EE 315

MICROPROCESSORS

LABORATORY MANUAL

2019

Erhan AKAN

Introduction

This document is the laboratory manual for the EE459 Microprocessor-based System Design course. The document includes information on the evaluation kit (EK) and the simulation environment that will be used in the labs.

Lab Rules

- In the laboratory sessions, you are expected to learn to program an ARM based micro-controller using a Texas Tiva C LaunchPad TM4C123G and the Keil µVision **I**ntegrated **D**evelopment **K**it.
- For this purpose, we strongly advise you to install Keil µVision IDE on your PCs.
- There will be quizzes before the labs practice, which will contain questions relating to the experiment to be held on that lab session. Both the quizzes and your lab performance will be graded.
- You will perform your experiments in groups of two.

About the Kit We Will Use

The TM4C123G LaunchPad Evaluation Kit is a low-cost evaluation platform for ARM Cortex-M4F based microcontrollers from Texas Instruments. The design of the TM4C123G LaunchPad highlights the TM4C123GH6PM microcontroller with a USB 2.0 device interface and hibernation module.

The EK-TM4C123GXL also features programmable user buttons and an RGB LED for custom applications. The stackable headers of the TM4C123G LaunchPad BoosterPack™ XL Interface make it easy and simple to expand the functionality of the TM4C123G LaunchPad when interfacing to other peripherals with Texas Instruments MCU BoosterPack.

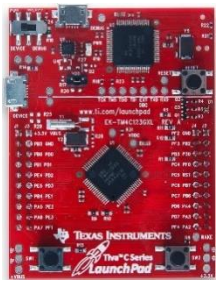


Figure 1 TM4C123G LaunchPad

Features:

The ARM Cortex-M4F Based MCU TM4C123G LaunchPad Evaluation Kit (EK-TM4C123GXL) offers these features:

- High Performance TM4C123GH6PM MCU:
- 80MHz 32-bit ARM Cortex-M4-based microcontrollers CPU
- 256KB Flash, 32KB SRAM, 2KB EEPROM
- Two Controller Area Network (CAN) modules
- USB 2.0 Host/Device/OTG + PHY
- Dual 12-bit 2MSPS ADCs, motion control PWMs
- 8 UART, 6 I2C, 4 SPI
- On-board In-Circuit Debug Interface (ICDI)

It is possible to buy a EK-TM4C123GXL LaunchPad in Turkey. Please check the web for different sellers. The prices are around 80₺.

About Keil µvision

Keil µvision is free up to 32kb of code size. The µVision IDE combines project management, run-time environment, build facilities, source code editing, and program debugging in a single powerful environment. µVision supports multiple screens and allows you to create individual window layouts anywhere on the visual surface.

The µVision Debugger provides a single environment in which you may test, verify, and optimize your application code. The debugger includes traditional features like simple and complex breakpoints, watch windows, and execution control and provides full visibility to device peripherals.

µVision Project Manager and Run-Time Environment

With the µVision Project Manager and Run-Time Environment you create software application using pre-build software components and device support from Software Packs. The software components contain libraries, source modules, configuration files, source code templates, and documentation. Software components can be generic to support a wide range of devices and applications.

