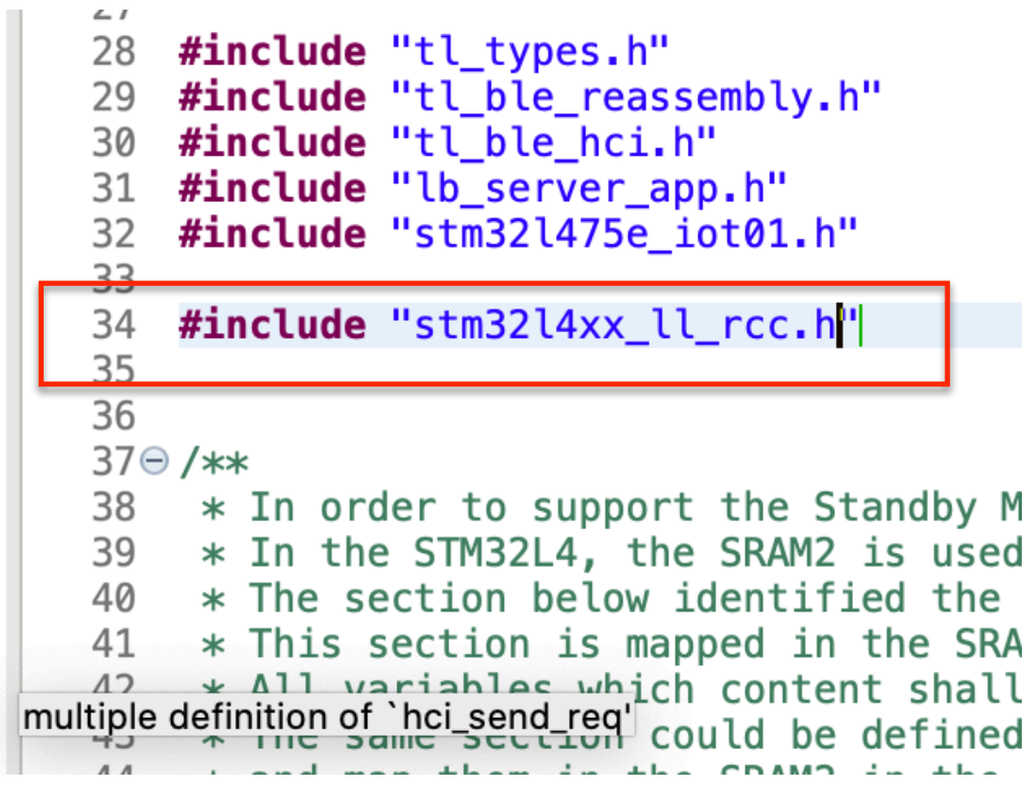
Attempt Build

```
arm-none-eabi-gcc "../BLE/Common/ble_core/bluenrg_l2cap_aci.c" -mcpu=cortex-m4 -std=gnu11 -g3 -DUSE_HAL_DRIVER -DBLUENRG_MS -DDEBUG -DSTM32L475xx -c -I../Core
arm-none-eabi-gcc "../BLE/Common/ble_core/hci_le.c" -mcpu=cortex-m4 -std=gnu11 -g3 -DUSE_HAL_DRIVER -DBLUENRG_MS -DDEBUG -DSTM32L475xx -c -I../Core/Inc -I../D
arm-none-eabi-gcc -o "HelloBLELED.elf" @"objects.list"   -mcpu=cortex-m4 -T"/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/STM32L475VGTX_FLASH.ld"
BLE/Common/ble_services/hrs.o: In function `HearRate_Event_Handler':
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/Common/ble_services/hrs.c:123: undefined reference to `HRS_Notification'
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/Common/ble_services/hrs.c:155: undefined reference to `HRS_Notification'
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/Common/ble_services/hrs.c:160: undefined reference to `HRS_Notification'
BLE/Common/hw/hw_timerserver.o: In function `HW_TS_Init':
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/Common/hw/hw_timerserver.c:600: undefined reference to `LL_EXTI_EnableRisingTrig_0_31'
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/Common/hw/hw_timerserver.c:601: undefined reference to `LL_EXTI_EnableIT_0_31'
BLE/P2P_LedButton/Src/main.o: In function `main':
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/P2P_LedButton/Src/main.c:92: undefined reference to `LL_RCC_IsActiveFlag_PINRST'
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/P2P_LedButton/Src/main.c:104: undefined reference to `LL_RCC_ForceBackupDomainReset'
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/P2P_LedButton/Src/main.c:106: undefined reference to `LL_RCC_ReleaseBackupDomainReset'
collect2: error: ld returned 1 exit status
make: *** [makefile:82: HelloBLELED.elf] Error 1
"make -j3 all" terminated with exit code 2. Build might be incomplete.
```

HAL_RTC errors resolved.
Next to resolve LL_RCC errors.

Add Header File

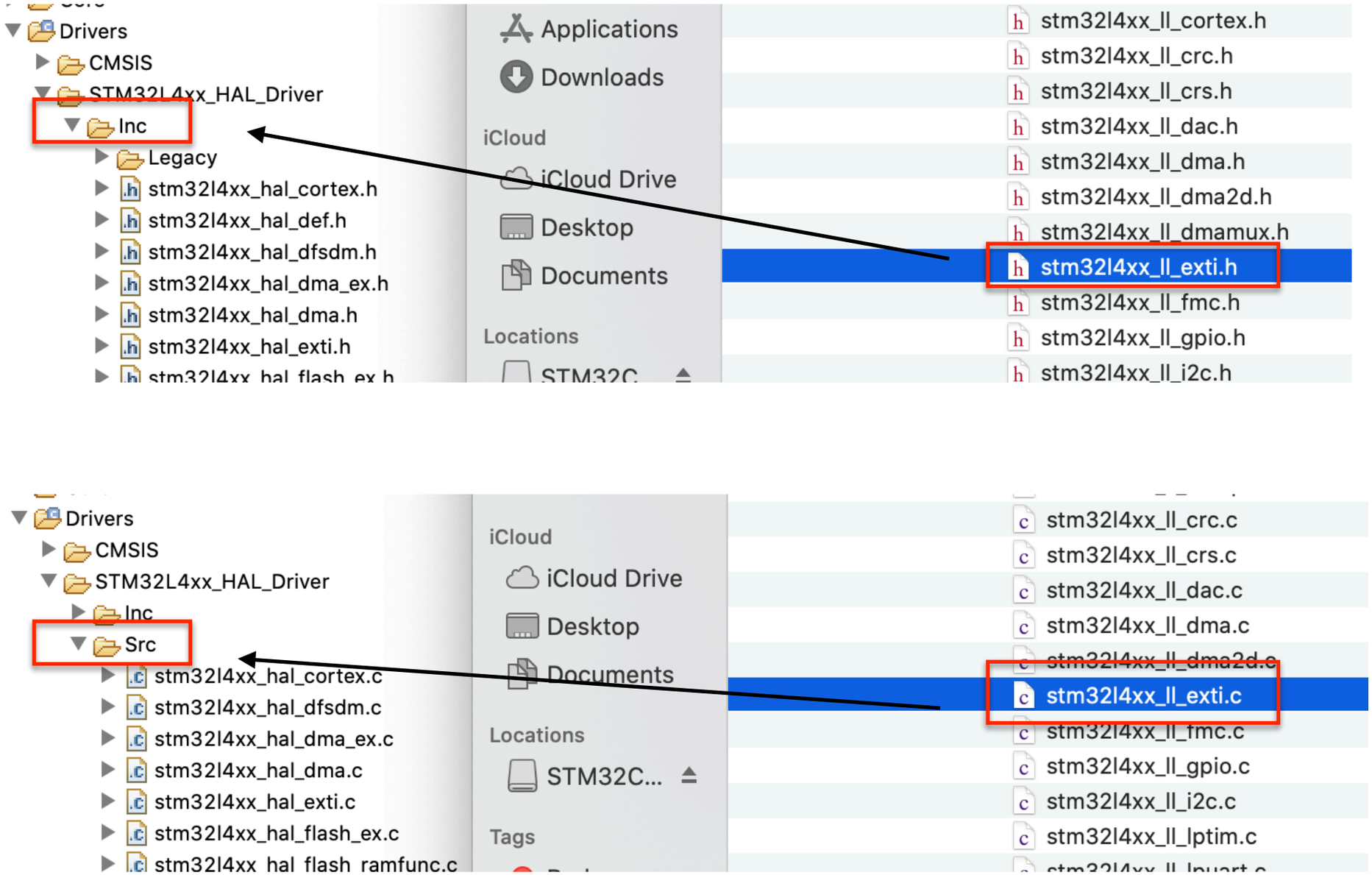




Attempt Build

```
gcc "../BLE/P2P_LedButton/Src/main.c" -mcpu=cortex-m4 -std=gnu11 -g3 -DUSE_HAL_DRIVER -DBLUENRG_MS -DDEBUG -DSTM32L475xx -c -I../Core/Inc -I../Dri
gcc -o "HelloBLELED.elf" @"objects.list"   -mcpu=cortex-m4 -T"/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/STM32L475VGTX_FLASH.ld" --
_services/hrs.o: In function `HearRate_Event_Handler':
re/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/Common/ble_services/hrs.c:123: undefined reference to `HRS_Notification'
re/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/Common/ble_services/hrs.c:155: undefined reference to `HRS_Notification'
re/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/Common/ble_services/hrs.c:160: undefined reference to `HRS_Notification'
hw_timerserver.o: In function `HW_TS_Init':
re/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/Common/hw/hw_timerserver.c:600  undefined reference to `LL_EXTI_EnableRisingTrig_0_31'
re/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/Common/hw/hw_timerserver.c:601  undefined reference to `LL_EXTI_EnableIT_0_31'
r: ld returned 1 exit status
efile:82: HelloBLELED.elf] Error 1
 terminated with exit code 2. Build might be incomplete.

 Failed. 6 errors, 0 warnings. (took 1s.738ms)
```

Copy Files stm32l4xx_ll_exti.[hc]



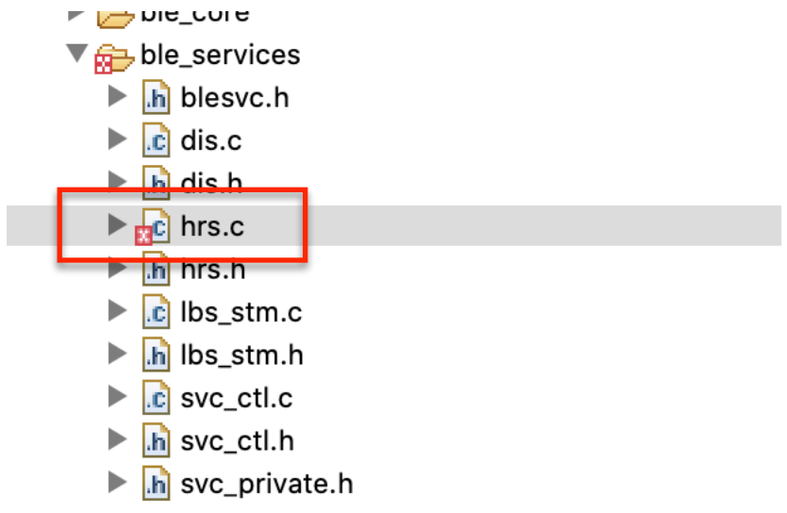
Add Header File

Attempt Build

```
CDT Build Console [HelloBLELED]
11:13:35 **** Incremental Build of configuration Debug for project HelloBLELED ****
make -j3 all
arm-none-eabi-gcc "../BLE/Common/hw/hw_timerserver.c" -mcpu=cortex-m4 -std=gnu11 -g3 -DUSE_HAL_DRIVER -DBLUENRG_MS -DDEBUG -DSTM32L475xx -c -I../Co
arm-none-eabi-gcc -o "HelloBLELED.elf" @"objects.list"   -mcpu=cortex-m4 -T"/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/STM32L475VGTX_
BLE/Common/ble_services/hrs.o: In function `HearRate_Event_Handler':
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/Common/ble_services/hrs.c:123: undefined reference to `HRS_Notification'
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/Common/ble_services/hrs.c:155: undefined reference to `HRS_Notification'
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLELED/Debug/../BLE/Common/ble_services/hrs.c:160: undefined reference to `HRS_Notification'
collect2: error: ld returned 1 exit status
make: *** [makefile:82: HelloBLELED.elf] Error 1
"make -j3 all" terminated with exit code 2. Build might be incomplete.

11:13:37 Build Failed. 4 errors, 0 warnings. (took 1s.948ms)
```

No code for HRS_Notification!

```
Normans-MacBook-Air-674:workspace_1.4.0 nmcentire$ grep -r HRS_Notification HelloBLELED/
HelloBLELED//BLE/Common/ble_services/hrs.h:  void HRS_Notification(HRS_NotCode_t notification);
HelloBLELED//BLE/Common/ble_services/hrs.c:              HRS_Notification(HRS_RESET_ENERGY_EXPENDED_EVT);
HelloBLELED//BLE/Common/ble_services/hrs.c:              HRS_Notification(HRS_NOTIFICATION_ENABLED);
HelloBLELED//BLE/Common/ble_services/hrs.c:              HRS_Notification(HRS_NOTIFICATION_DISABLED);
Binary file HelloBLELED//Debug/BLE/Common/ble_services/hrs.o matches
```




```
112
113             aci_gatt_write_response(write_perm_req->conn_handle,
114                                     write_perm_req->attr_handle,
115                                     0x00, /* write_status = 0 (no error
116                                     (uint8_t)HRS_CNTL_POINT_VALUE_IS_SU
117                                     write_perm_req->data_length,
118                                     (uint8_t *)&write_perm_req->data[0]
119
120             /**
121              * Notify the application to Reset The Energy Expended Valu
122              */
123             HRS_Notification(HRS_RESET_ENERGY_EXPENDED_EVT);
124           }
125           else
```

For now comment out code With TODO

FINALLY!

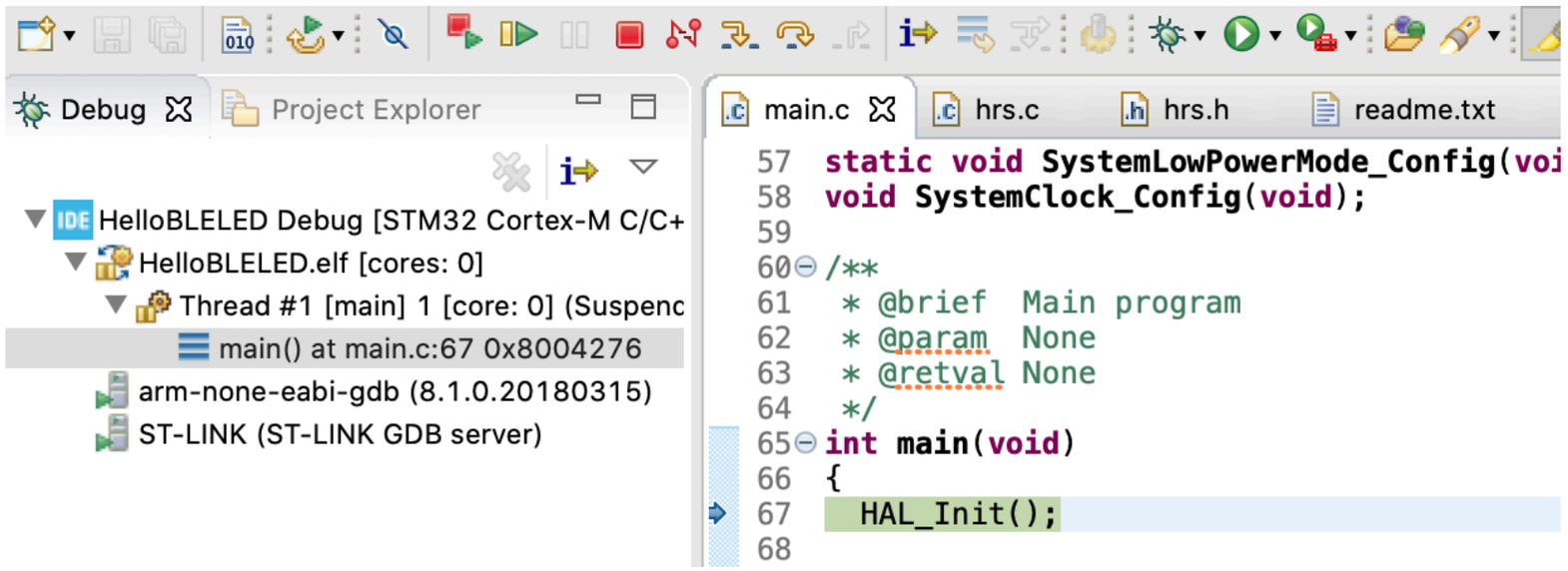
CDT Build Console [HelloBLELED]

```
   text    data     bss     dec     hex filename
  25260      32    4304   29596    739c HelloBLELED.elf
Finished building: default.size.stdout

Finished building: HelloBLELED.bin

Finished building: HelloBLELED.list

11:28:23 Build Finished. 0 errors, 0 warnings. (took 2s.75ms)
```

Default Code Runs As Server (Central)

```
43 /*****************************************************************************
44  * LB CONFIGURATION //Routeur or End Dev 1 or End Dev 2
45  *****************************************************************************/
46
47 #define LB_CLIENT  0     /*1 = Device is GAP Central & GATT Client */
48 #define LB_SERVER  1     /*1 = Device is GAP Peripherique & GATT SERVER*/
49
```