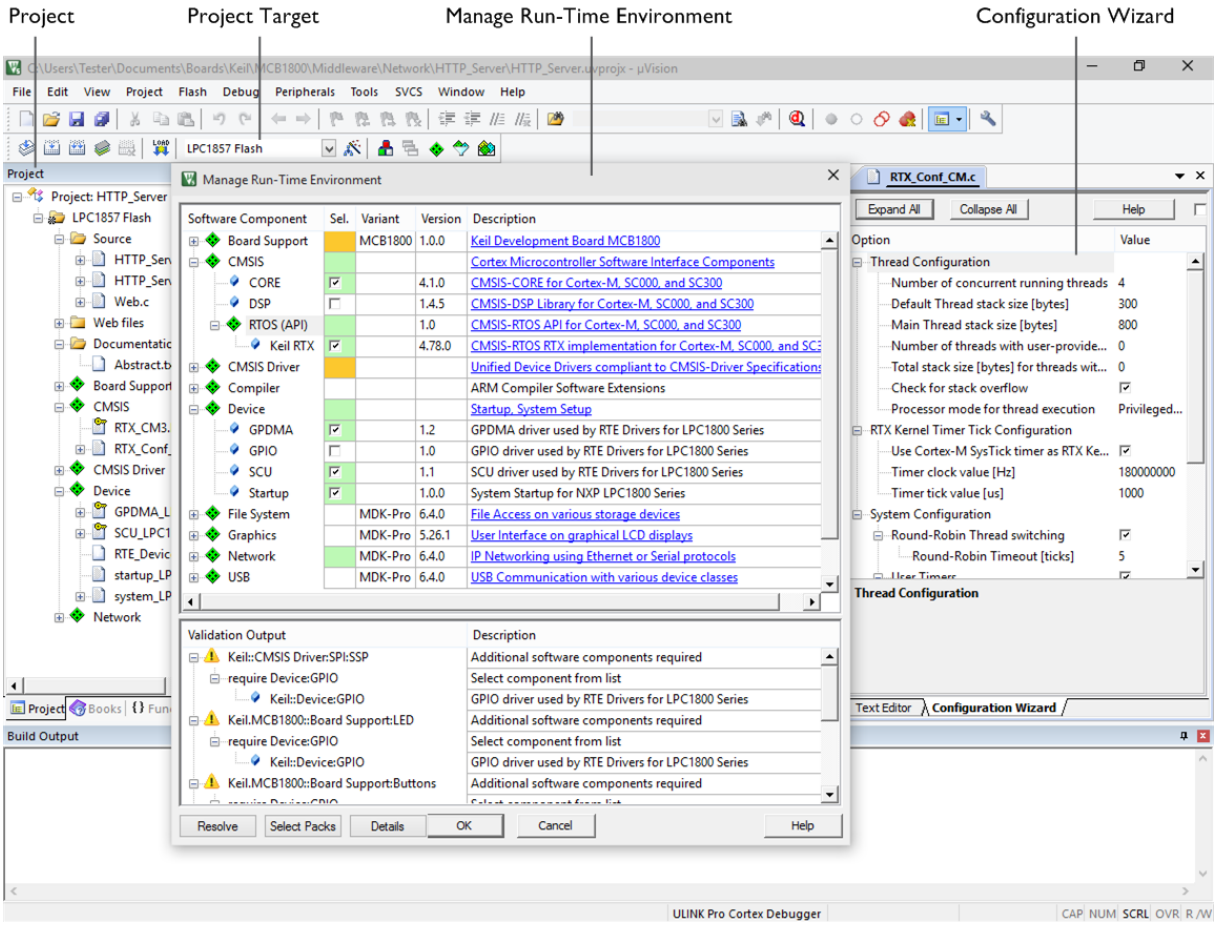


Figure 2

- The Project window shows application source files and selected software components. Below the components you will find corresponding library and configuration files.
- Projects support multiple targets. They ease configuration management and may be used to generate debug and release builds or adoptions for different hardware platforms.
- The Manage Run-Time Environment window shows all software components that are compatible with the selected device. Inter-dependencies of software components are clearly identified with validation messages.
- The Configuration Wizard is an integrated editor utility for generating GUI-like configuration controls in assembler, C/C++, or initialization files.

µVision Editor

The integrated µVision Editor includes all standard features of a modern source code editor and is also available during debugging. Color syntax highlighting, text indentation, and source outlining are optimized for C/C++.

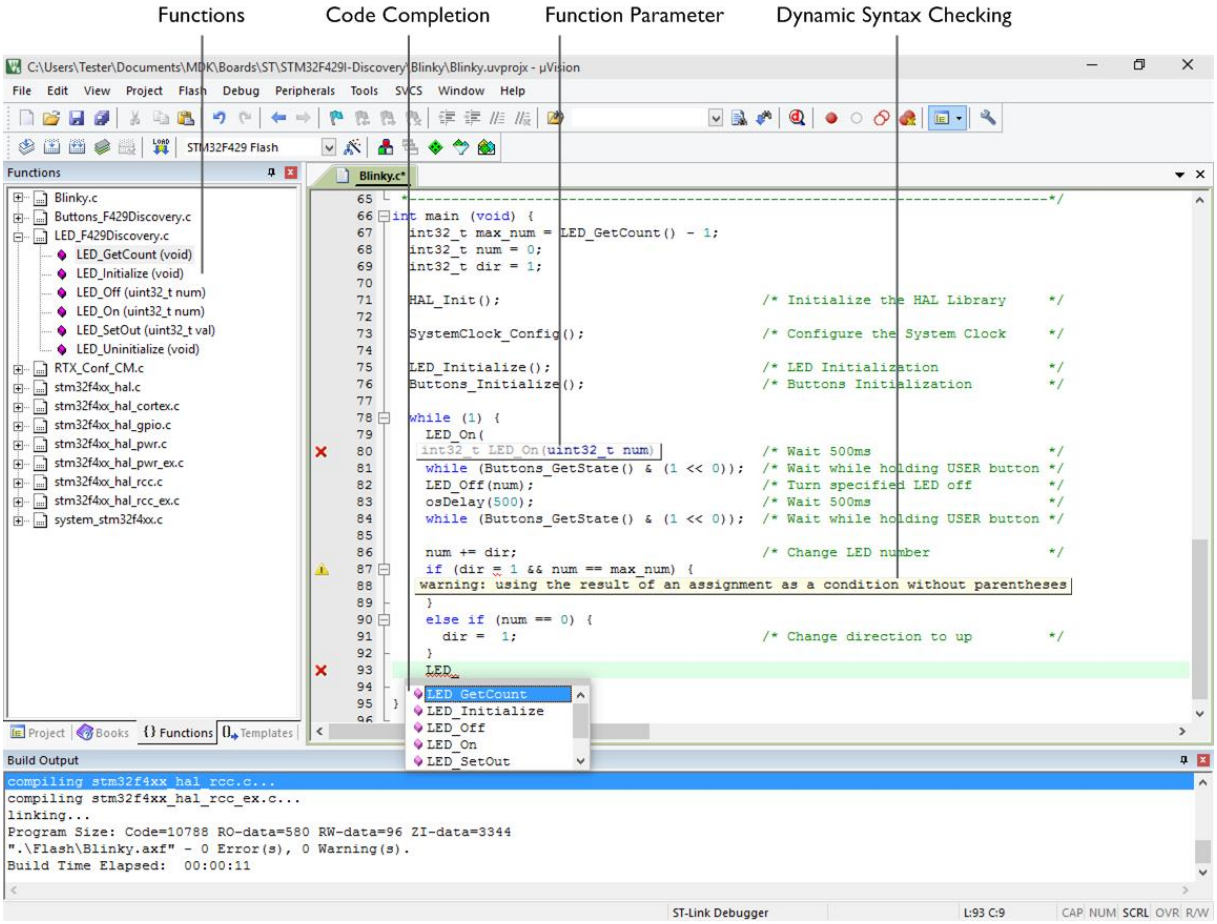


Figure 3

- The Functions window gives fast access to the functions in each C/C++ source code module.
- The Code Completion list and Function Parameter information helps you to keep track of symbols, functions, and parameters.
- Dynamic Syntax Checking validates the program syntax while you are typing and provides real-time alerts to potential code violations before compilation.

Download Software

First, download the files below using the links:

1. Keil µVision 5 for ARM processors:

   http://www.keil.com/fid/3qowa9wtdy9j1wzibrw1uymbumlgr1a96d2wd1/files/eval/mdk524a.exe

   If the link above does not work, use this (requires information):

   https://www.keil.com/demo/eval/arm.htm#/DOWNLOAD

2. Driver support for the launchpad:

   http://www.ti.com/general/docs/lit/getliterature.tsp?literatureNumber=spmc016a&fileType=zip

3. A useful version (2013) TM4C123GH6PM header file defines the register addresses as mnemonics for C language:

   http://users.ece.utexas.edu/~valvano/Volume1/tm4c123gh6pm.h

4. A useful version (2013) TM4C123GH6PM header file defines the register addresses as mnemonics for ASSEMBLY language:

   http://users.ece.utexas.edu/~valvano/arm/tm4c123gh6pm.s

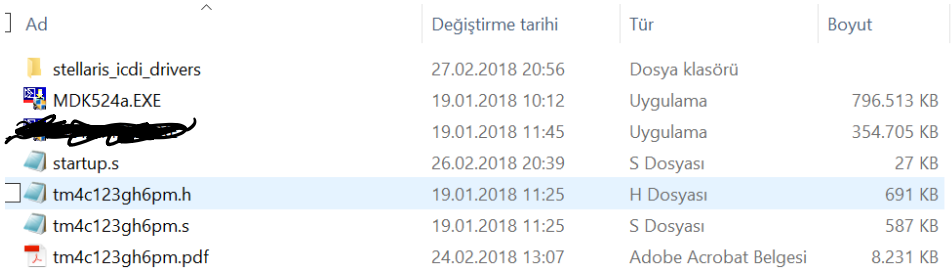
5. An old version of ASSEMBLY startup file (startup.s):

   http://ee315.cankaya.edu.tr/uploads/files/startup.s

6. TM4C123GH6PM Datasheet

   http://www.ti.com/lit/ds/symlink/tm4c123gh6pm.pdf

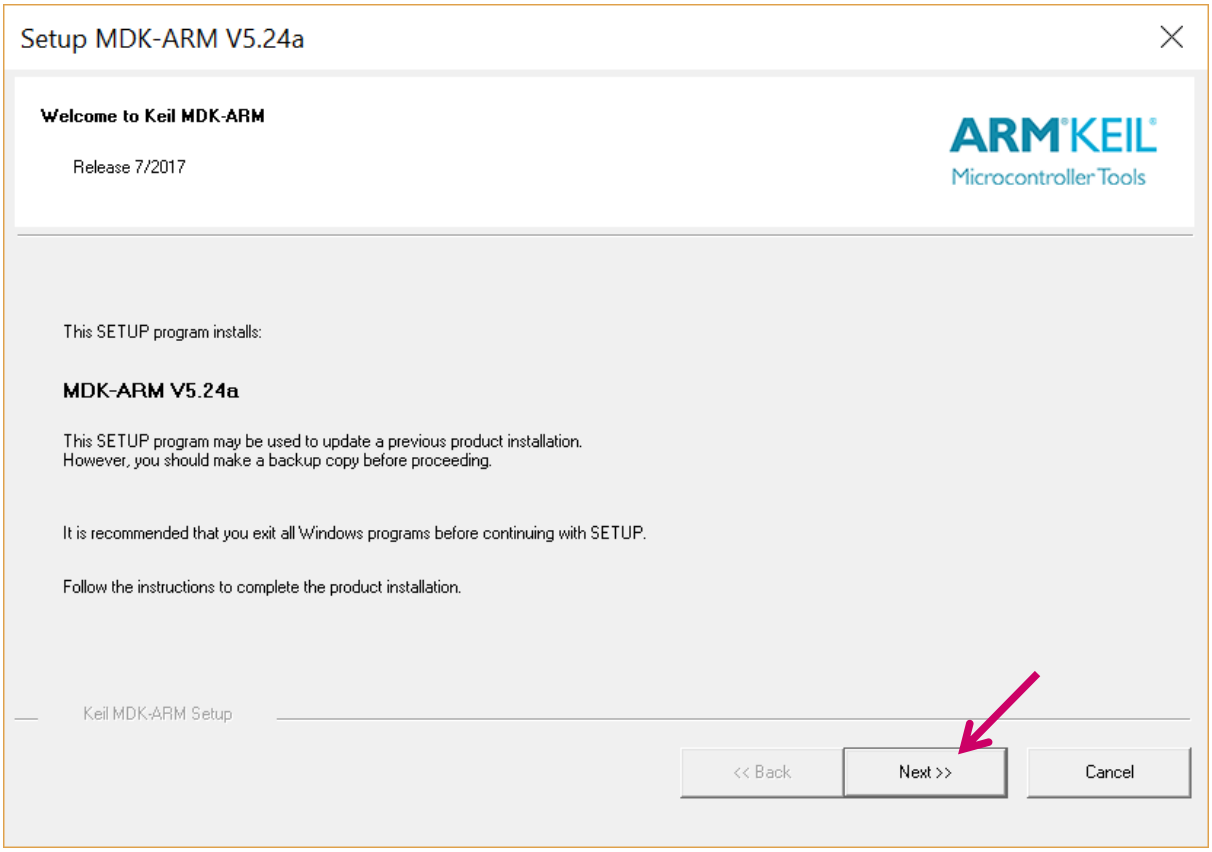
The folder should be like below:

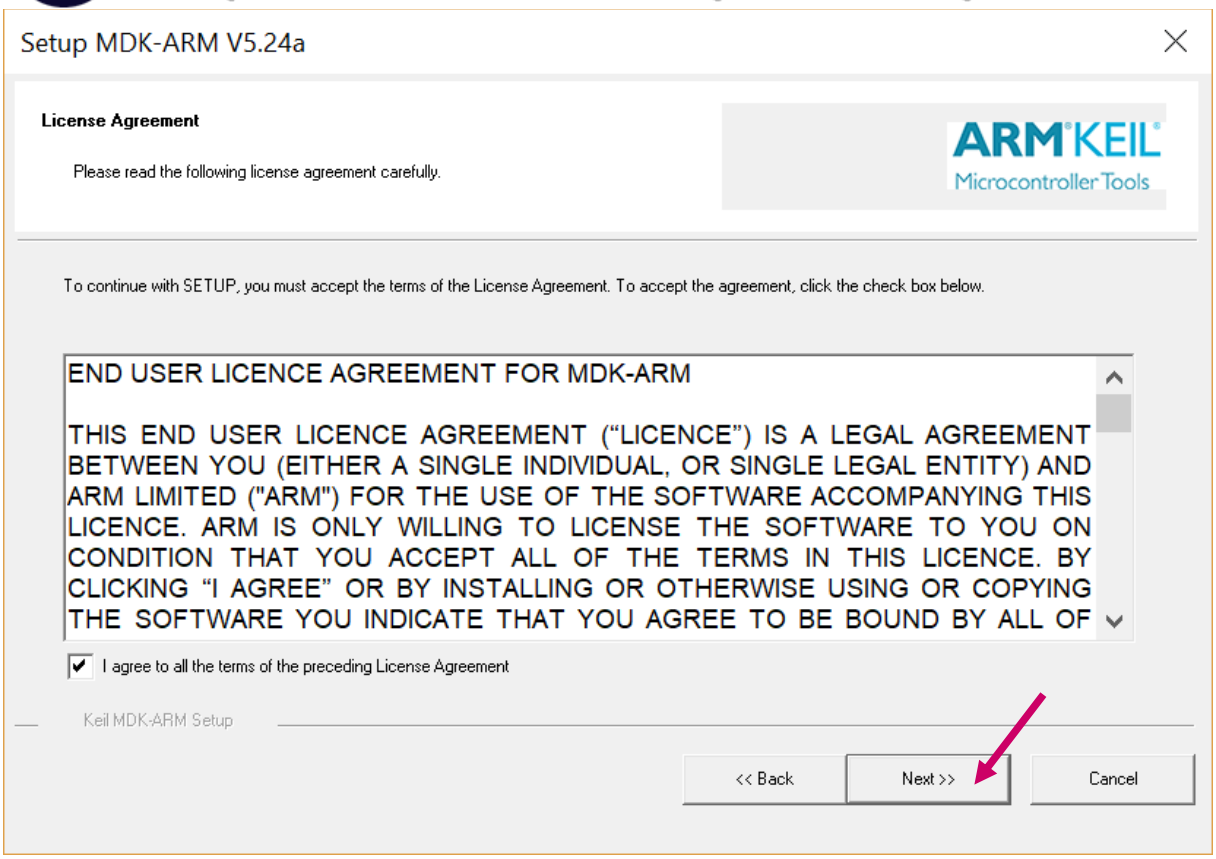


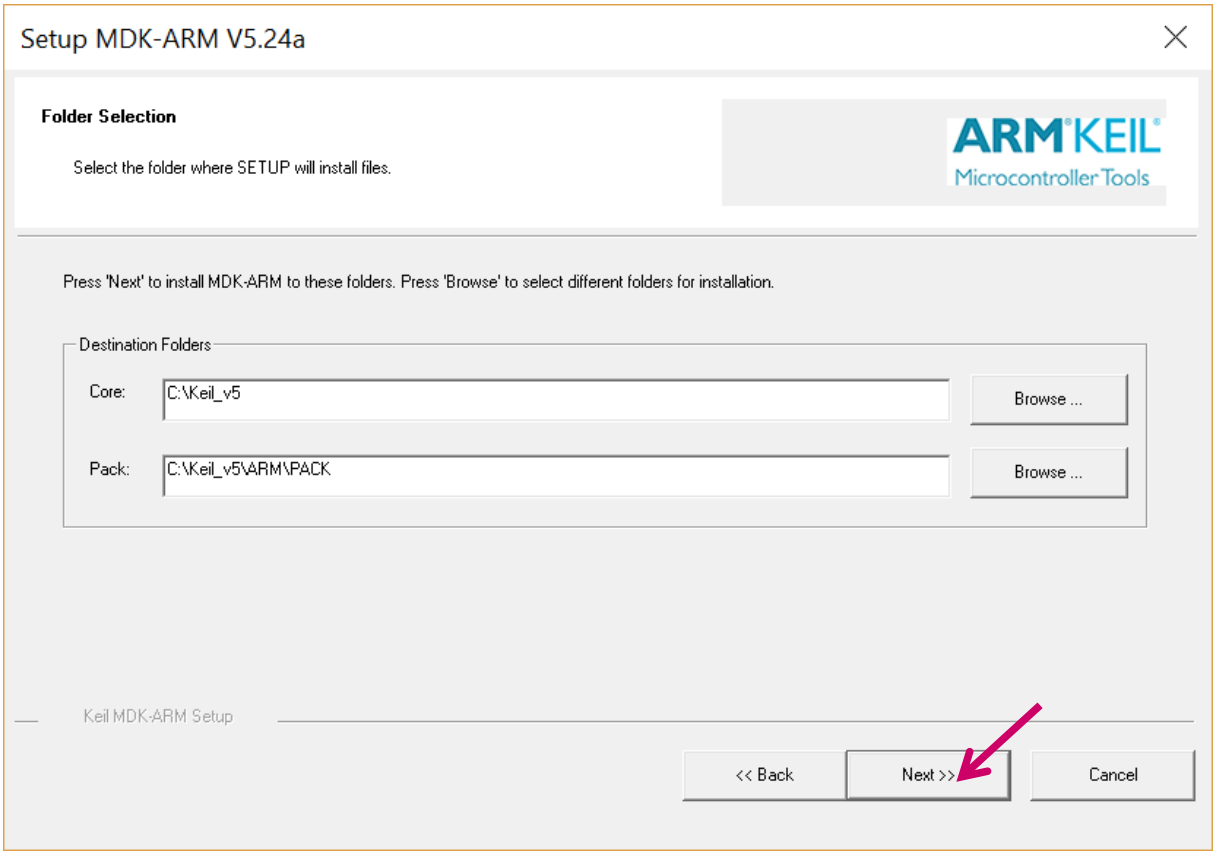
Ad	Değiştirme tarihi	Tür	Boyut
stellaris_icdi_drivers	27.02.2018 20:56	Dosya klasörü	
MDK524a.EXE	19.01.2018 10:12	Uygulama	796.513 KB
[redacted]	19.01.2018 11:45	Uygulama	354.705 KB
startup.s	26.02.2018 20:39	S Dosyası	27 KB
tm4c123gh6pm.h	19.01.2018 11:25	H Dosyası	691 KB
tm4c123gh6pm.s	19.01.2018 11:25	S Dosyası	587 KB
tm4c123gh6pm.pdf	24.02.2018 13:07	Adobe Acrobat Belgesi	8.231 KB