Start Code Running



Heart Rate Monitor

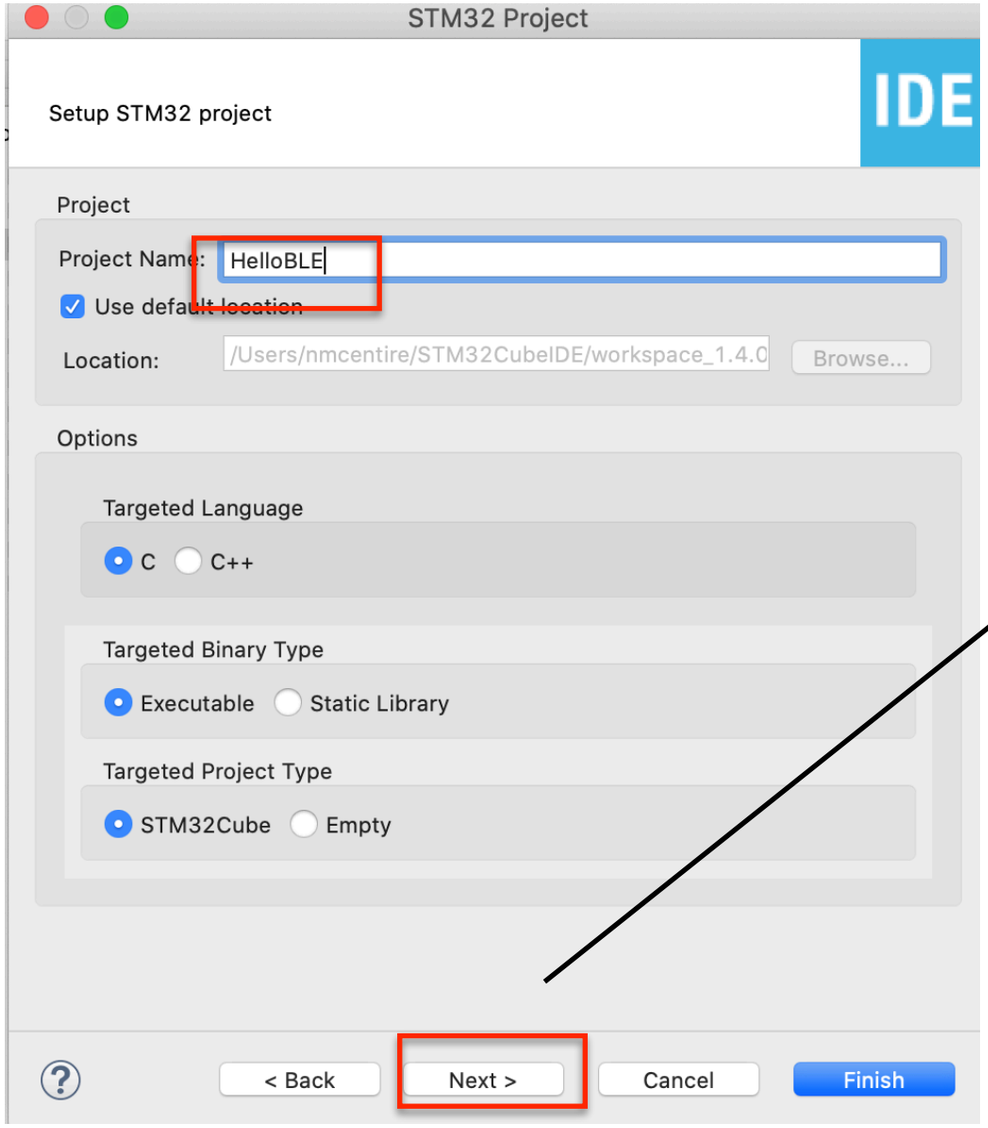
Heart Rate ReadMe

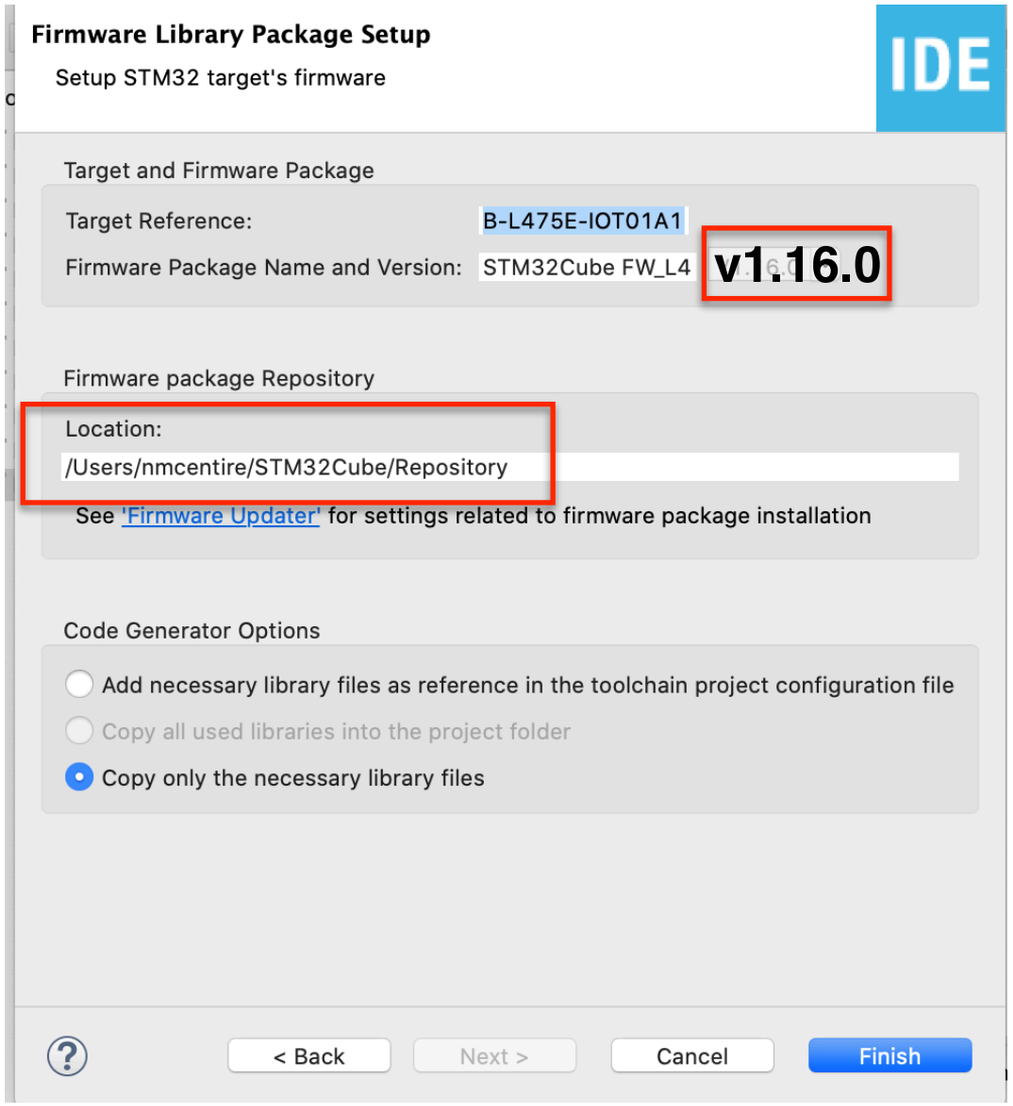
```
This application shows how to use BLE component for HeartRate profile application.

The STM32 B-L475E-IOT01A Discovery board acts as GATT server.
Once the code is downloaded on the STM32 B-L475E-IOT01A Discovery board and executed,
the modules are initialized and the device starts advertising.
The user needs an application (running for example on smartphone) in order to act as GATT client.
ST provides the following application (STM32 BLE Profiles):
https://play.google.com/store/apps/details?id=com.stm.bluetoothlevalidation
Tip:
To quickly download and launch the "STM32 BLE Profiles" application the NFC tag can be used.
By executing the NFC example (available in /Applications/NFC/WrAARtoRunBLEapp/) the NFC EEPROM
is programmed (and it remains programmed) such that, each time the smartphone approches the NFC
antenna, the "STM32 BLE Profiles" application is automatically launched on the smartphone.

The user should activate Bluetooth Smart, execute such application, and SCAN for Bluetooth devices.
The device HR_L475_IoT will be detected.
The user should connect the smartphone to the STM32 B-L475E-IOT01A.
The presence of HeartRate profile should be detected by the smartphone application.
The user should click on the Heart Rate profile (this depends on the smartphone application used).
In general any smartphone application should allow the user to see the heart Rate measurement.
STM32 BLE Profiles smartphone application displays and expresses them in BPM (beat per minute).
In this example HR_L475_IoT Discovery sends dummy values each second.

The STM32 B-L475E-IOT01A example supports the full feature of Heart Rate Service as from specification
https://www.bluetooth.com/specifications/gatt/viewer?attributeXmlFile=org.bluetooth.service.heart_rate.xml
i.e. it provides other information like the sensor location and by writing 0x1 to the Heart Rate Control point
the Energy Expanded field is reset.
STM32 BLE Profiles smartphone application does not support these options but other smartphone applications
can be found on the internet and used to test these features.
```

Heart Rate README Part 2

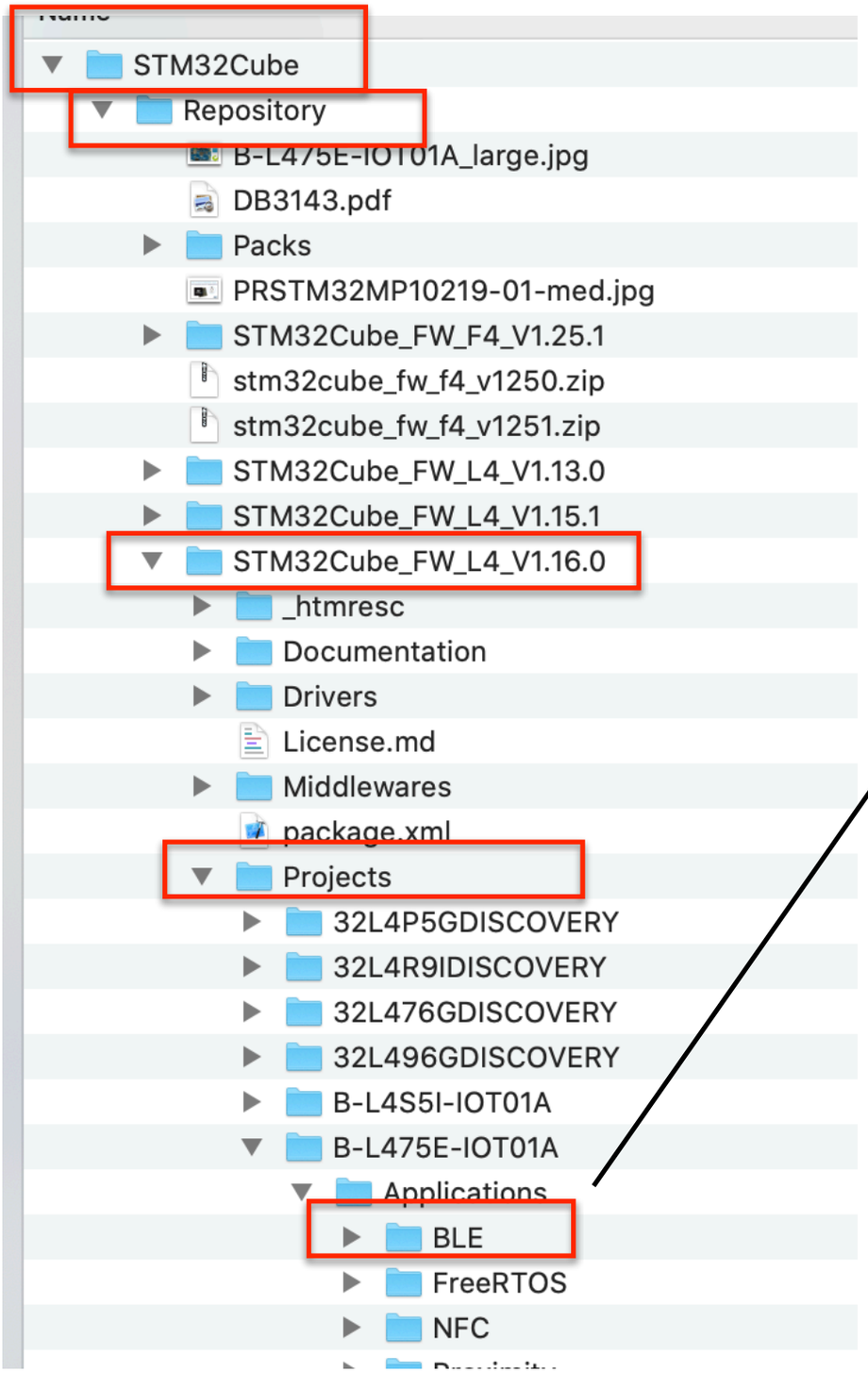
```
- BLE/HeartRate/Src/main.c                    Main Program
- BLE/HeartRate/Src/system_stm32l4xx.c        STM32L4xx system clock configuration file
- BLE/HeartRate/Src/stm32l4xx_it.c            STM32 interrupt handlers
- BLE/HeartRate/Src/hr.c                      Heart Rate application
- BLE/HeartRate/Src/hrs_app.c                 Heart Rate Service Application
- BLE/HeartRate/Src/dis_app.c                 Device Information Service Application
- BLE/HeartRate/Inc/config.h                  Application configuration file
- BLE/HeartRate/Inc/stm32l4xx_hal_conf.h      HAL configuration file
- BLE/HeartRate/Inc/stm32l4xx_it.h            STM32 interrupt handlers header file
- BLE/HeartRate/Inc/hr.h                      Exported files and function of hr.c
- BLE/HeartRate/Inc/hrs_app.h                 Exported files and function of hrs_app.c
- BLE/HeartRate/Inc/dis_app.h                 Exported files and function of dis_app.c
- BLE/Common/                                 These files are Common also to other applic/examples then HeartRate
- BLE/Common/ble_core/*.*                     BlueNRG-MS Bluetooth Low Energy device driver
- BLE/Common/ble_services/*.*                 GATT services according to BLE spec
- BLE/Common/debug/*.*                        Code usefull for debugging (DBG should be activated in config.h)
- BLE/Common/tl/*.*                           HCI layer and SPI protocol
- BLE/Common/hw/*.*                           HW board and device dependencies (SPI pins, timeserver, low power)
- BLE/Common/utilities/*.*                    Scheduler, memory/queue/fifo/list management, otp, etc
```

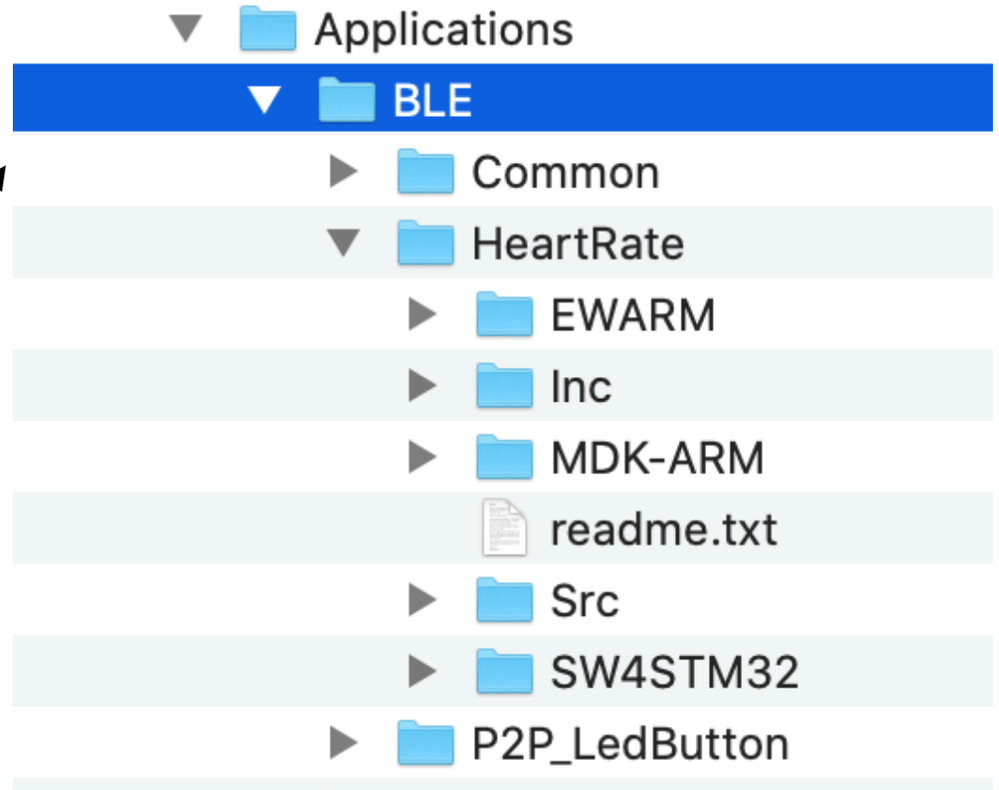
Create New Project
(And Find Location of Repository)