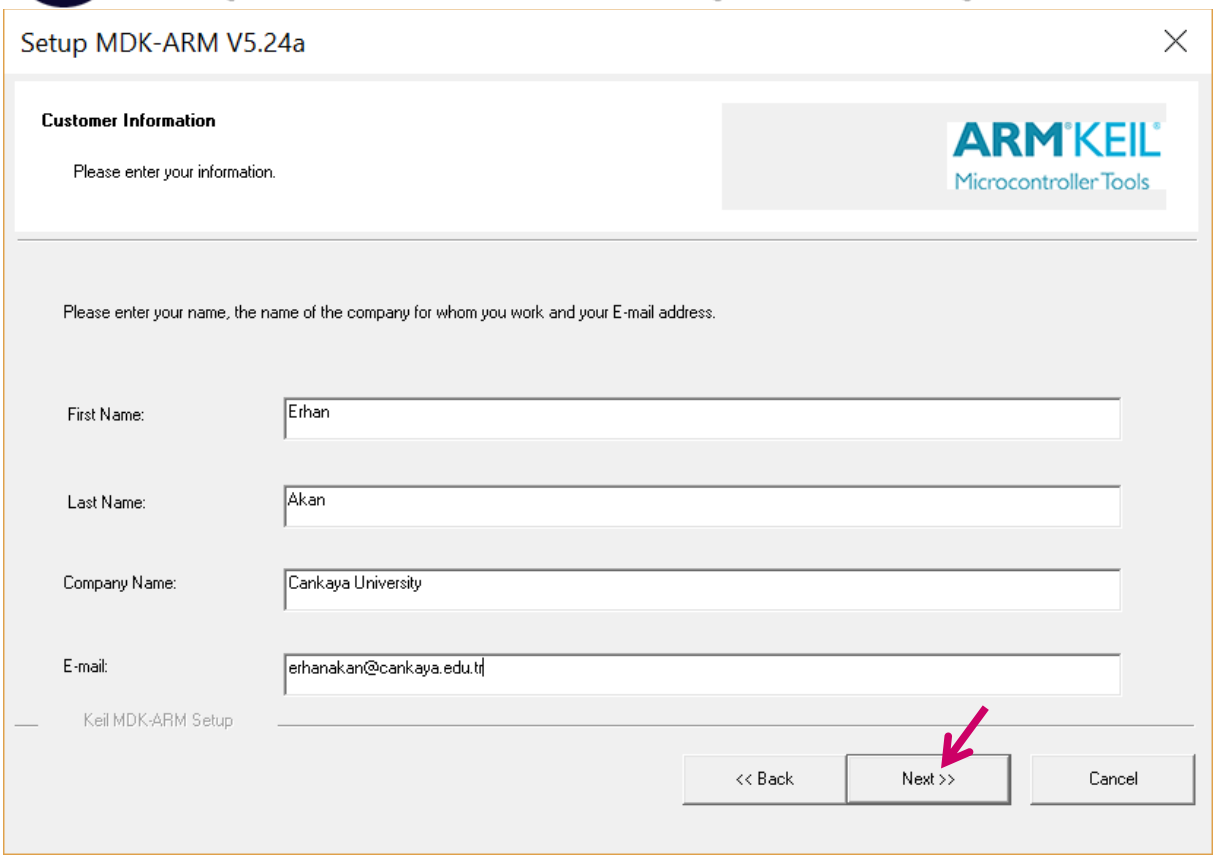
Installation of Software

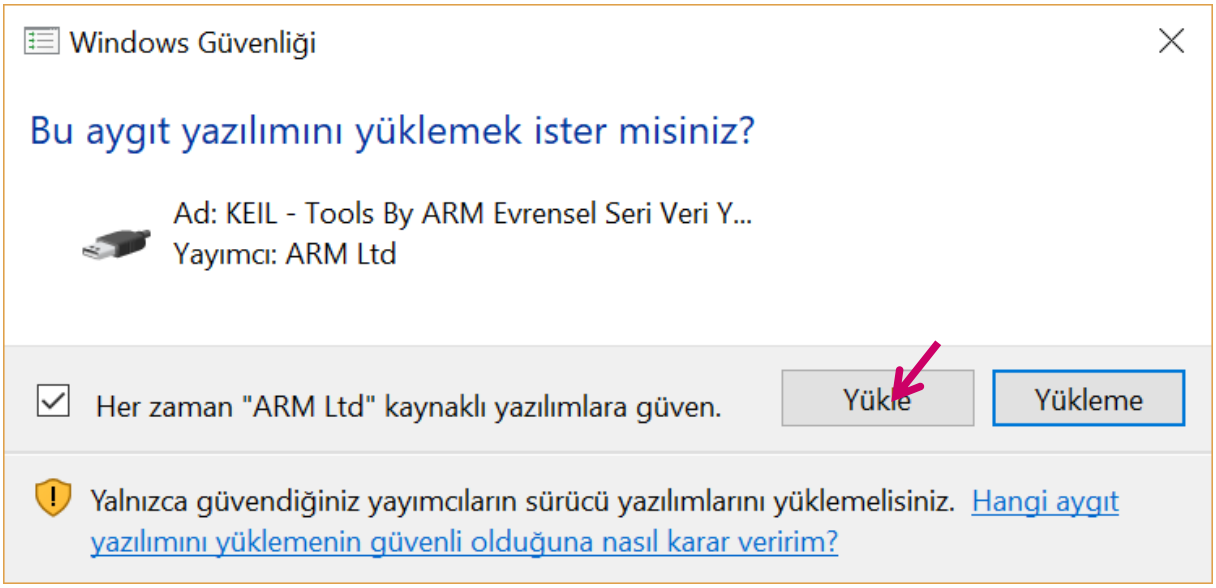
1. First, run MDK524a.exe and follow the instructions below:

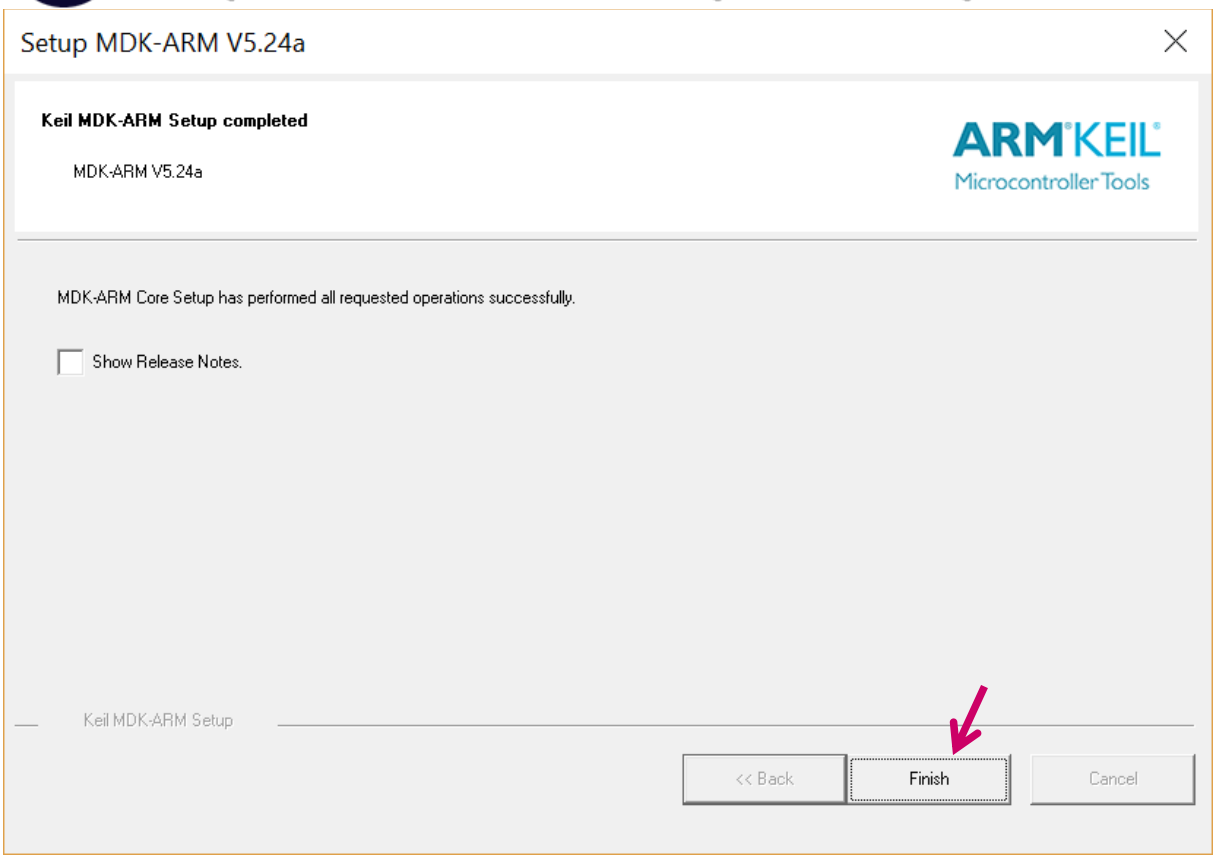


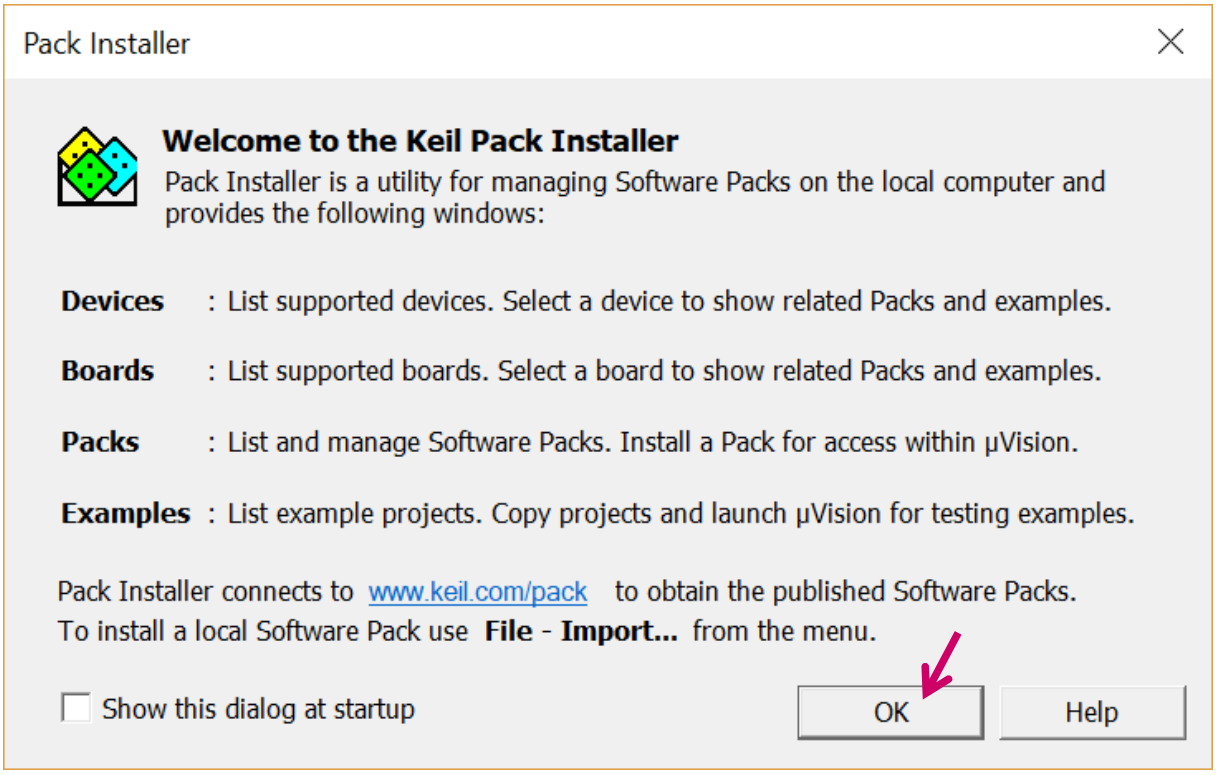

Setup MDK-ARM V5.24a
License Agreement
Please read the following license agreement carefully.
ARM KEIL Microcontroller Tools
To continue with SETUP, you must accept the terms of the License Agreement. To accept the agreement, click the check box below.
END USER LICENCE AGREEMENT FOR MDK-ARM
THIS END USER LICENCE AGREEMENT ("LICENCE") IS A LEGAL AGREEMENT BETWEEN YOU (EITHER A SINGLE INDIVIDUAL, OR SINGLE LEGAL ENTITY) AND ARM LIMITED ("ARM") FOR THE USE OF THE SOFTWARE ACCOMPANYING THIS LICENCE. ARM IS ONLY WILLING TO LICENSE THE SOFTWARE TO YOU ON CONDITION THAT YOU ACCEPT ALL OF THE TERMS IN THIS LICENCE. BY CLICKING "I AGREE" OR BY INSTALLING OR OTHERWISE USING OR COPYING THE SOFTWARE YOU INDICATE THAT YOU AGREE TO BE BOUND BY ALL OF