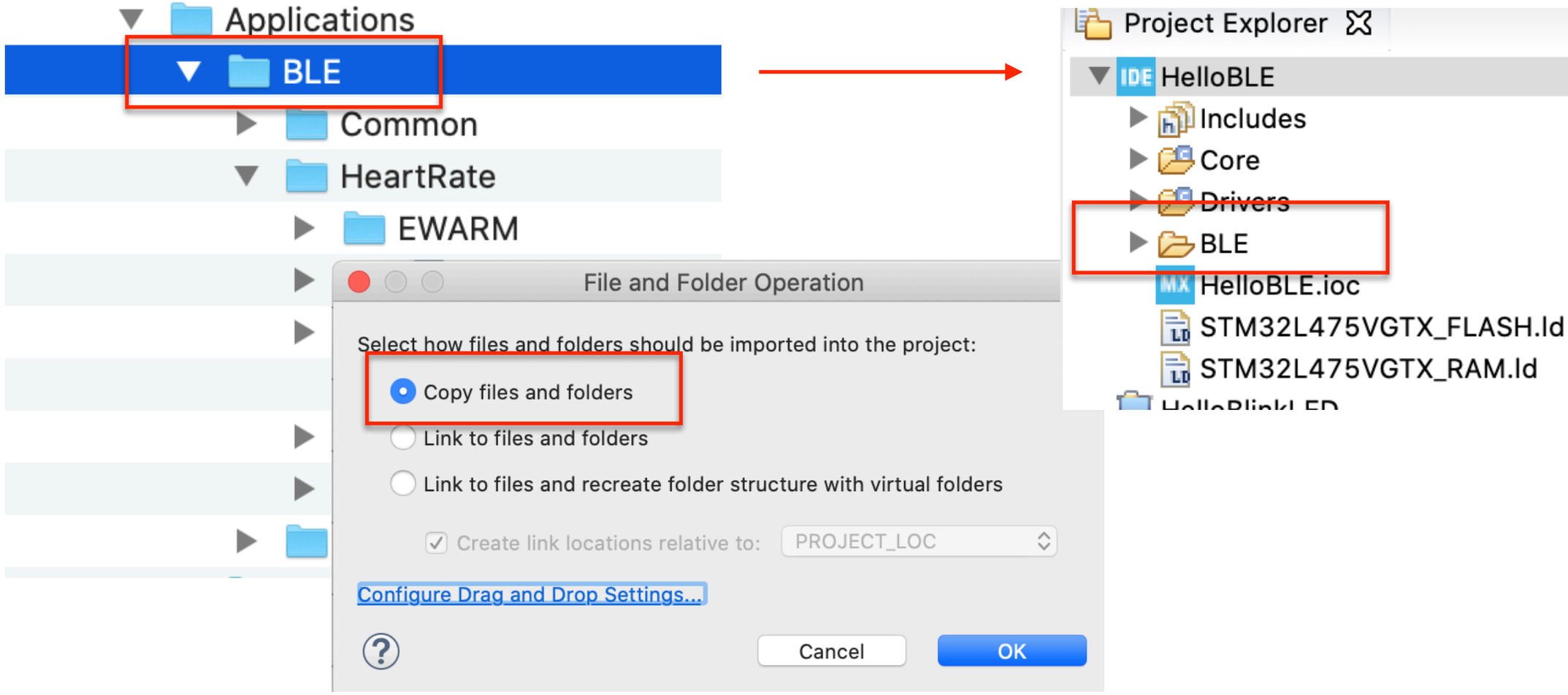


Projects/B-L475E-IOT01A/BLE

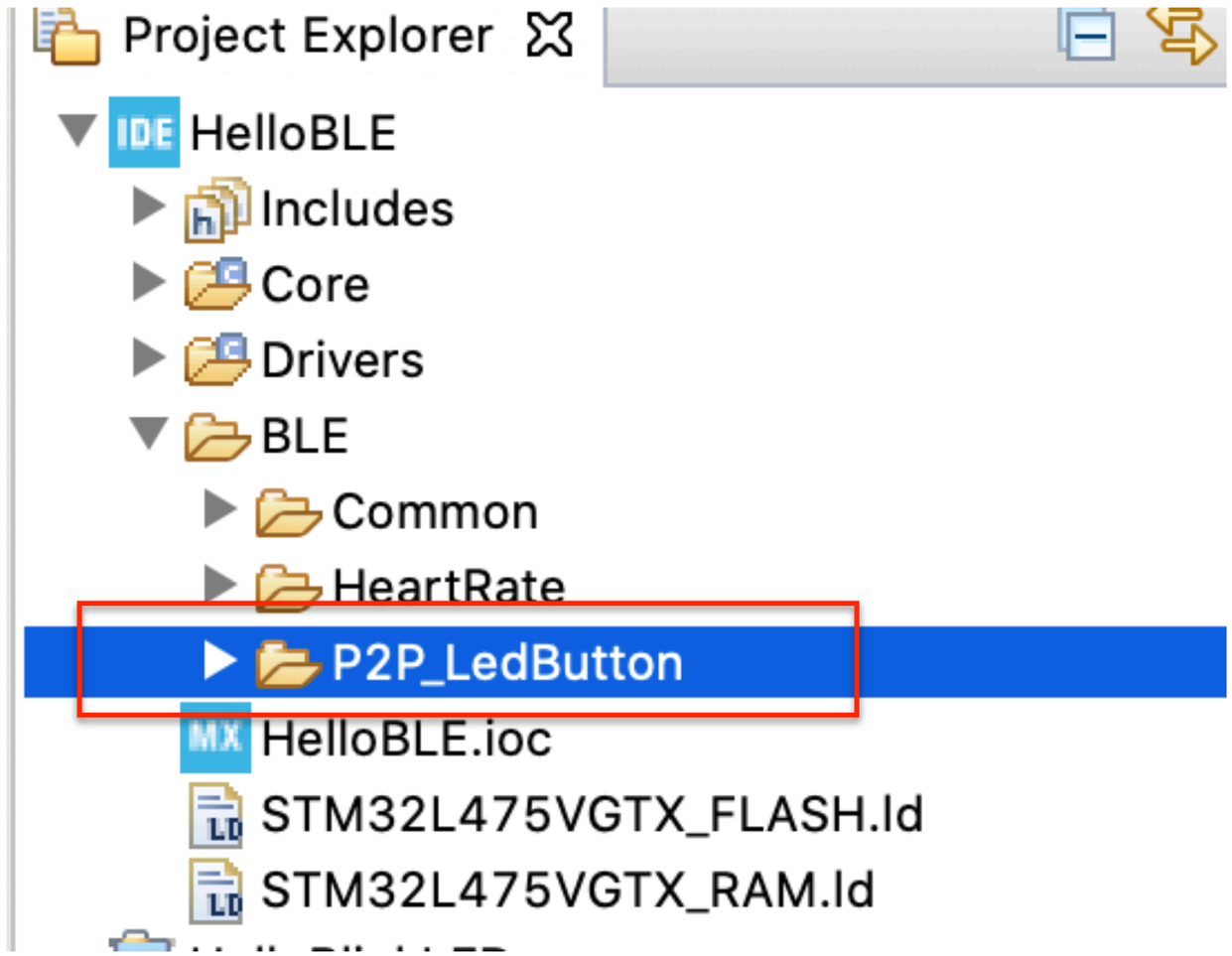




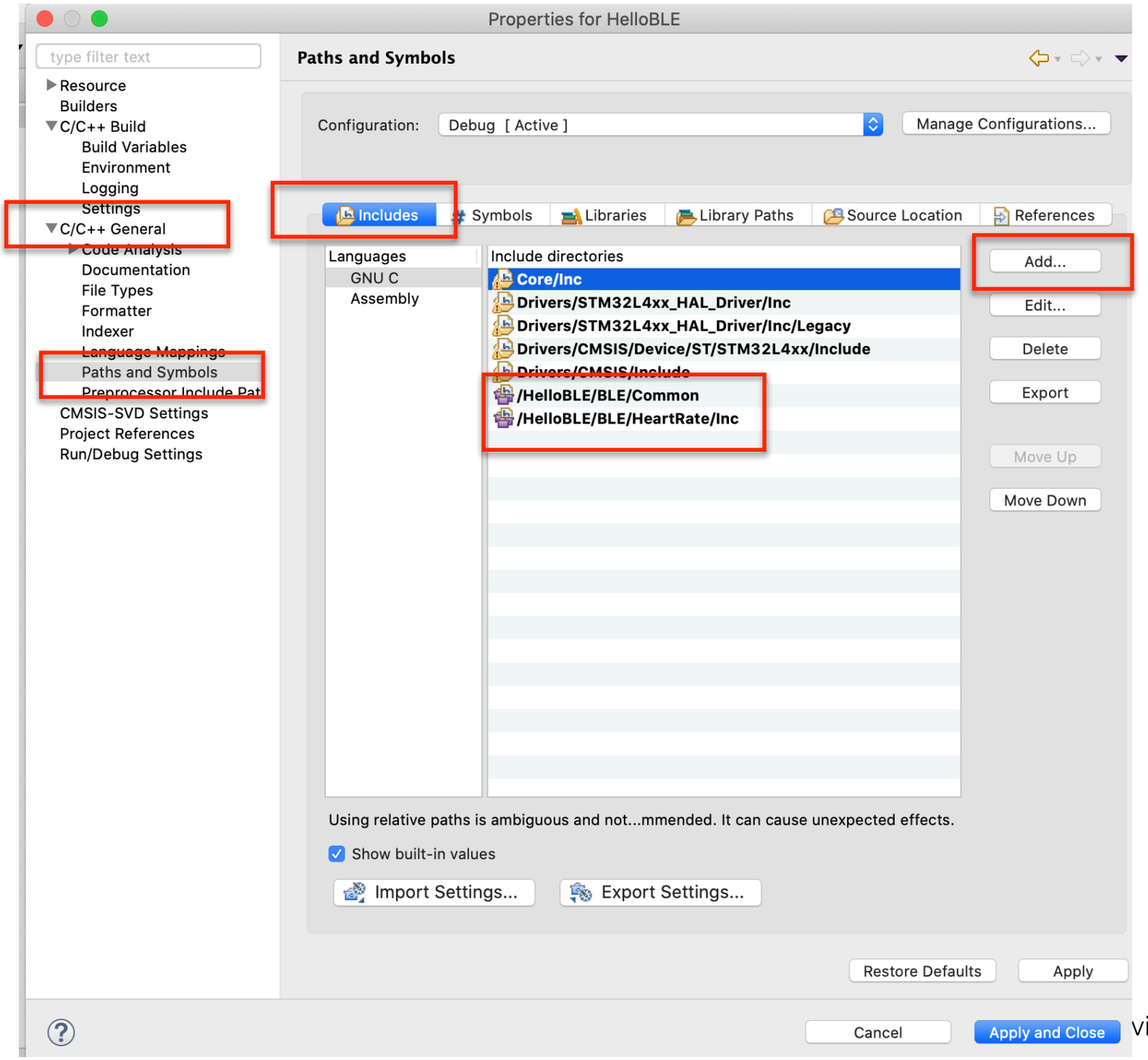
BLE Folder Drag/Drop (COPY FILES)



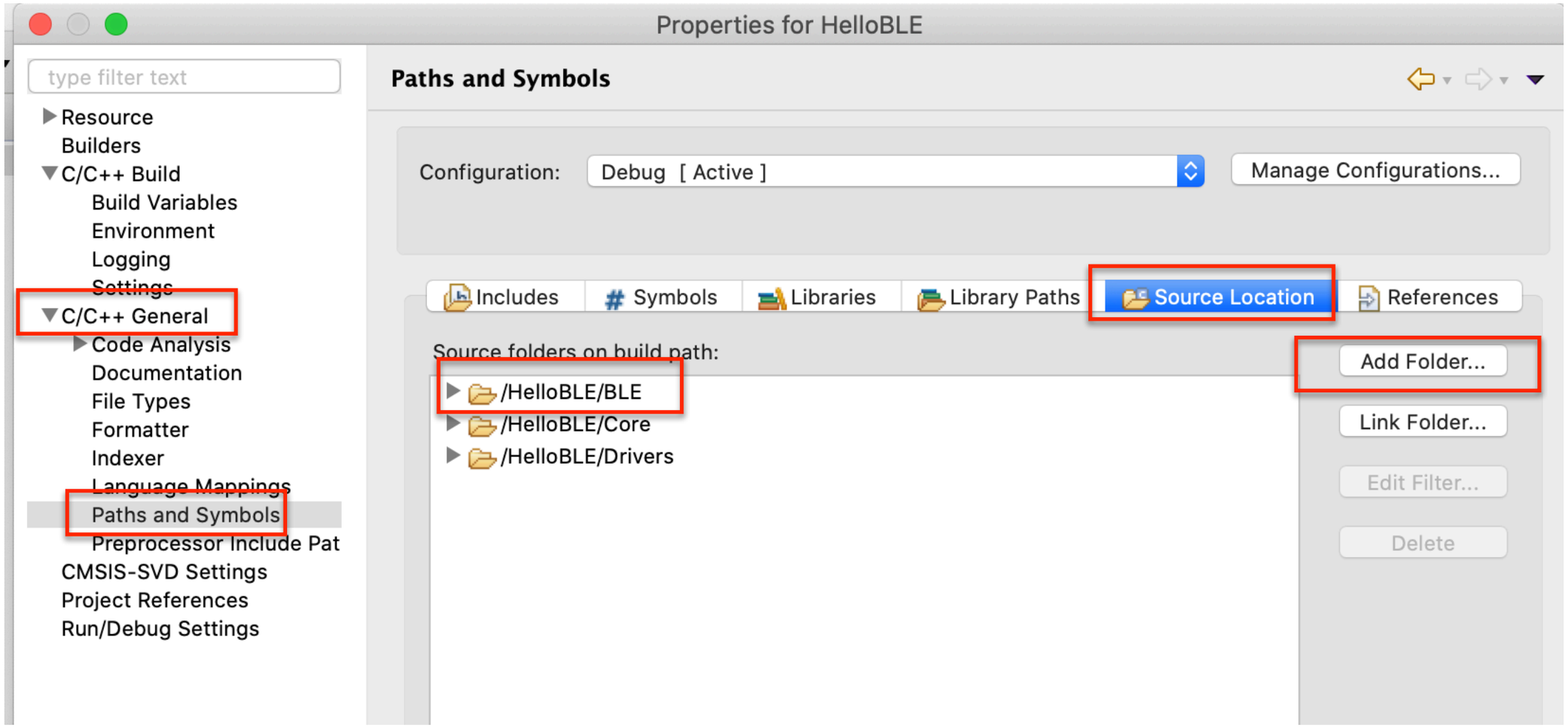
Delete P2P_LedButton Folder



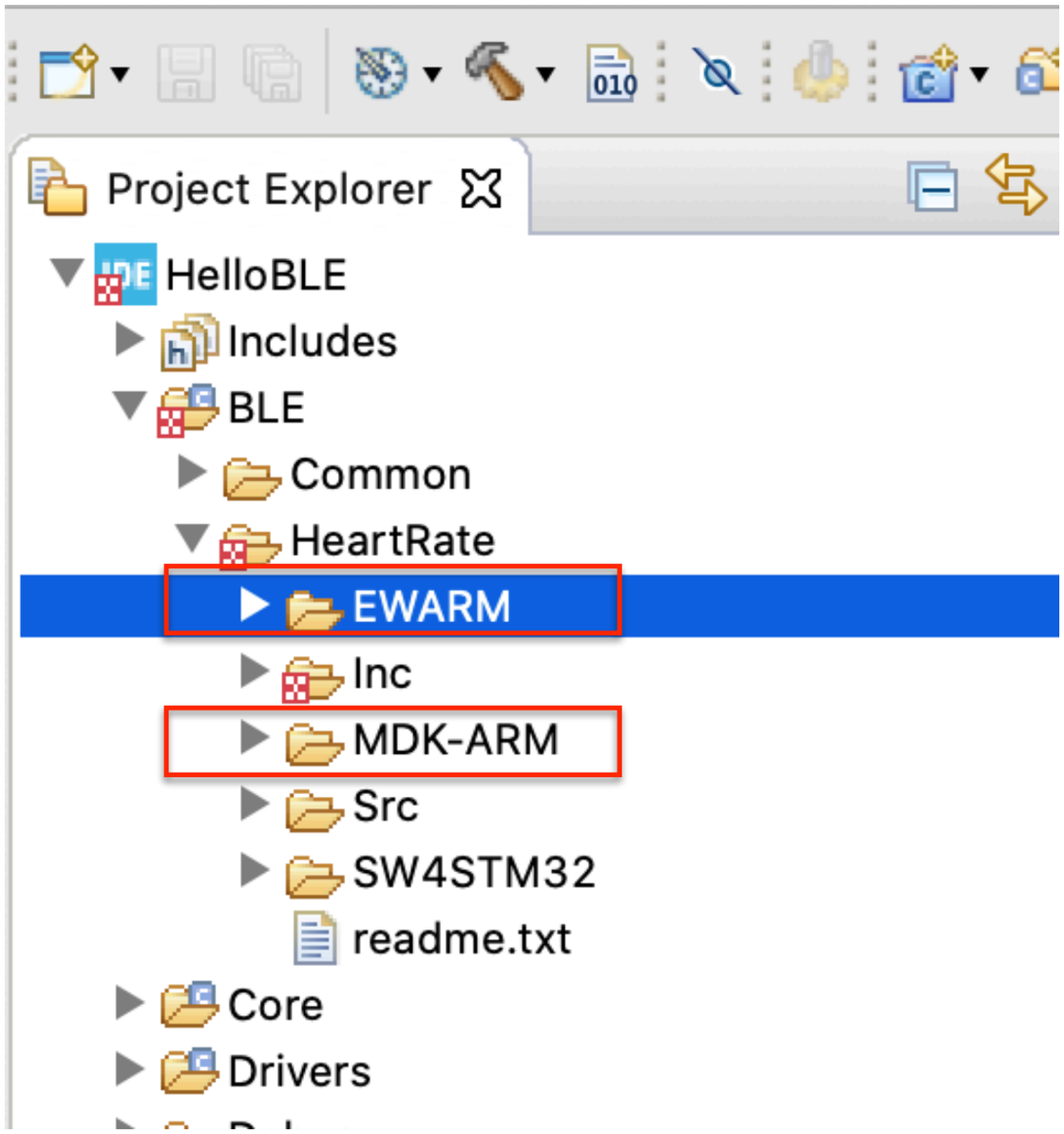
Add Include Paths To Project Properties



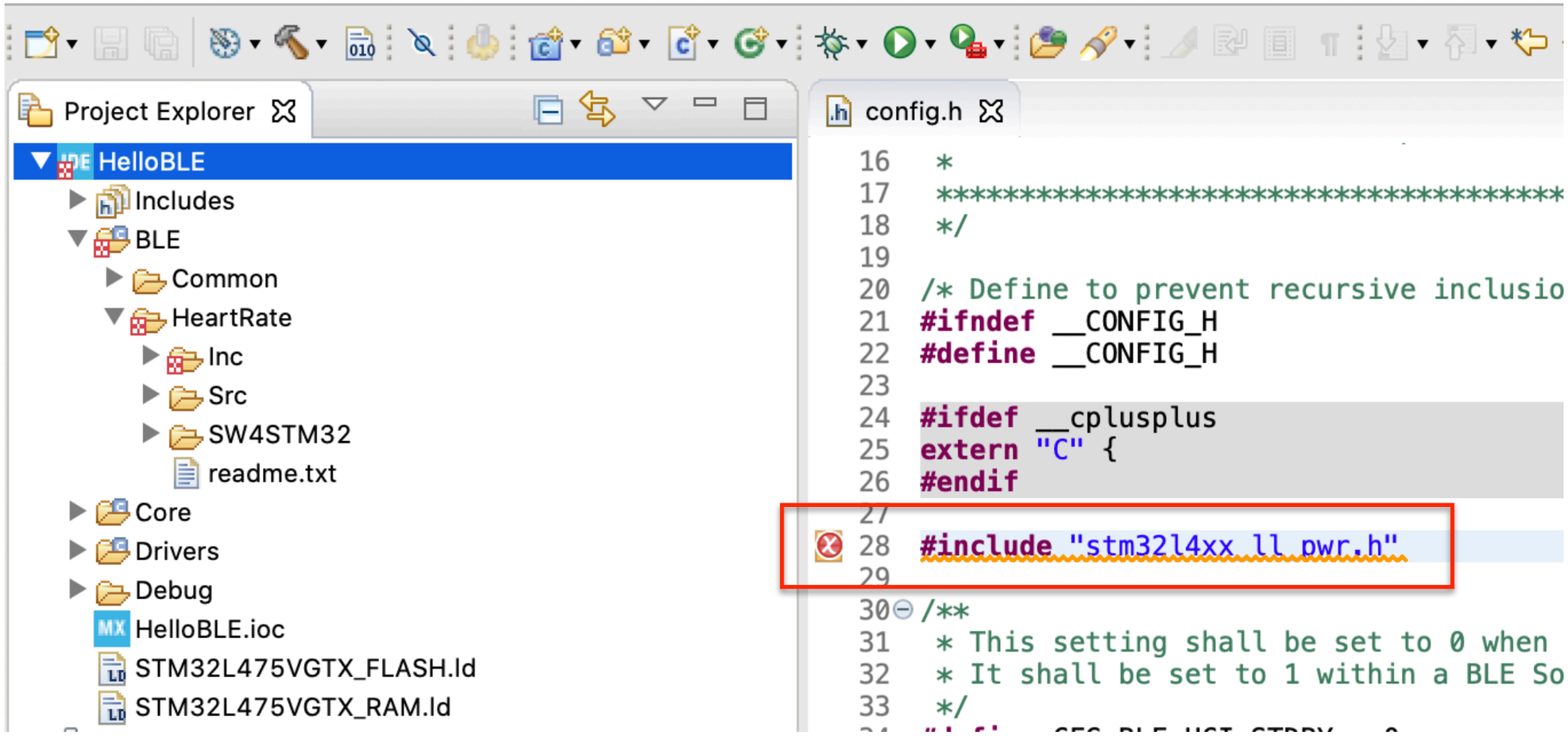
Add Source Paths To Project Properties



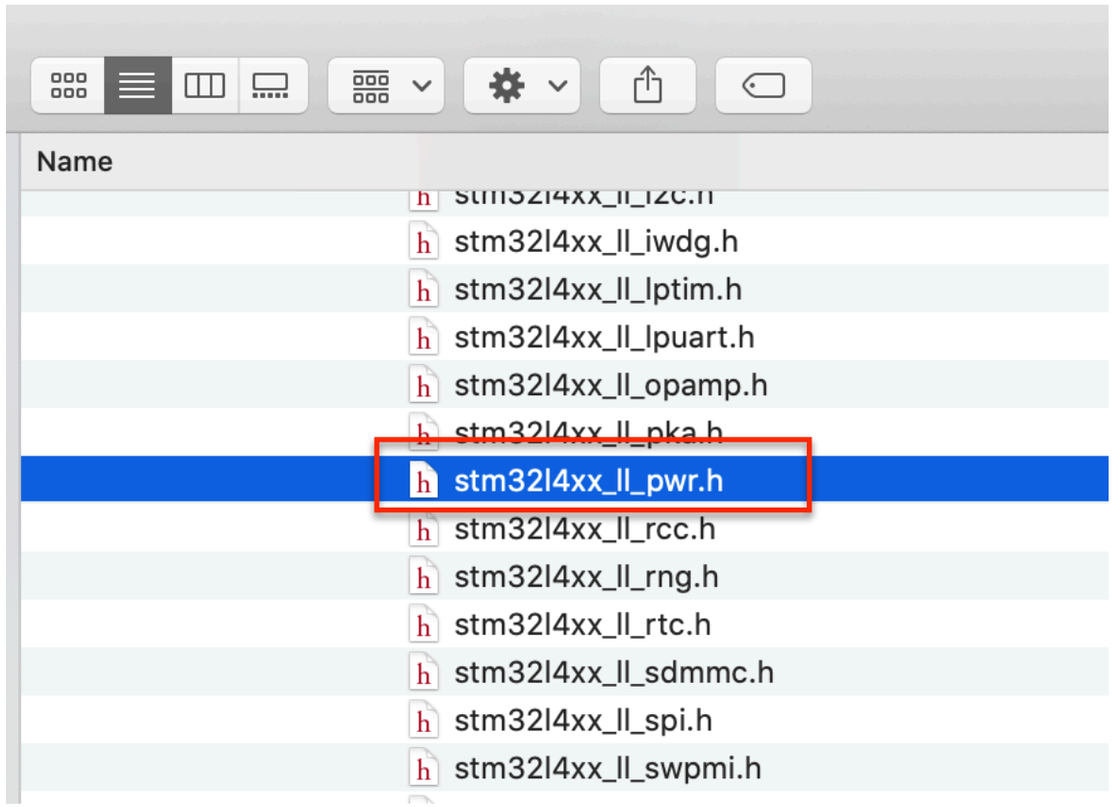
Delete Folders EWARM and MDK-ARM



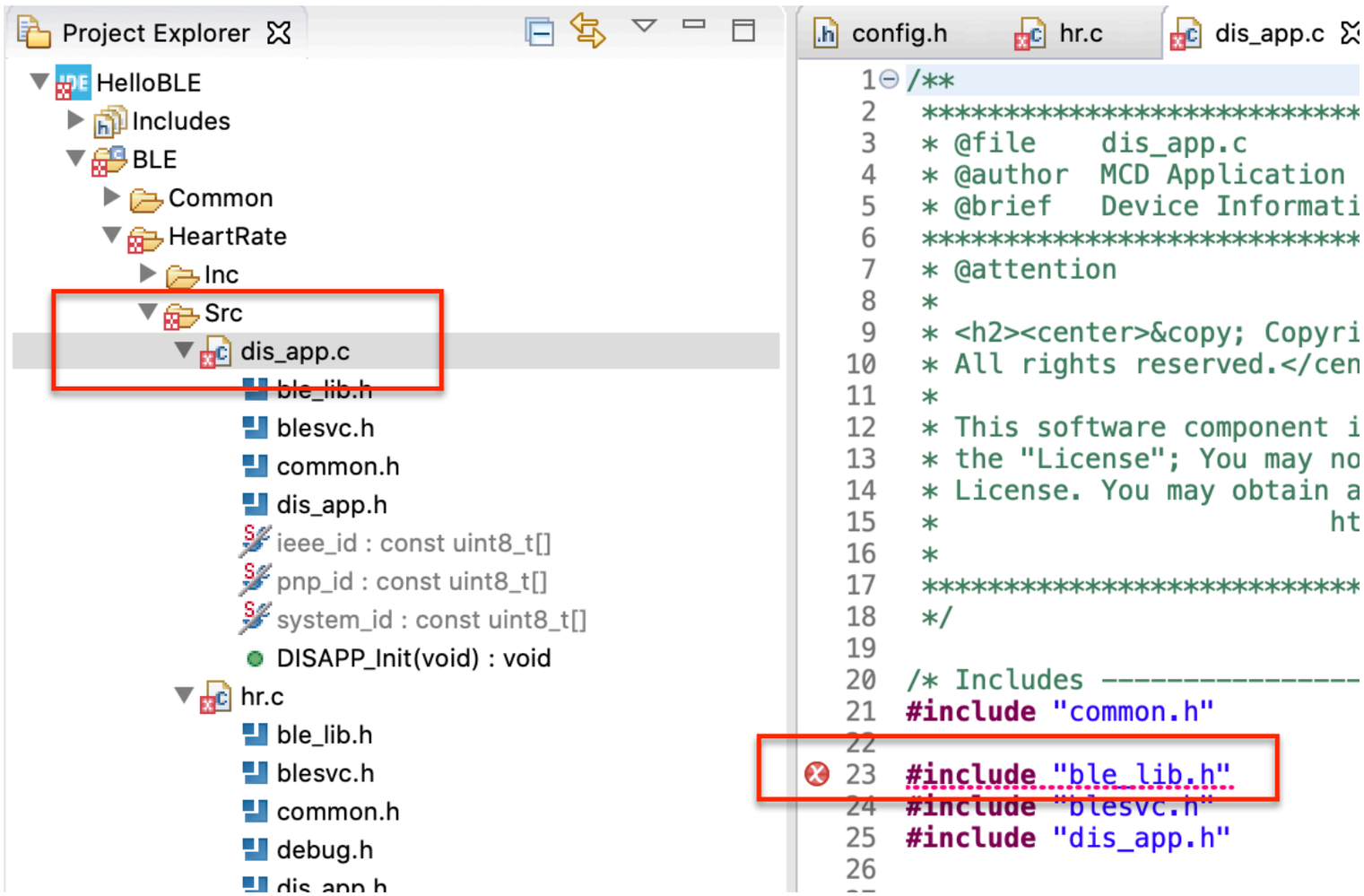
First Build Attempt
Missing LL Power



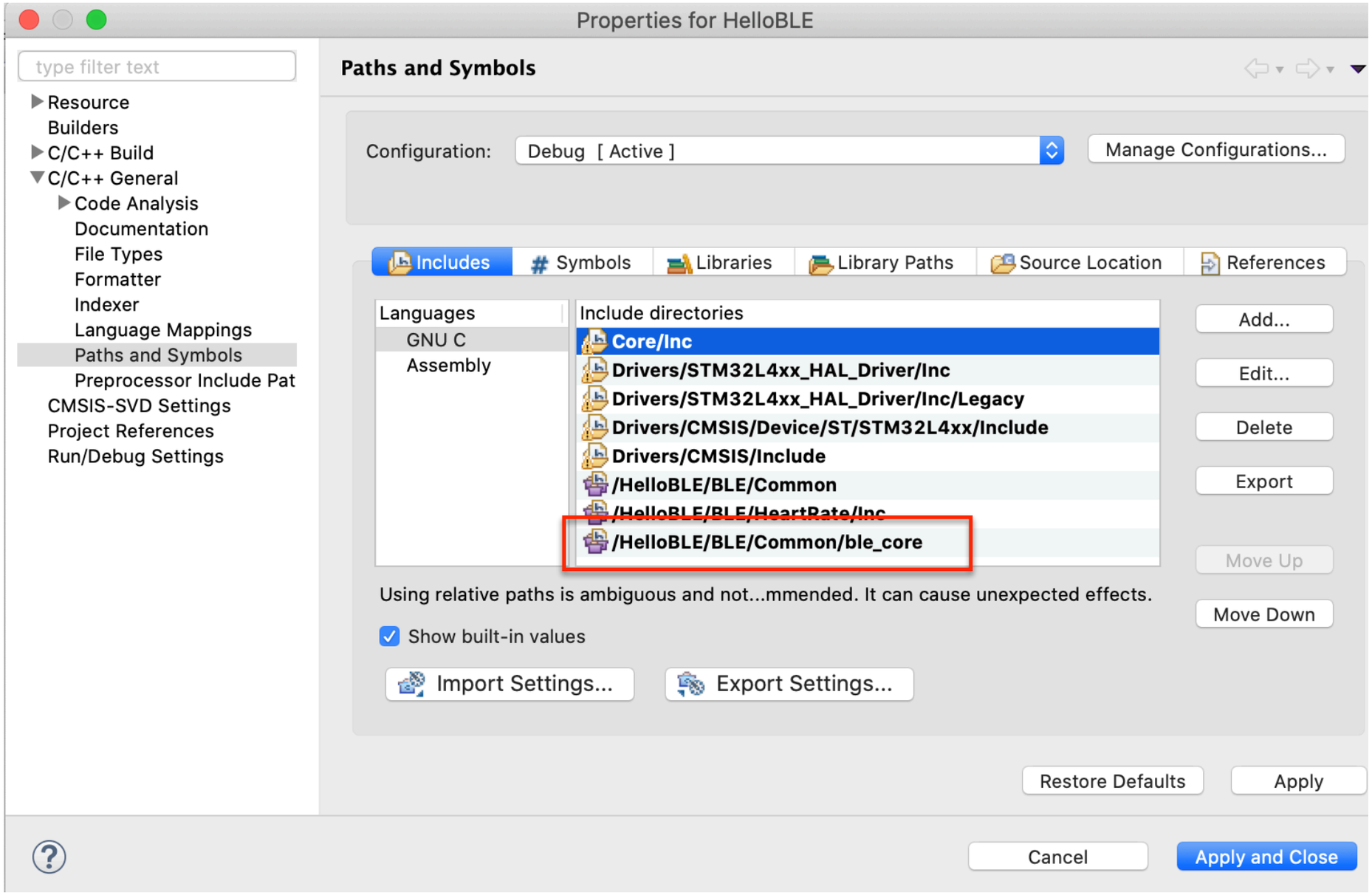
Drag Missing LL file to project



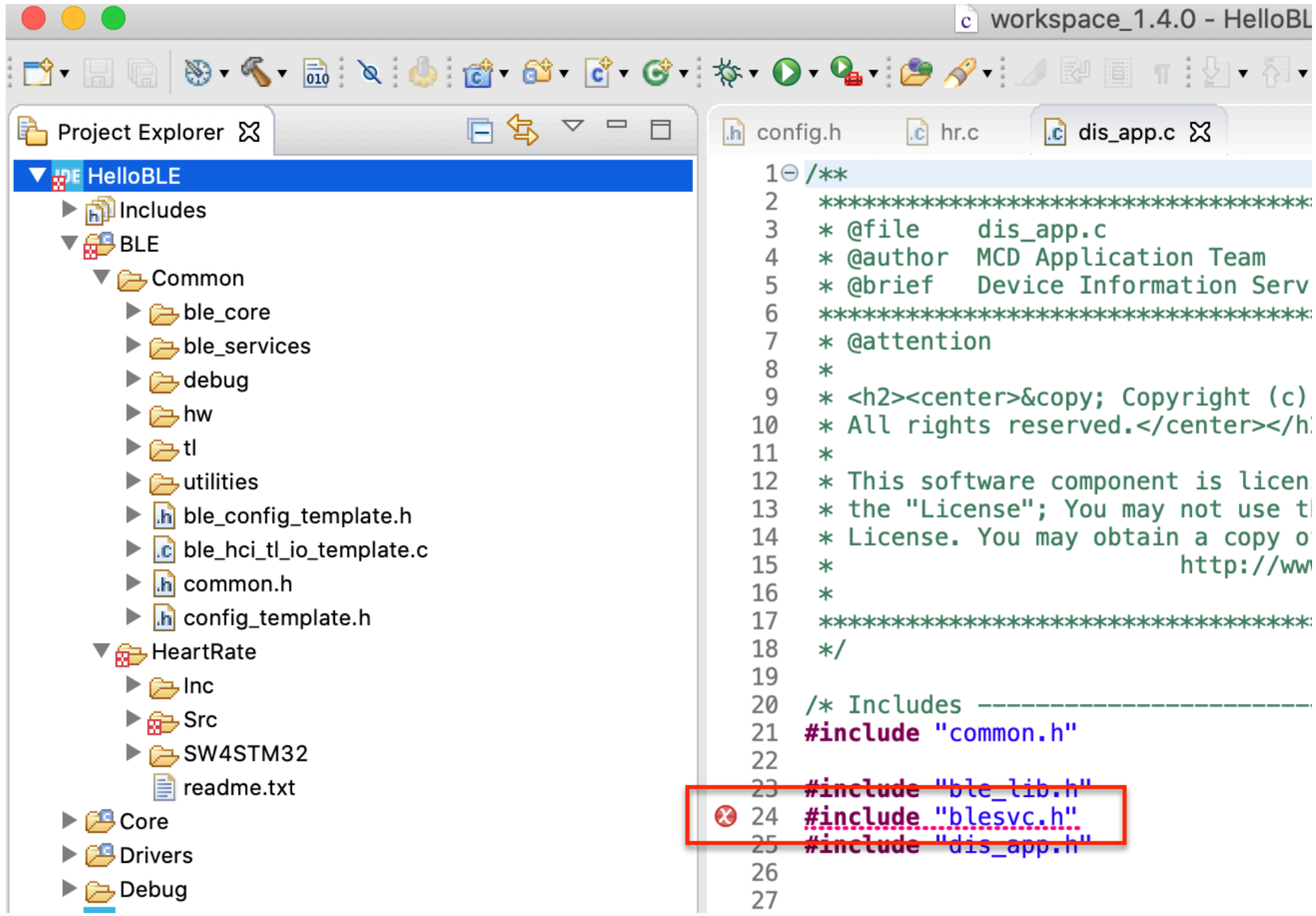
Attempt to build, observe error



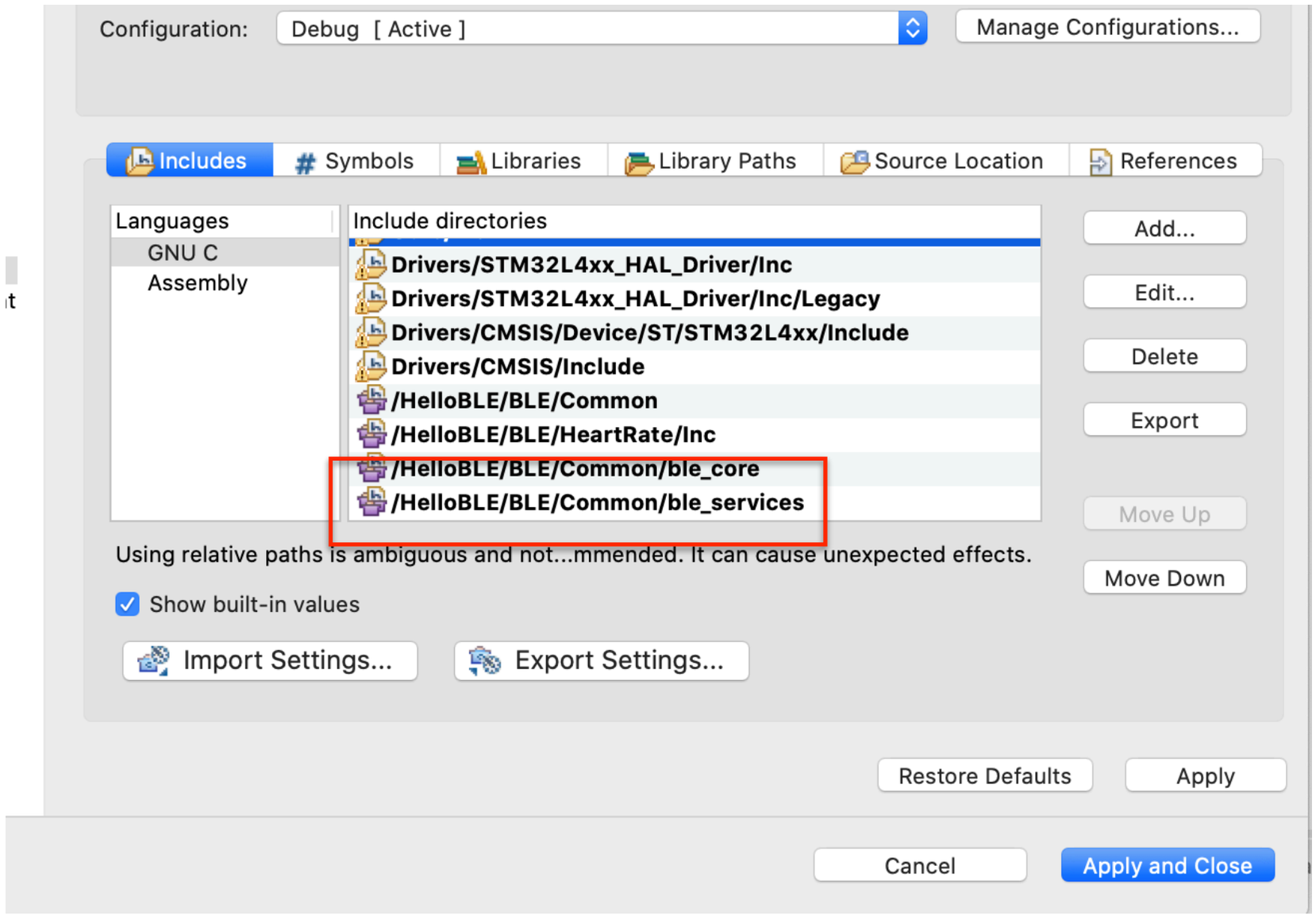
Add BLE/Common/ble_core to path



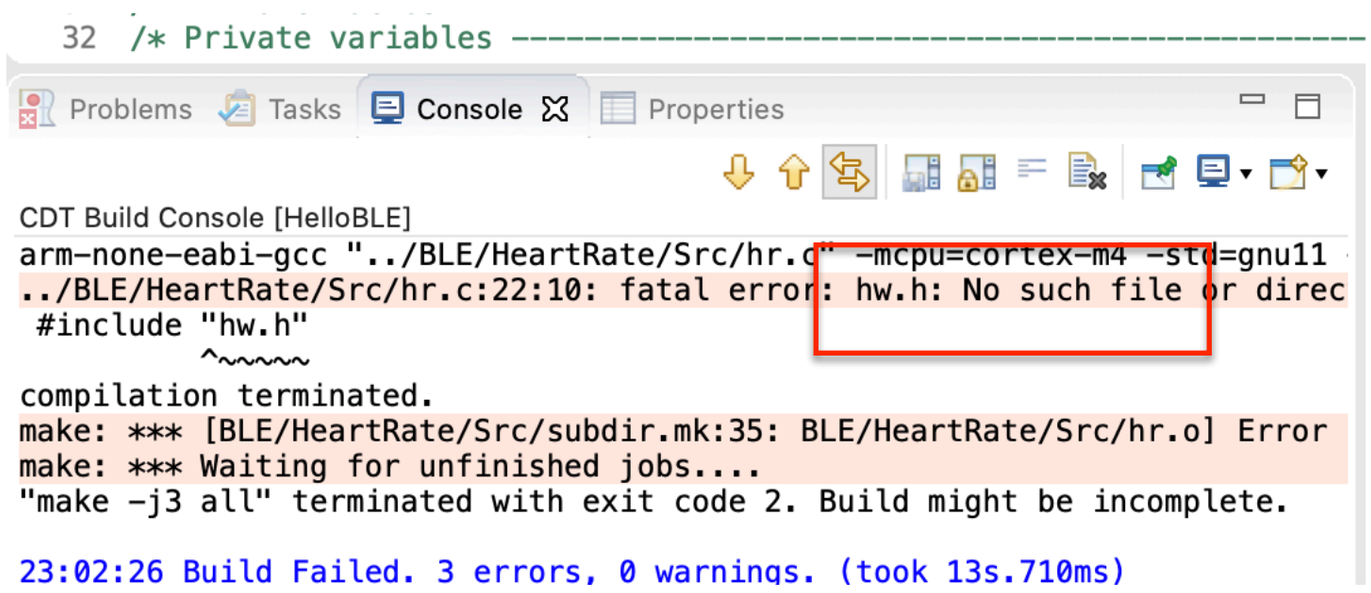
Attempt to build



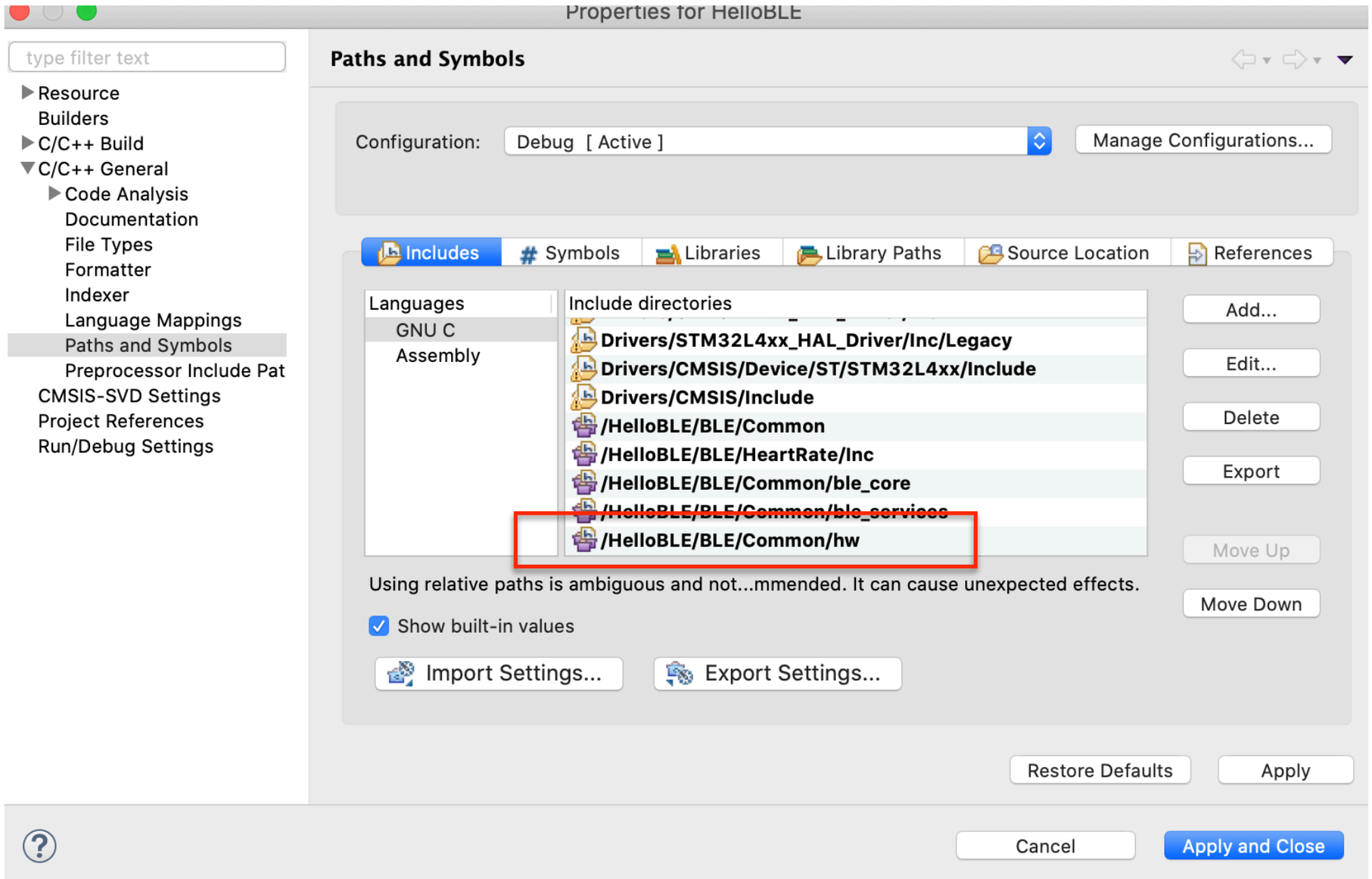
Add BLE/Common/ble_services to path



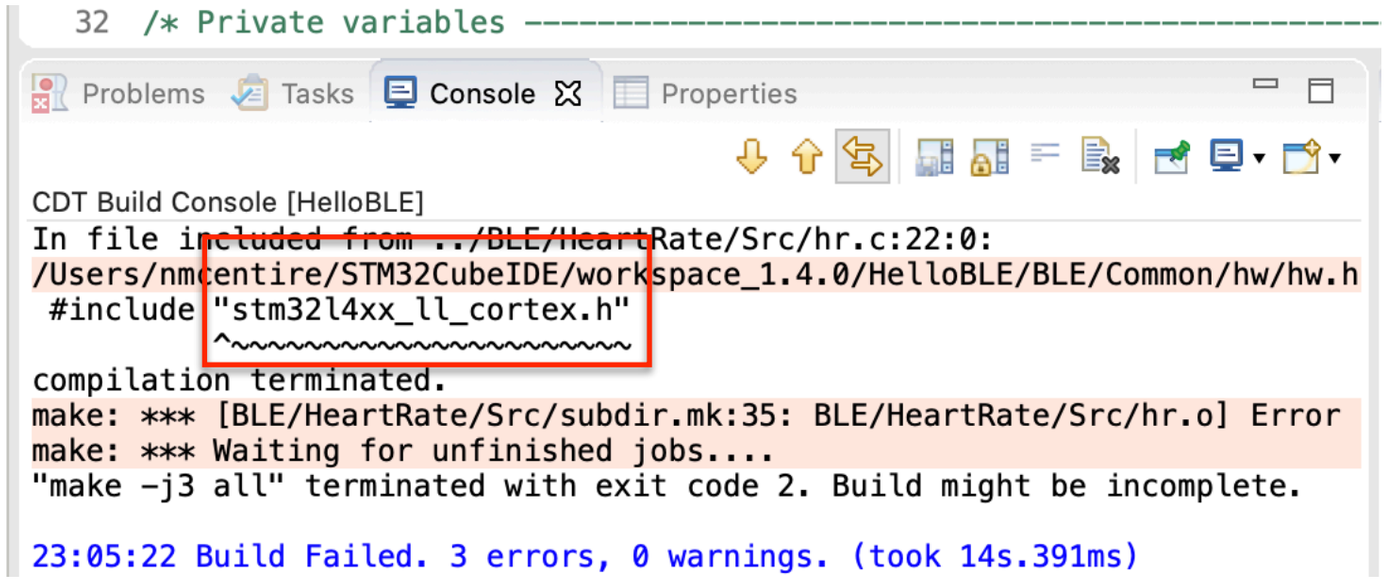
Attempt to build