I agree to all the terms of the preceding License Agreement
Keil MDK-ARM Setup
<< Back
Next >>
Cancel


Setup MDK-ARM V5.24a
Folder Selection
Select the folder where SETUP will install files.
ARM KEIL Microcontroller Tools
Press 'Next' to install MDK-ARM to these folders. Press 'Browse' to select different folders for installation.
Destination Folders
Core:
C:\Keil_v5
Browse ...
Pack:
C:\Keil_v5\ARM\PACK
Browse ...
Keil MDK-ARM Setup
<< Back
Next >>
Cancel

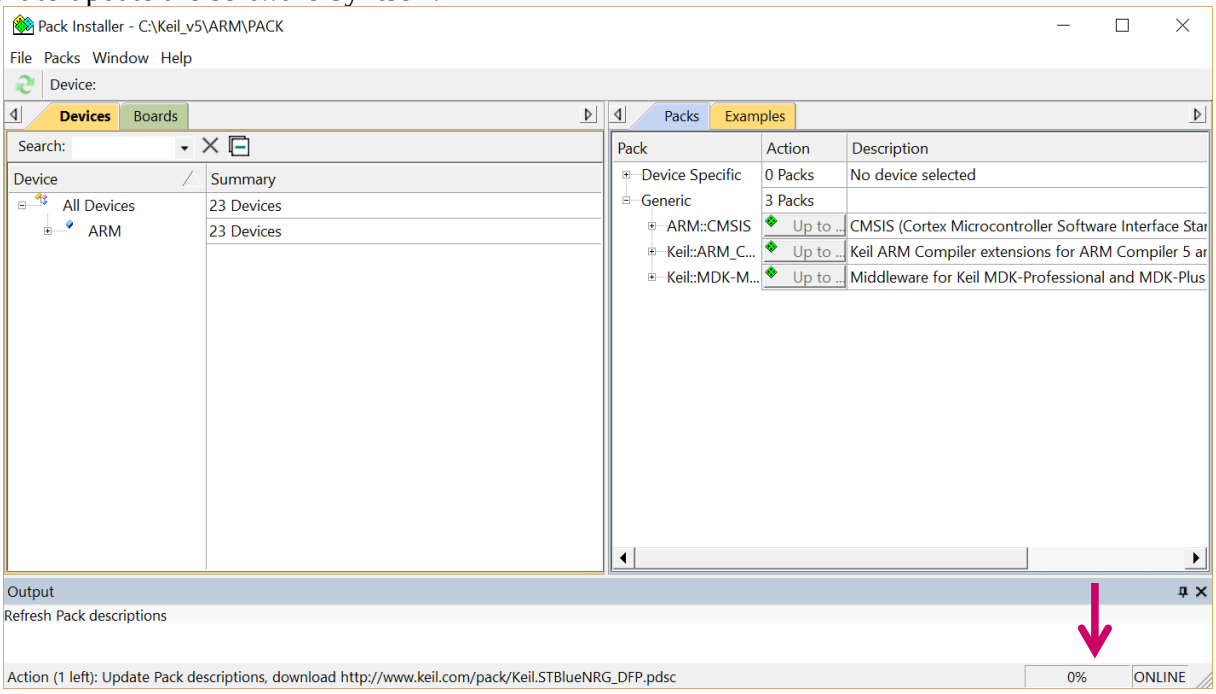

Setup MDK-ARM V5.24a
Customer Information
Please enter your information.
ARM KEIL
Microcontroller Tools
Please enter your name, the name of the company for whom you work and your E-mail address.
First Name:
Erhan
Last Name:
Akan
Company Name:
Cankaya University
E-mail:
erhanakan@cankaya.edu.tr
Keil MDK-ARM Setup
<< Back
Next >>
Cancel