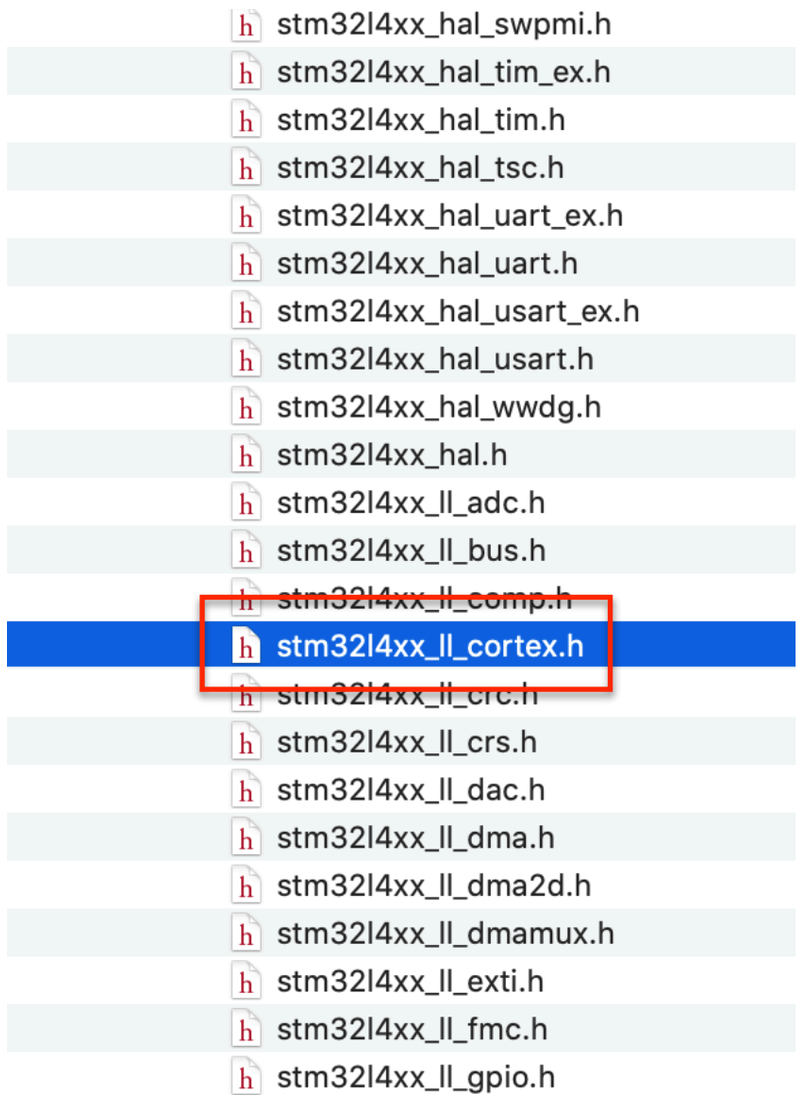
Add BLE/Common/hw to path

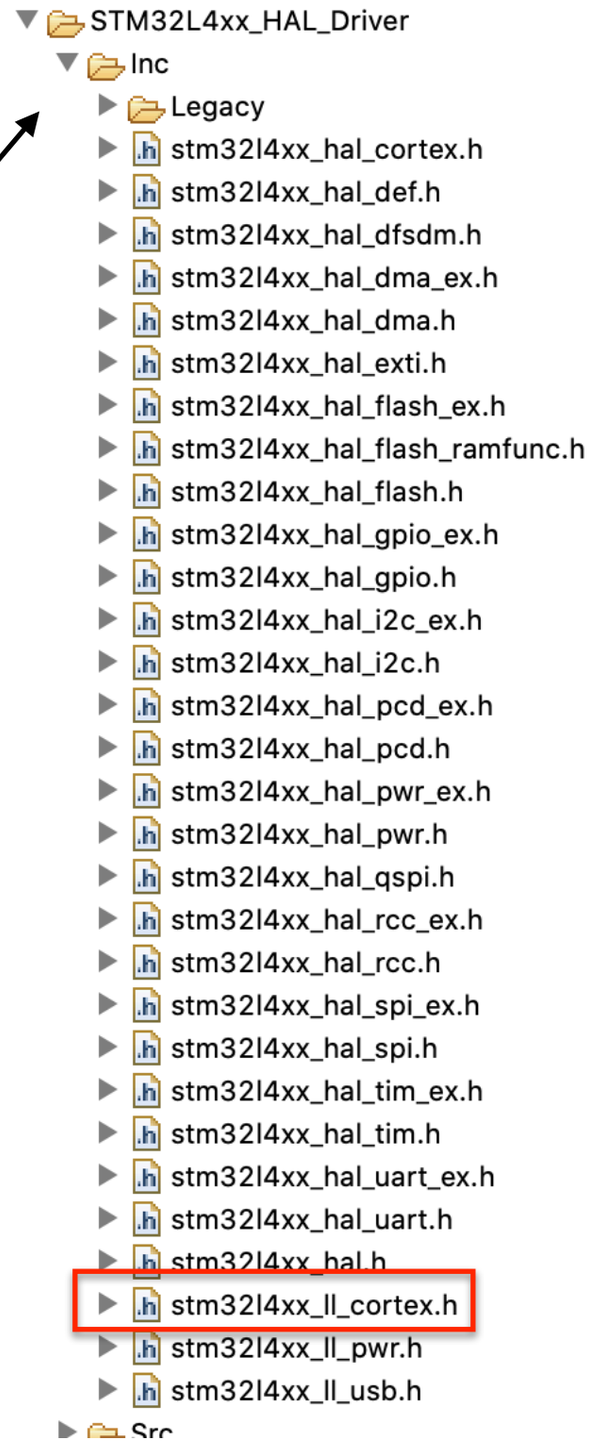


Attempt to build

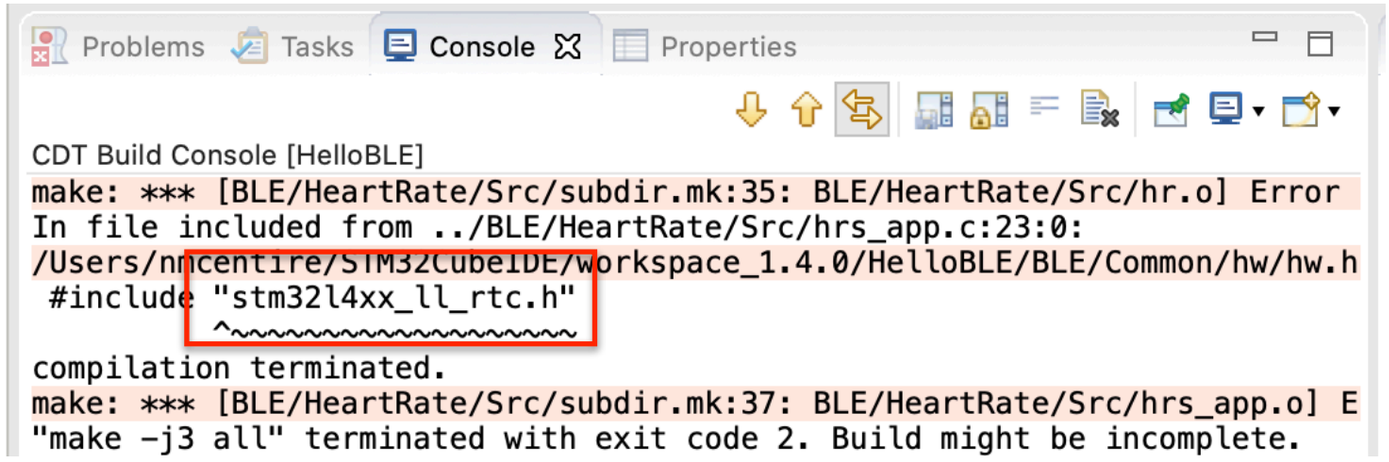


Copy File

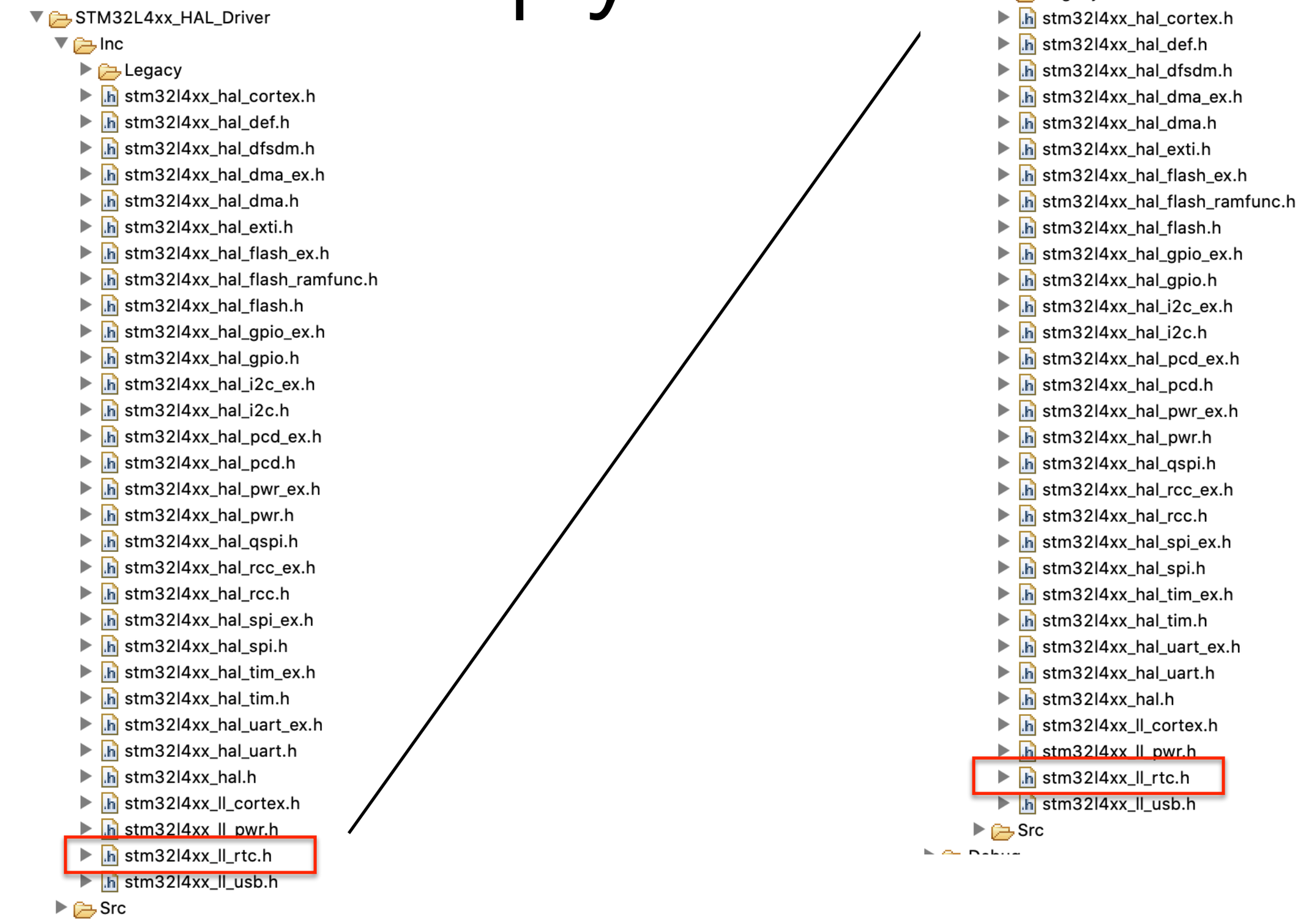




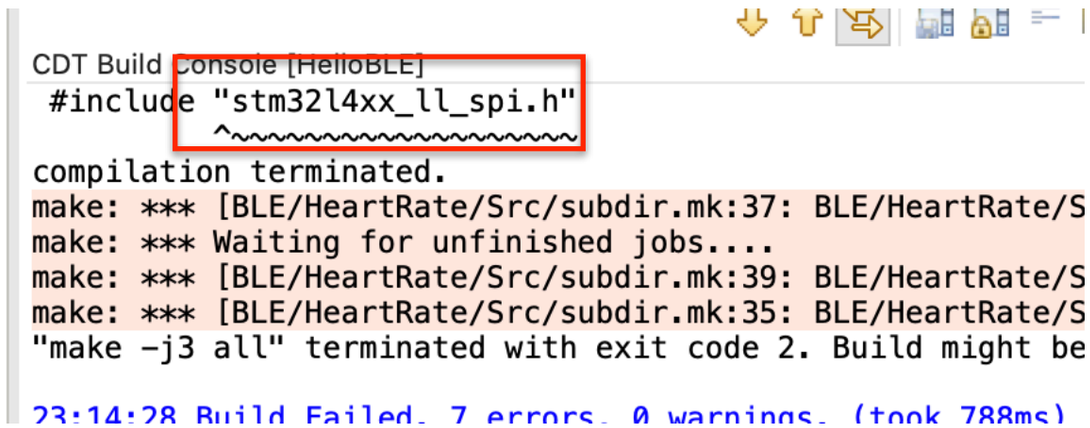
Attempt to build



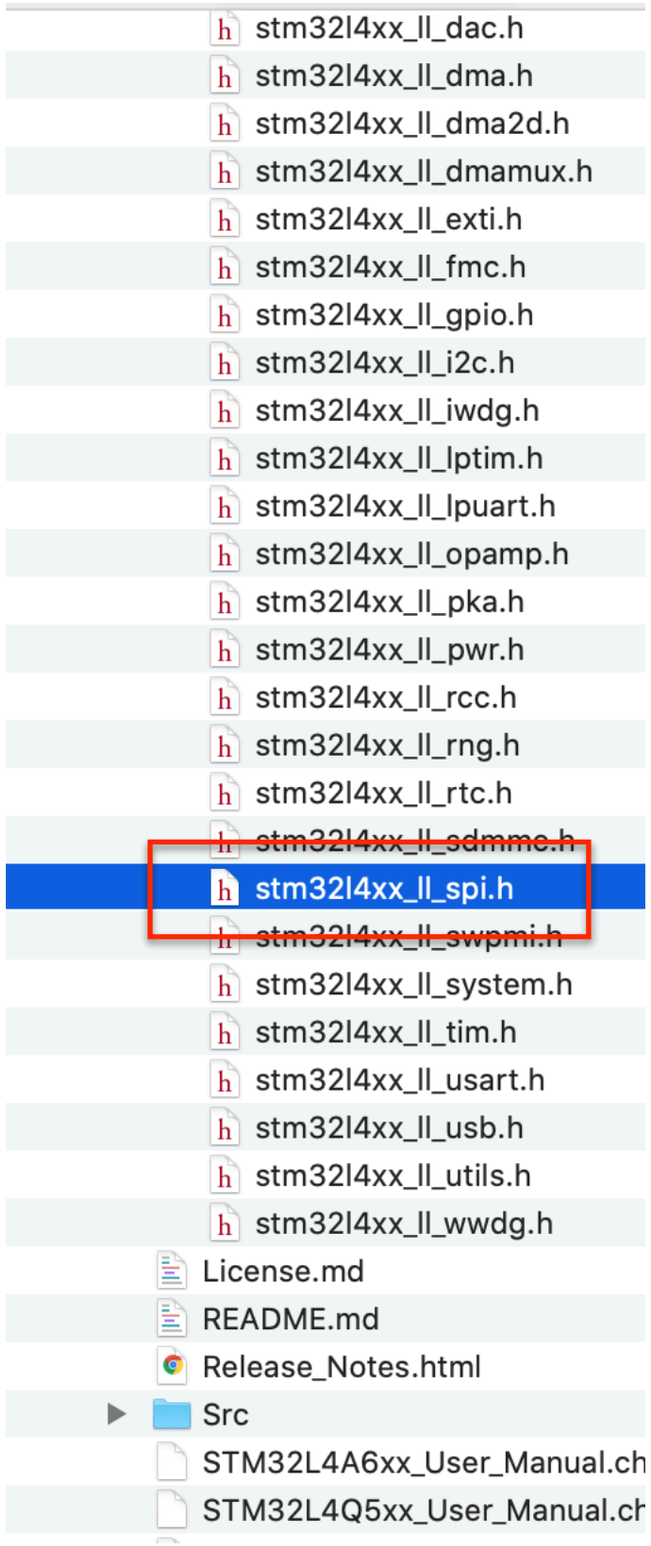
Copy File

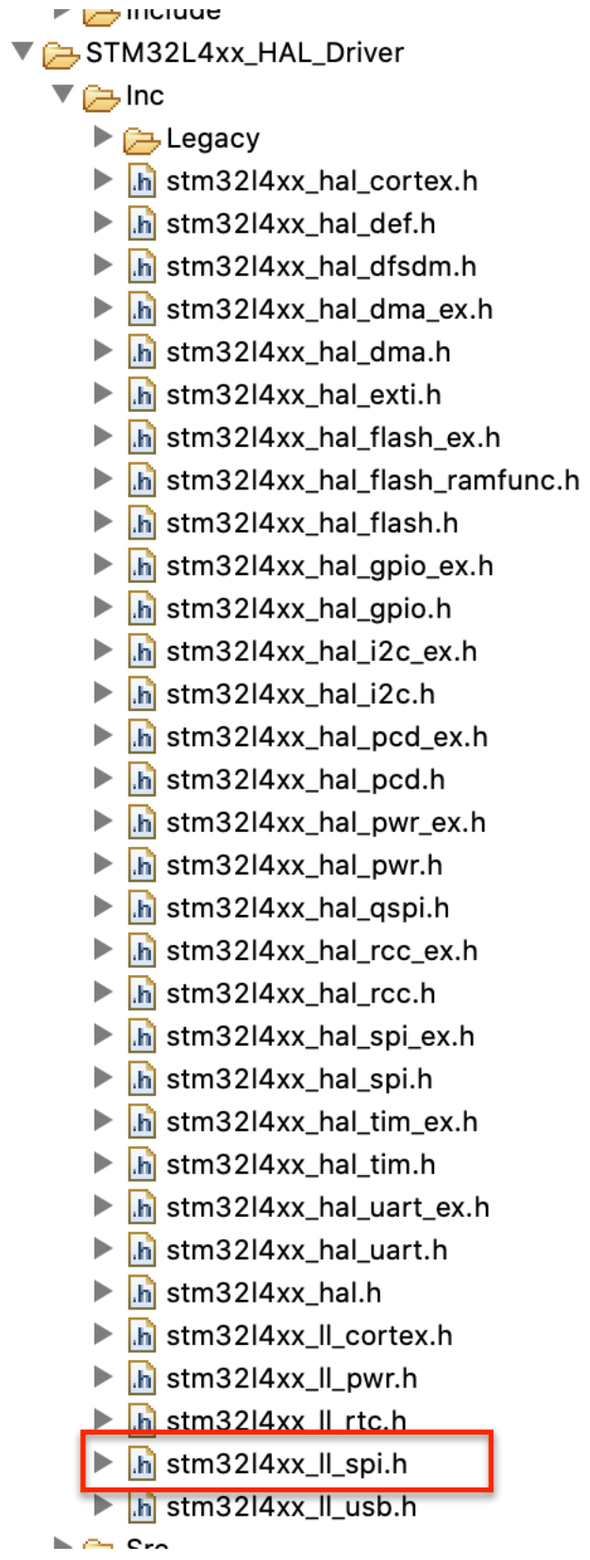


Attempt to build

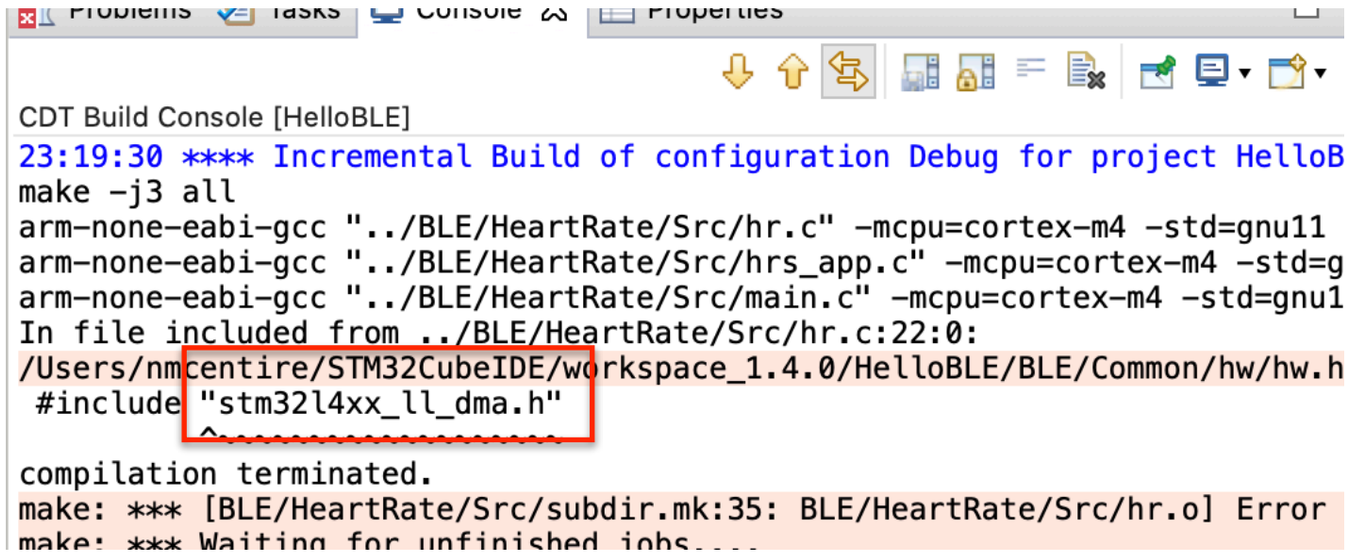


Copy File

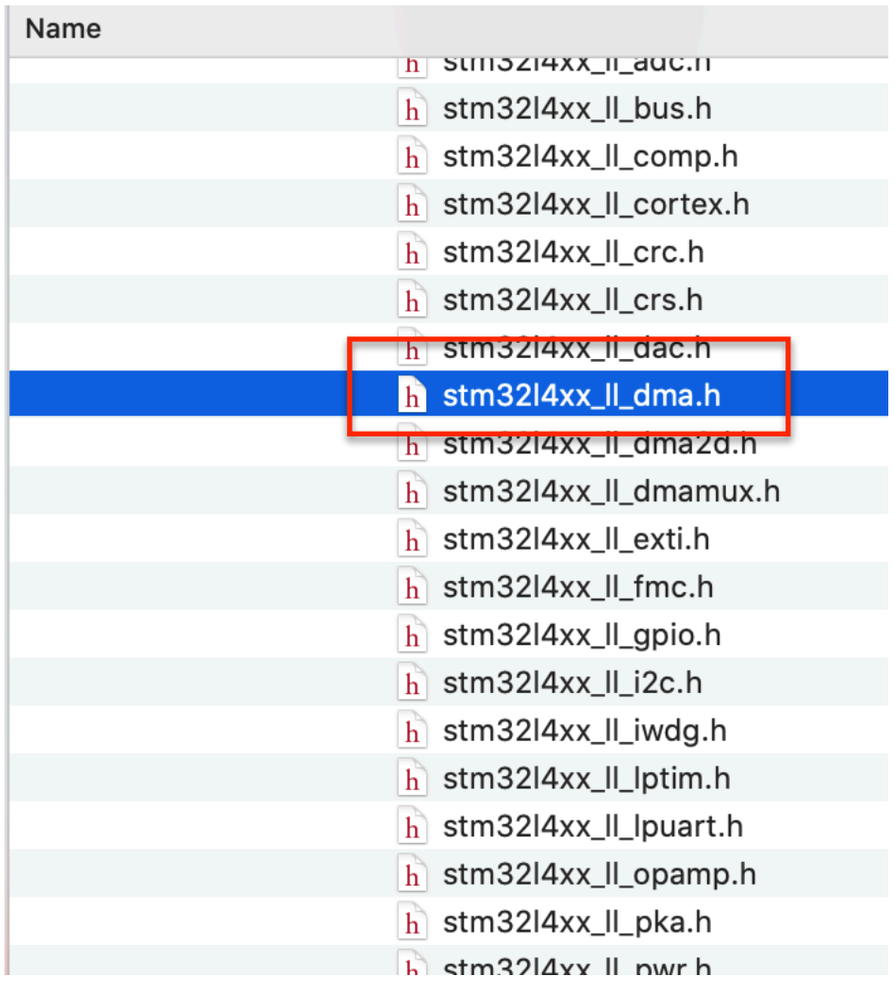


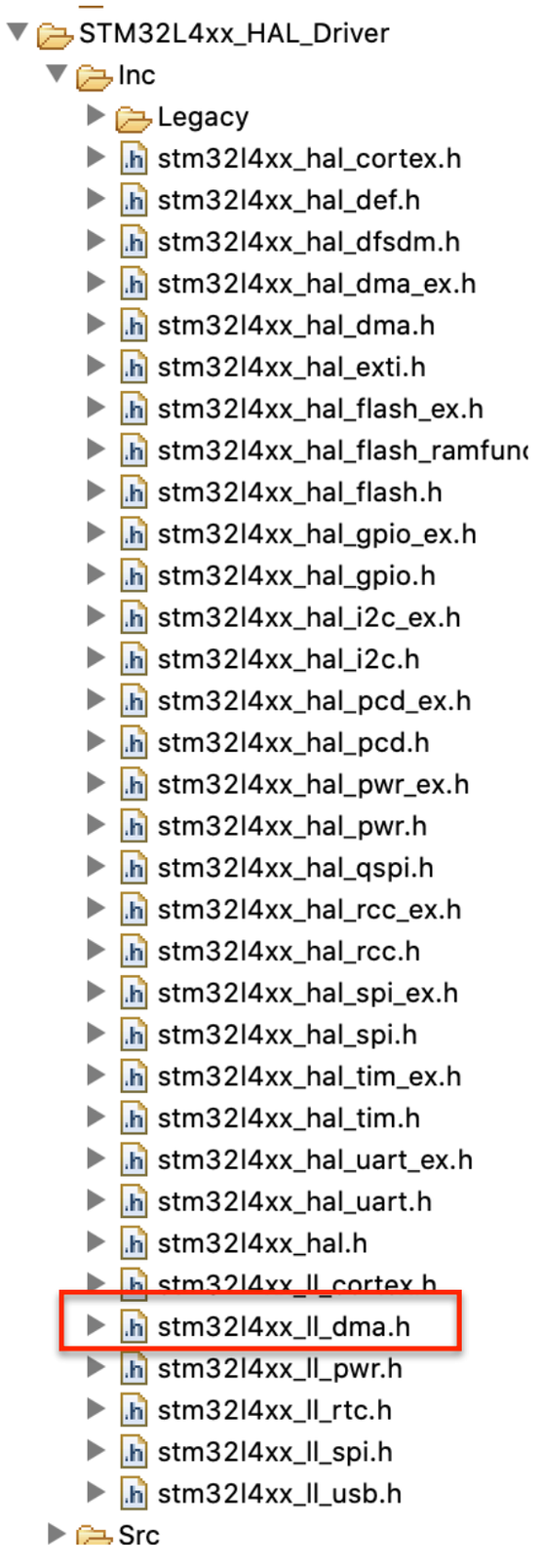


Attempt to build

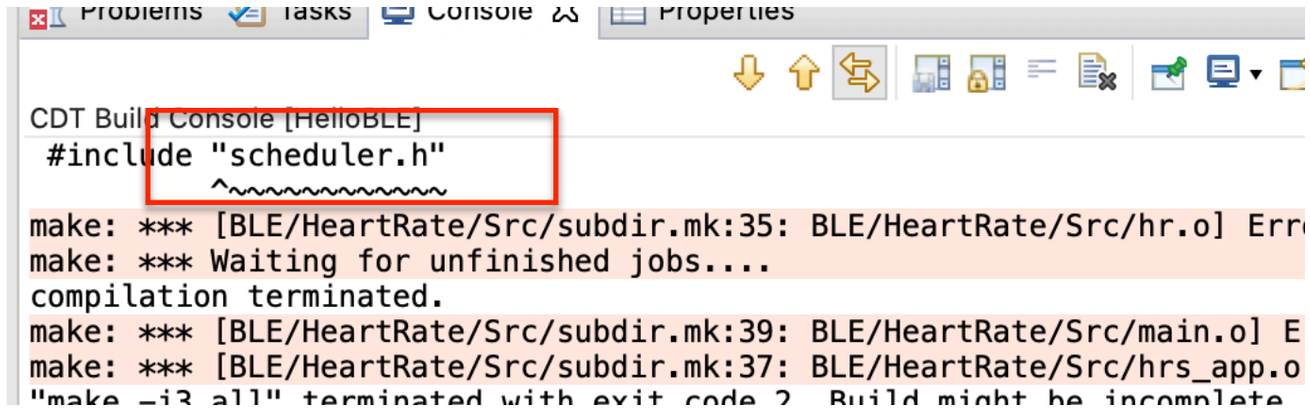


Copy File

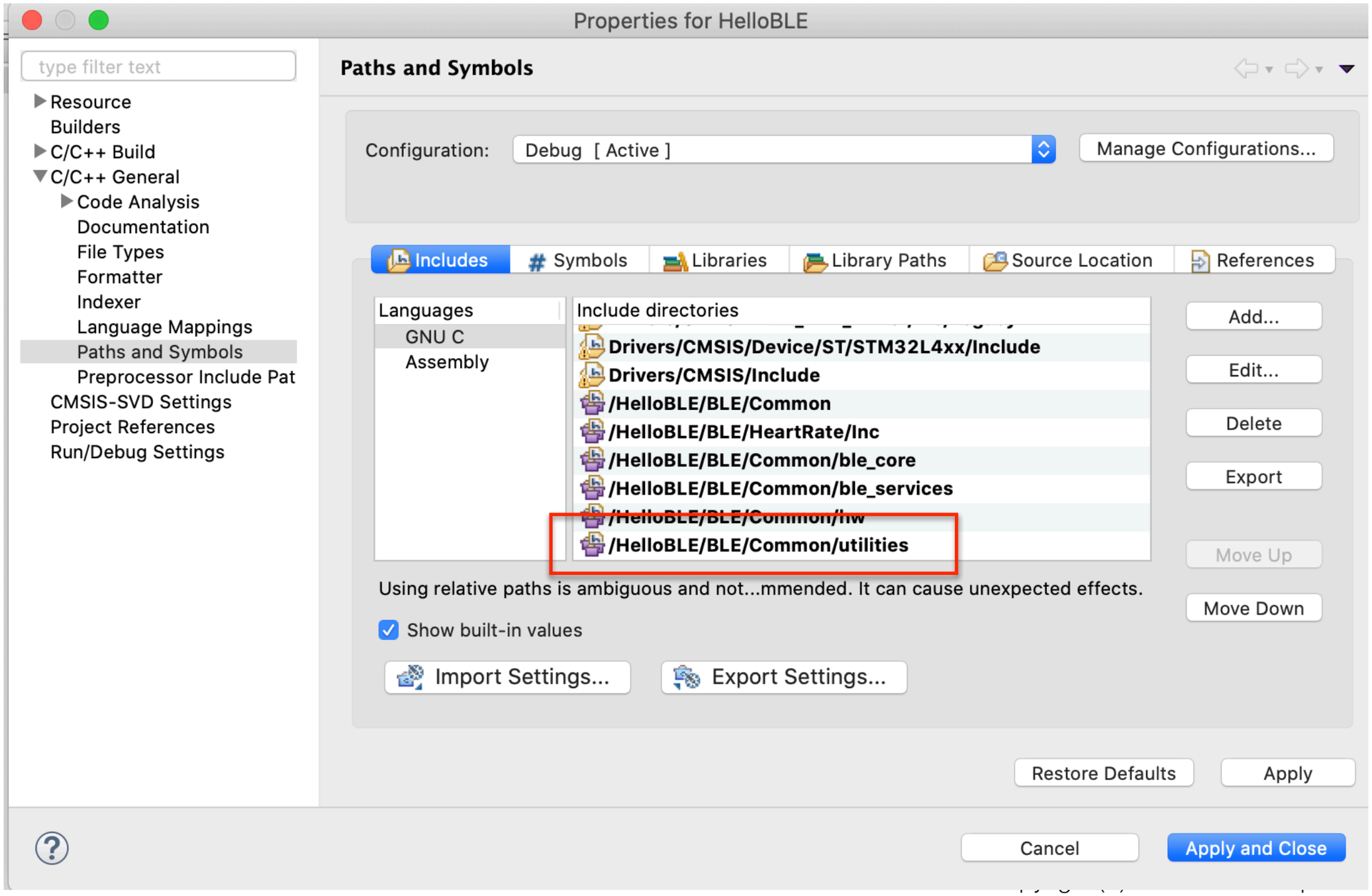




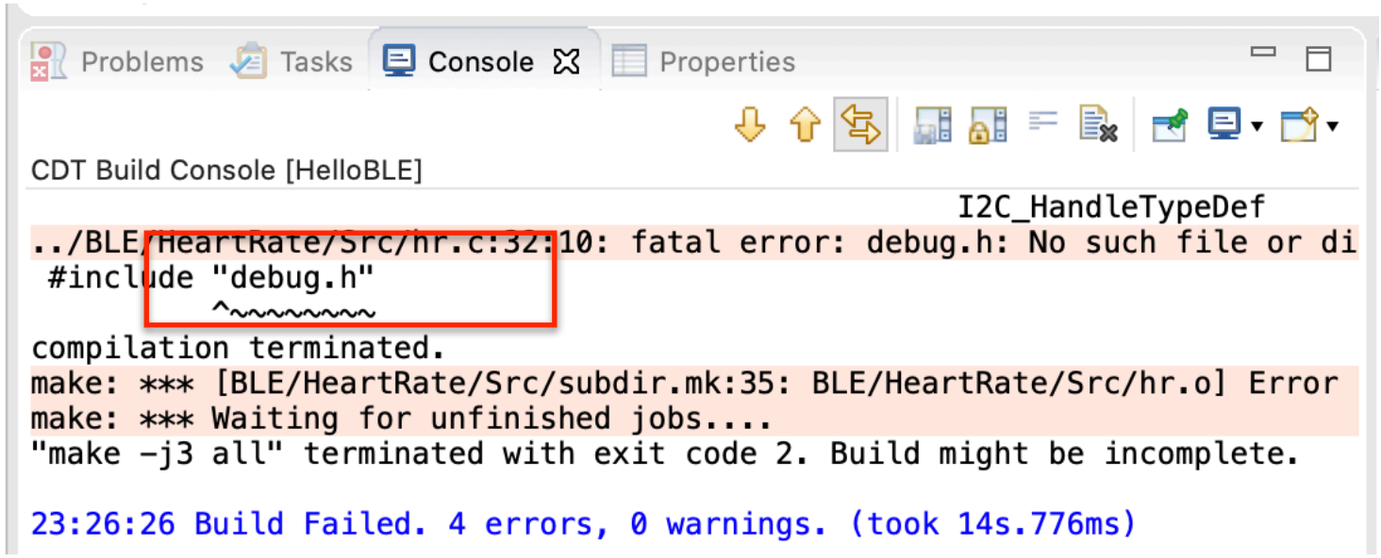
Attempt to build



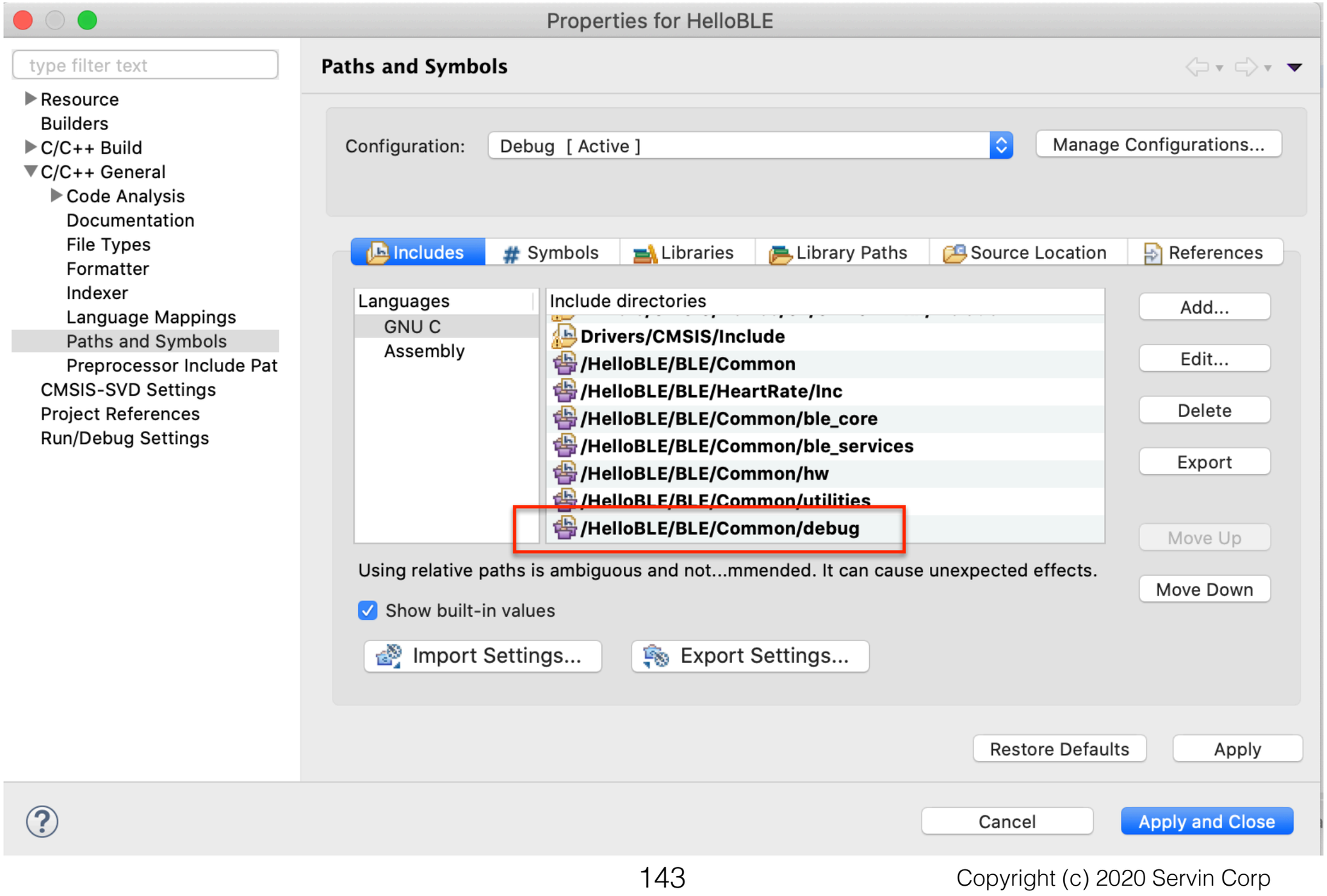
Add Path


Properties for HelloBLE
type filter text
Resource
Builders
C/C++ Build
C/C++ General
Code Analysis
Documentation
File Types
Formatter
Indexer
Language Mappings
Paths and Symbols
Preprocessor Include Pat
CMSIS-SVD Settings
Project References
Run/Debug Settings
Paths and Symbols
Configuration:
Debug [Active]
Manage Configurations...
Includes
Symbols
Libraries
Library Paths
Source Location
References
Languages
GNU C
Assembly
Include directories
Drivers/CMSIS/Device/ST/STM32L4xx/Include
Drivers/CMSIS/Include
/HelloBLE/BLE/Common
/HelloBLE/BLE/HeartRate/Inc
/HelloBLE/BLE/Common/ble_core
/HelloBLE/BLE/Common/ble_services
/HelloBLE/BLE/Common/hw
/HelloBLE/BLE/Common/utilities
Add...
Edit...
Delete
Export
Move Up
Move Down
Using relative paths is ambiguous and not...mmended. It can cause unexpected effects.
Show built-in values
Import Settings...
Export Settings...
Restore Defaults
Apply
Cancel
Apply and Close

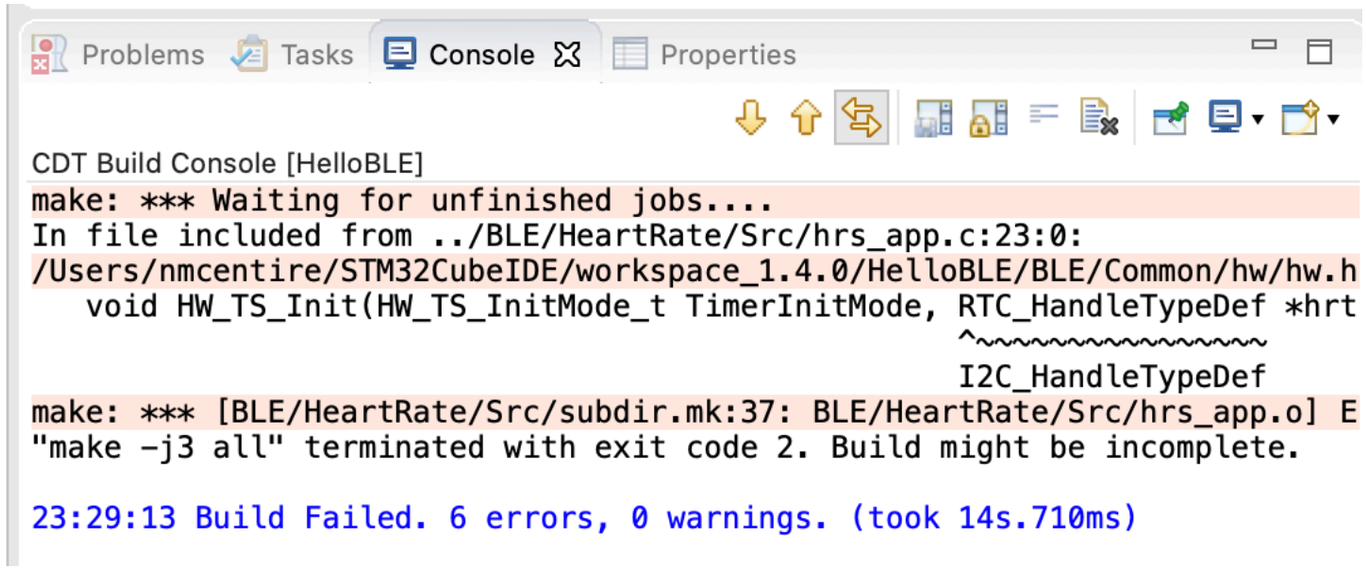
Attempt to build



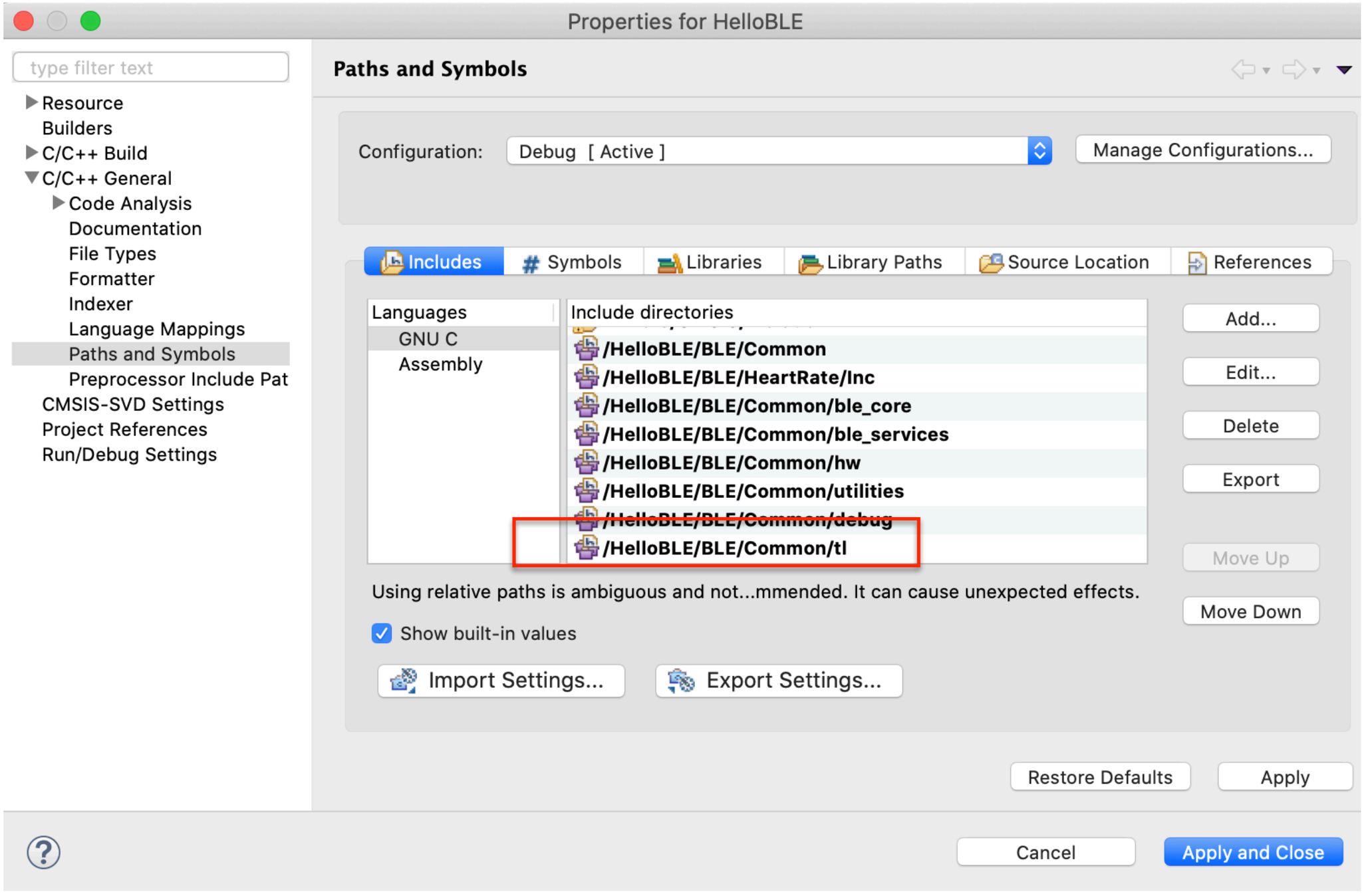
Add Path



Attempt to build



Add Path


Properties for HelloBLE
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Libraries
Library Paths
Source Location
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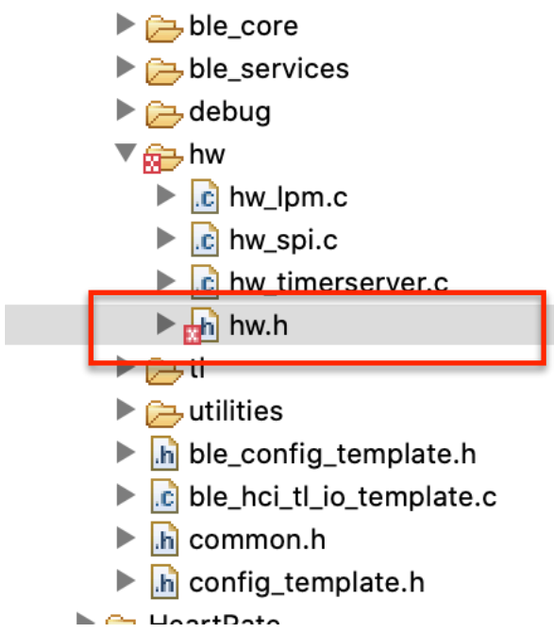
Languages
GNU C
Assembly
Include directories
/HelloBLE/BLE/Common
/HelloBLE/BLE/HeartRate/Inc
/HelloBLE/BLE/Common/ble_core
/HelloBLE/BLE/Common/ble_services
/HelloBLE/BLE/Common/hw
/HelloBLE/BLE/Common/utilities
/HelloBLE/BLE/Common/debug
/HelloBLE/BLE/Common/tl
Add...
Edit...
Delete
Export
Move Up
Move Down
Using relative paths is ambiguous and not...mmended. It can cause unexpected effects.
Show built-in values
Import Settings...
Export Settings...
Restore Defaults
Apply
Cancel
Apply and Close

Copy File

Attempt Build

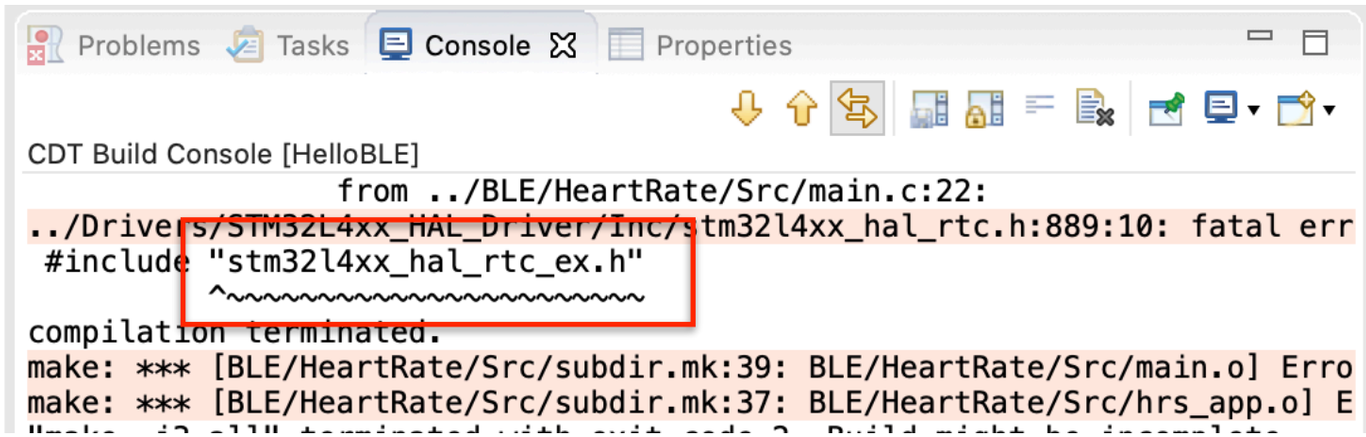
```
CDT Build Console [HelloBLE]
23:39:07 **** Incremental Build of configuration Debug for project HelloBLE ****
make -j3 all
arm-none-eabi-gcc "../BLE/HeartRate/Src/hr.c" -mcpu=cortex-m4 -std=gnu11 -g3 -DUSE_HAL_DRIVER -DDEBUG -DSTM32L475xx -c -I../Core/
arm-none-eabi-gcc "../BLE/HeartRate/Src/hrs_app.c" -mcpu=cortex-m4 -std=gnu11 -g3 -DUSE_HAL_DRIVER -DDEBUG -DSTM32L475xx -c -I../
arm-none-eabi-gcc "../BLE/HeartRate/Src/main.c" -mcpu=cortex-m4 -std=gnu11 -g3 -DUSE_HAL_DRIVER -DDEBUG -DSTM32L475xx -c -I../Cor
In file included from ../BLE/HeartRate/Src/hrs_app.c:23:0:
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLE/BLE/Common/hw/hw.h:97:51: error: unknown type name 'RTC_HandleTypeDef'; di
   void HW_TS_Init(HW_TS_InitMode_t TimerInitMode, RTC_HandleTypeDef *hrtc);
                                                   ^~~~~~~~~~~~~~~~~
                                                   I2C_HandleTypeDef
In file included from ../BLE/HeartRate/Src/main.c:22:0:
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLE/BLE/Common/hw/hw.h:97:51: error: unknown type name 'RTC_HandleTypeDef'; di
   void HW_TS_Init(HW_TS_InitMode_t TimerInitMode, RTC_HandleTypeDef *hrtc);
                                                   ^~~~~~~~~~~~~~~~~
                                                   I2C_HandleTypeDef
../BLE/HeartRate/Src/main.c:47:8: error: unknown type name 'RTC_HandleTypeDef'
 static RTC_HandleTypeDef hrtc; /**< RTC handler declaration */
```

Edit Header file to add HAL RTC

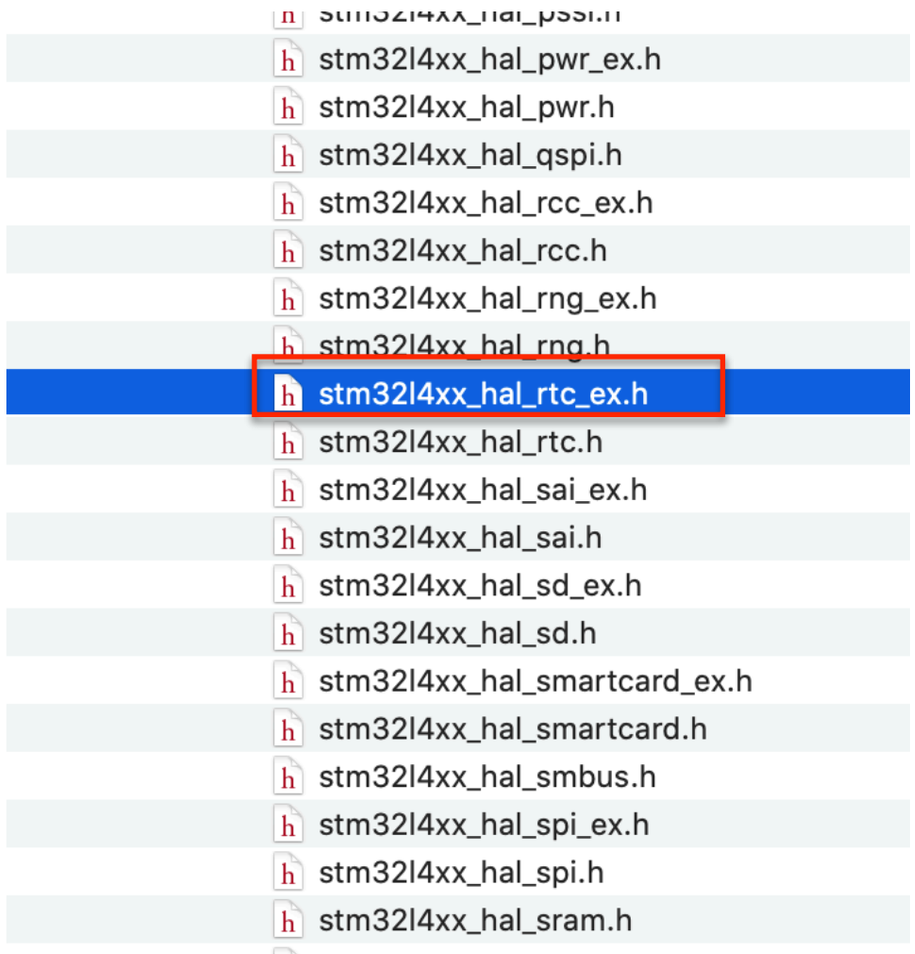


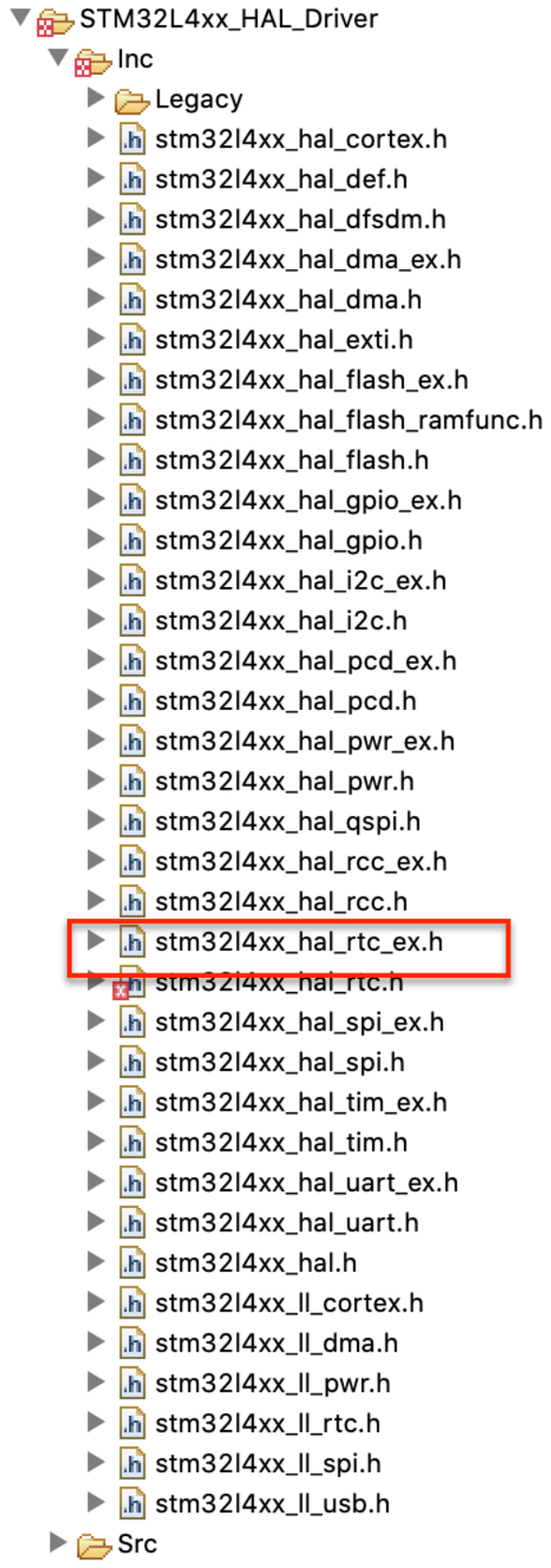

```
23
24  #ifdef __cplusplus
25  extern "C" {
26  #endif
27
28    /* Includes ------------------------------------------------------------------
29  #include "stm32l4xx.h"
30  #include "stm32l4xx_ll_pwr.h"
31  #include "stm32l4xx_ll_cortex.h"
32  #include "stm32l4xx_ll_rtc.h"
33  #include "stm32l4xx_ll_spi.h"
34  #include "stm32l4xx_ll_dma.h"
35
36  #include "stm32l4xx_hal_rtc.h" //For RTC_HandleTypeDef
37
38
39
```

Attempt Build



Copy File





Attempt Build

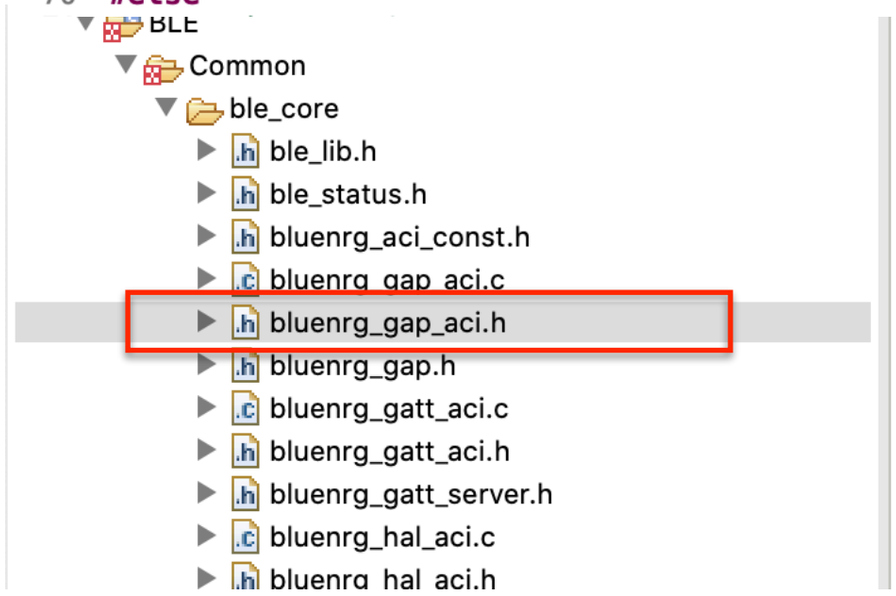
```
                 from ../BLE/Common/ble_services/svc_ctl.c:28:
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLE/BLE/Common/ble_core/bluenrg_gap_aci.h:103:12: note:
 tBleStatus aci_gap_init(uint8_t role,
            ^~~~~~~~~~~~
../BLE/Common/ble_services/svc_ctl.c:152:5: error: too many arguments to function 'aci_gap_init'
     aci_gap_init(role,
     ^~~~~~~~~~~~
In file included from /Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLE/BLE/Common/ble_core/ble_lib.h:
                 from ../BLE/Common/ble_services/svc_ctl.c:28:
/Users/nmcentire/STM32CubeIDE/workspace_1.4.0/HelloBLE/BLE/Common/ble_core/bluenrg_gap_aci.h:103:12: note:
 tBleStatus aci_gap_init(uint8_t role,
            ^~~~~~~~~~~~
make: *** [BLE/Common/ble_services/subdir.mk:33: BLE/Common/ble_services/svc_ctl.o] Error 1
make: *** Waiting for unfinished jobs....
"make -j3 all" terminated with exit code 2. Build might be incomplete.

05:20:45 Build Failed. 3 errors, 6 warnings. (took 8s.686ms)
```

Notice Function Prototype is inside #ifdef

```
#if BLUENRG_MS
///@cond BLUENRG_MS
/**
  * @brief  Initialize the GAP layer.
  * @note   Register the GAP service with the GATT.
  *         All the standard GAP characteristics will also be added:
  *         @li Device Name
  *         @li Appearance
  *         @li Peripheral Preferred Connection Parameters (peripheral role only)
  *         @code
  * @param       role     Bitmap of allowed roles: see @ref gap_roles "GAP roles".
  * @param       privacy_enabled     Enable (1) or disable (0) privacy.
  * @param       device_name_char_len Length of the device name characteristic
  * @param[out]  service_handle  Handle of the GAP service.
  * @param[out]  dev_name_char_handle  Device Name Characteristic handle
  * @param[out]  appearance_char_handle Appearance Characteristic handle
  * @retval tBleStatus Value indicating success or error code.
  */
tBleStatus aci_gap_init(uint8_t role, uint8_t privacy_enabled,
                        uint8_t device_name_char_len,
                        uint16_t* service_handle,
                        uint16_t* dev_name_char_handle,
                        uint16_t* appearance_char_handle);
///@endcond
#else
```

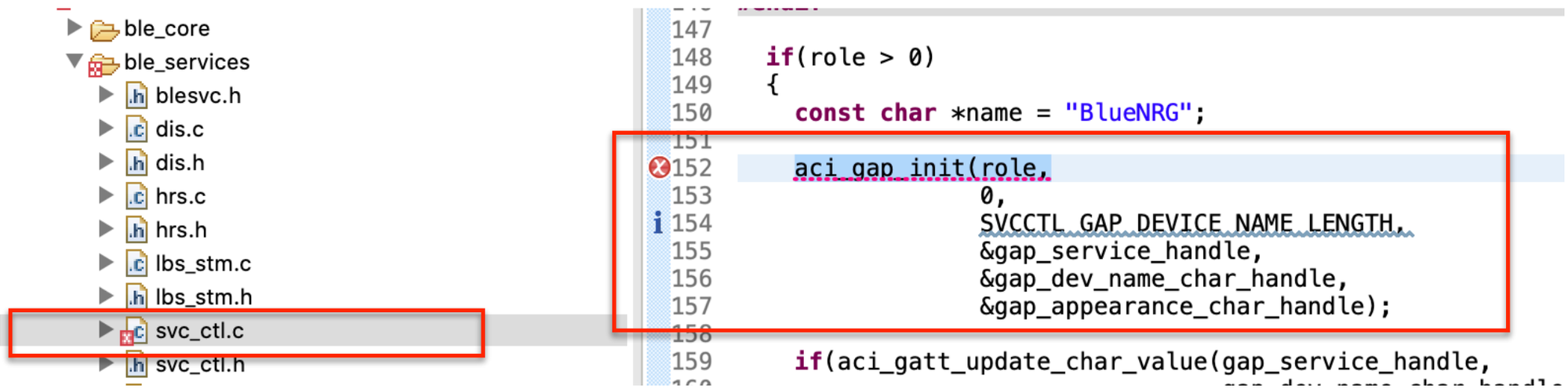
5-Params



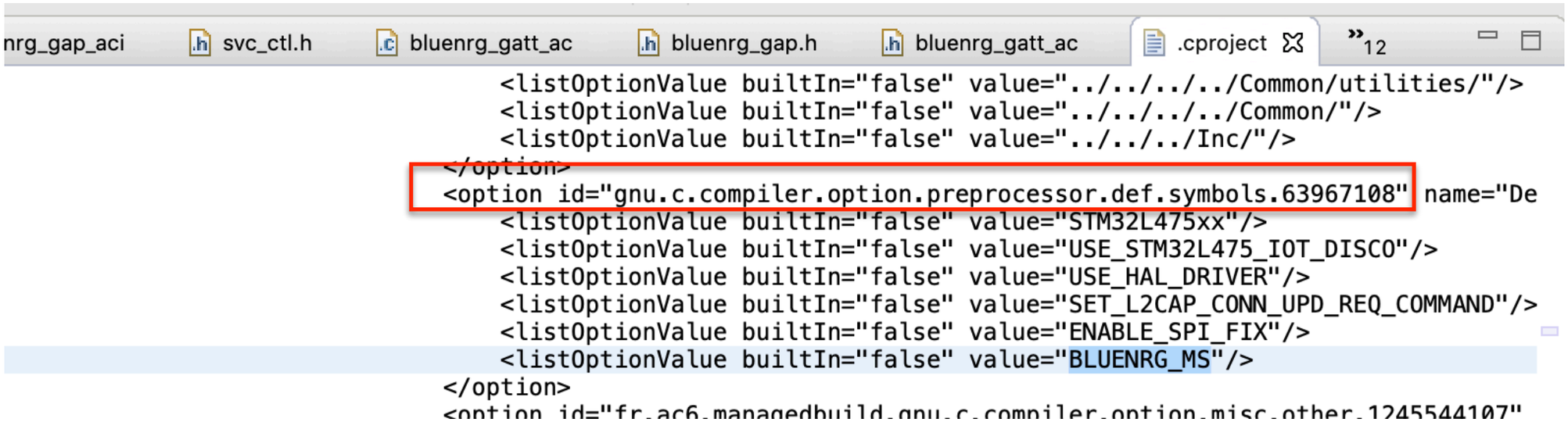

```
  *           if(ret){
  *             PRINTF("aci_gatt_update_char_value failed.\n");
  *           }
  *         @endcode
  * @param       role     One of the allowed roles: @ref GAP_PERIPHERAL_ROLE
  * @param[out]  service_handle  Handle of the GAP service.
  * @param[out]  dev_name_char_handle  Device Name Characteristic handle
  * @param[out]  appearance_char_handle Appearance Characteristic handle
  * @retval tBleStatus Value indicating success or error code.
  */
BleStatus aci_gap_init(uint8_t role,
                       uint16_t* service_handle,
                       uint16_t* dev_name_char_handle,
                       uint16_t* appearance_char_handle);
//@endcond
endif
```

4-Params

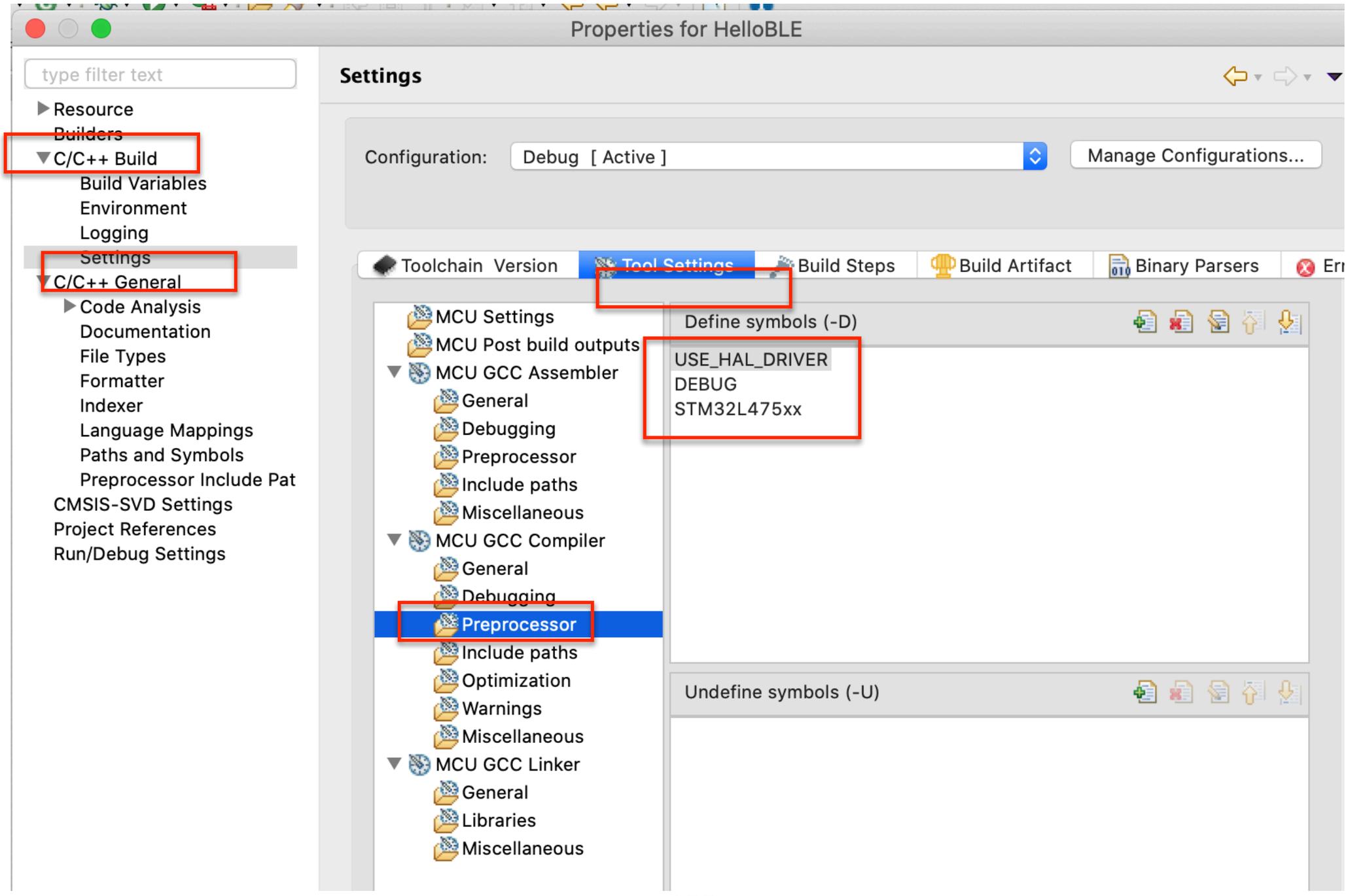
5-Param Version Used By Code



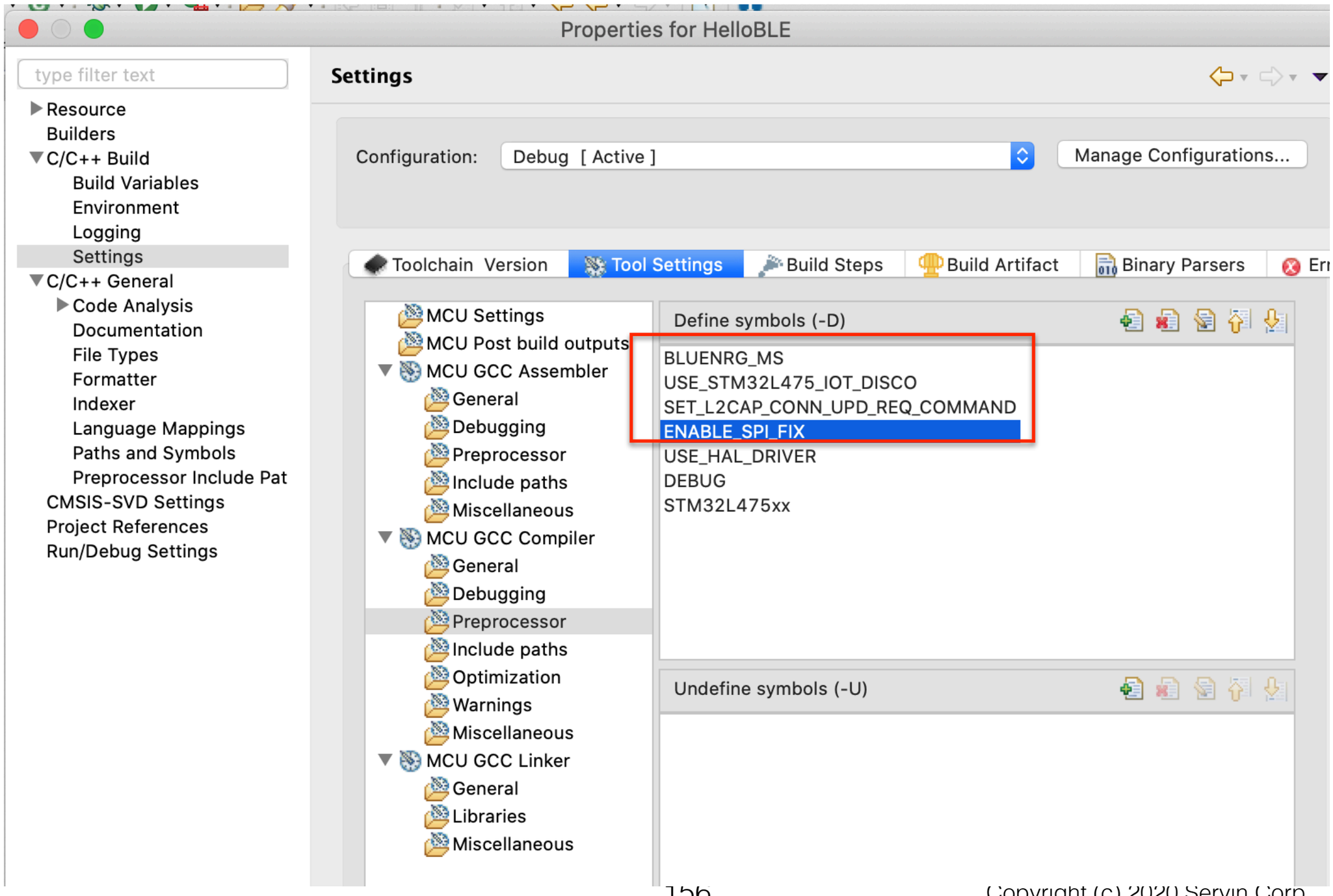
Value of BLUENRG_MS set to false



Original Values

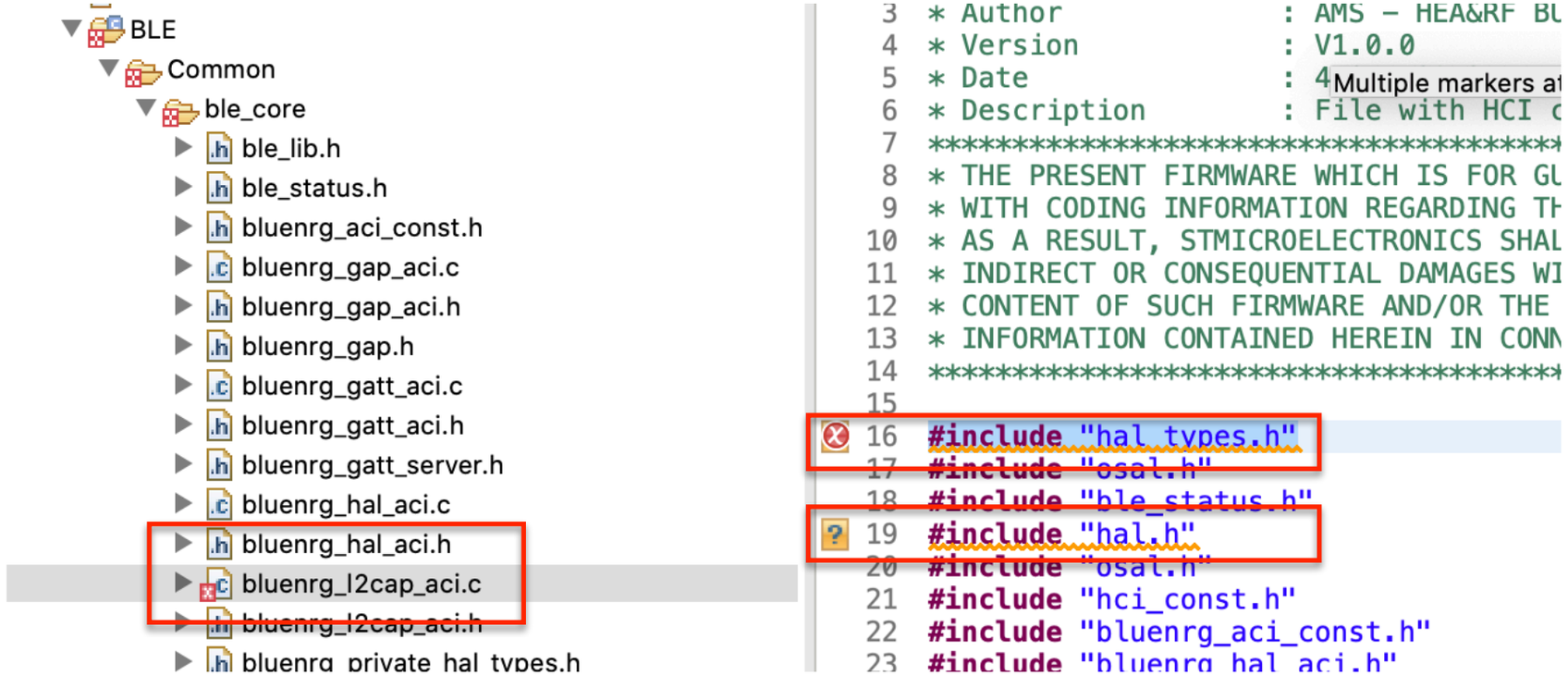


Add Values

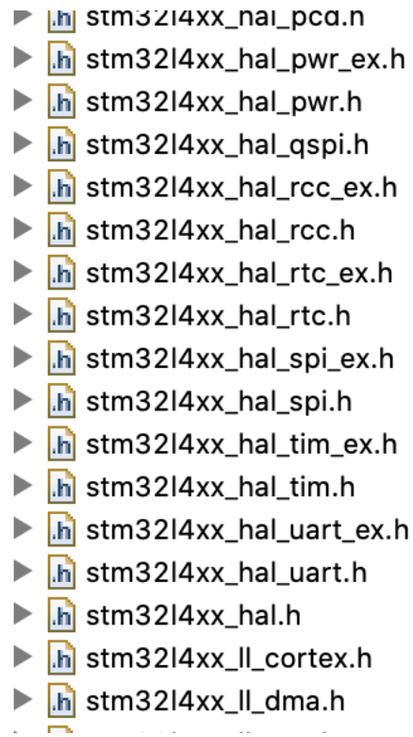


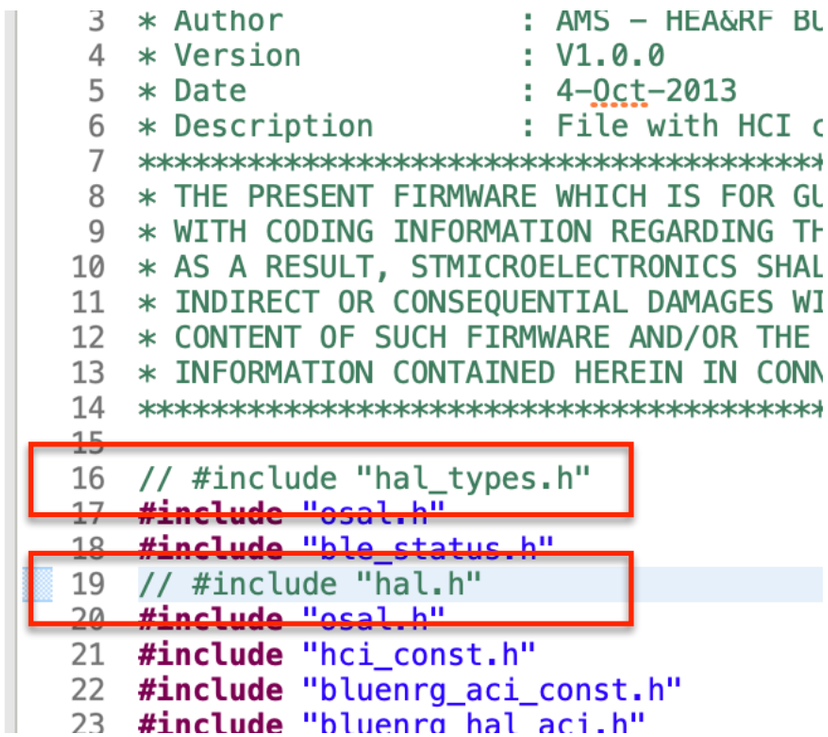
Attempt Build

```
../BLE/Common/ble_core/bluenrg_l2cap_aci.c:16:10: fatal error: hal_types.h: No such file or directory
 #include "hal_types.h"
          ^~~~~~~~~~~~~
compilation terminated.
make: *** [BLE/Common/ble_core/subdir.mk:39: BLE/Common/ble_core/bluenrg_l2cap_aci.o] Error 1
make: *** Waiting for unfinished jobs....
"make -j3 all" terminated with exit code 2. Build might be incomplete.
```



Comment Out Header Files





Attempt to build

```
make -j3 all
arm-none-eabi-gcc "../BLE/Common/ble_core/bluenrg_l2cap_aci.c" -mcpu=cortex-m4 -std=gnu11
arm-none-eabi-gcc "../BLE/Common/ble_core/hci_le.c" -mcpu=cortex-m4 -std=gnu11 -g3 -DBLUE
arm-none-eabi-gcc "../BLE/Common/ble_hci_tl_io_template.c" -mcpu=cortex-m4 -std=gnu11 -g3
../BLE/Common/ble_hci_tl_io_template.c:25:1: error: unknown type name 'int32_t'
 int32_t hci_send_req(struct hci_request *r, uint8_t async)
 ^~~~~~
../BLE/Common/ble_core/hci_le.c:19:10: fatal error: hal_types.h: No such file or director
 #include "hal_types.h"
          ^~~~~~~~~~~~~
compilation terminated.
../BLE/Common/ble_hci_tl_io_template.c:25:45: error: unknown type name 'uint8_t'
 int32_t hci_send_req(struct hci_request *r, uint8_t async)
                                             ^~~~~~
make: *** [BLE/Common/subdir.mk:18: BLE/Common/ble_hci_tl_io_template.o] Error 1
make: *** Waiting for unfinished jobs....
make: *** [BLE/Common/ble_core/subdir.mk:41: BLE/Common/ble_core/hci_le.o] Error 1
../BLE/Common/ble_core/bluenrg_l2cap_aci.c: In function 'aci_l2cap_connection_parameter_u
../BLE/Common/ble_core/bluenrg_l2cap_aci.c:37:20: warning: implicit declaration of functi
  cp.conn_handle = htobs(conn_handle);
                   ^~~~~
```

Summary

- BLE compared to Wi-Fi
- BLE Concepts
- BLE Data Sheet
- Schematics - BLE on STM32L Discovery Kit for IoT
- Hands-On Project - BLE