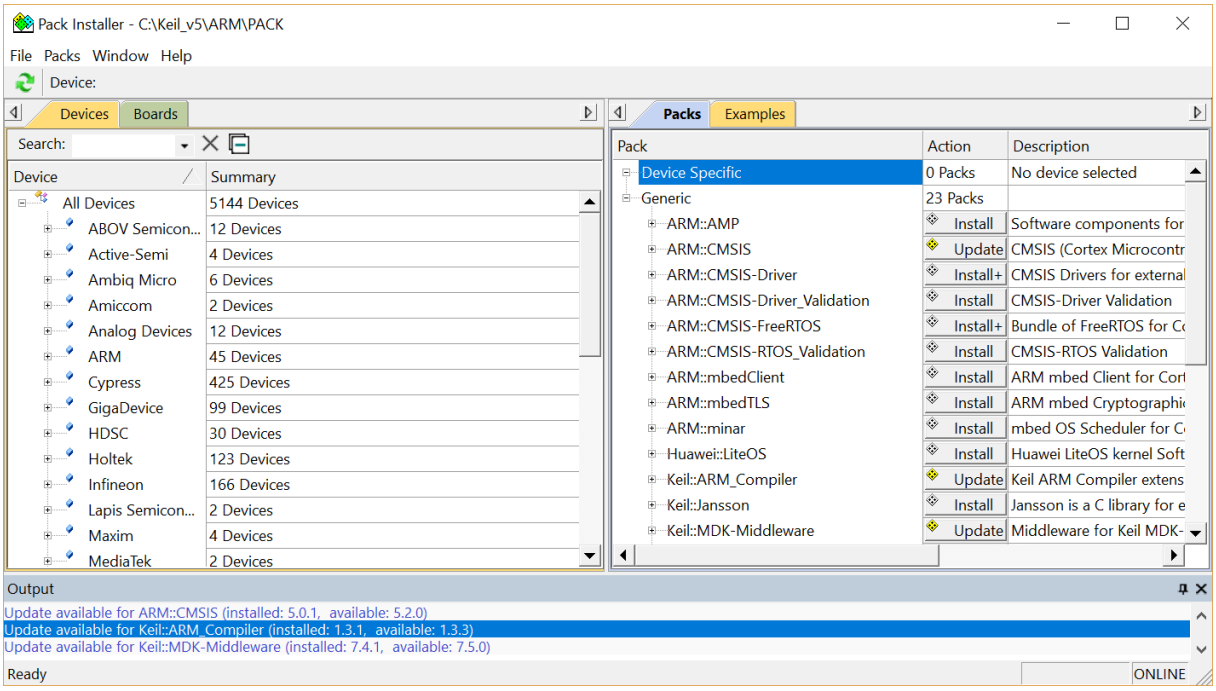

Windows Güvenliği
Bu aygıt yazılımını yüklemek ister misiniz?
Ad: KEIL - Tools By ARM Evrensel Seri Veri Y...
Yayımcı: ARM Ltd
Her zaman "ARM Ltd" kaynaklı yazılımlara güven.
Yükle
Yükleme
Yalnızca güvendiğiniz yayımcıların sürücü yazılımlarını yüklemelisiniz. Hangi aygıt yazılımını yüklemenin güvenli olduğuna nasıl karar veririm?


Setup MDK-ARM V5.24a
Keil MDK-ARM Setup completed
MDK-ARM V5.24a
ARM KEIL
Microcontroller Tools
MDK-ARM Core Setup has performed all requested operations successfully.
Show Release Notes.
Keil MDK-ARM Setup
<< Back
Finish
Cancel

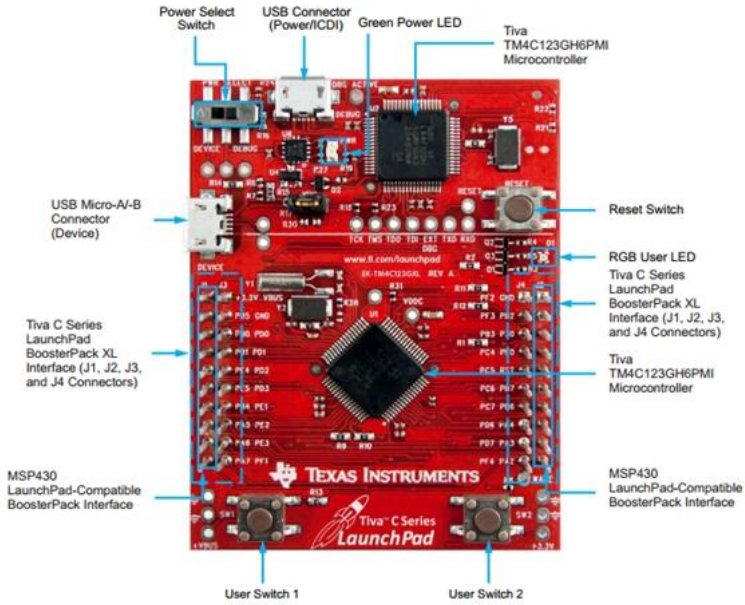

Pack Installer
Welcome to the Keil Pack Installer
Pack Installer is a utility for managing Software Packs on the local computer and provides the following windows:
Devices : List supported devices. Select a device to show related Packs and examples.
Boards : List supported boards. Select a board to show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

And let it to update the software by itself:



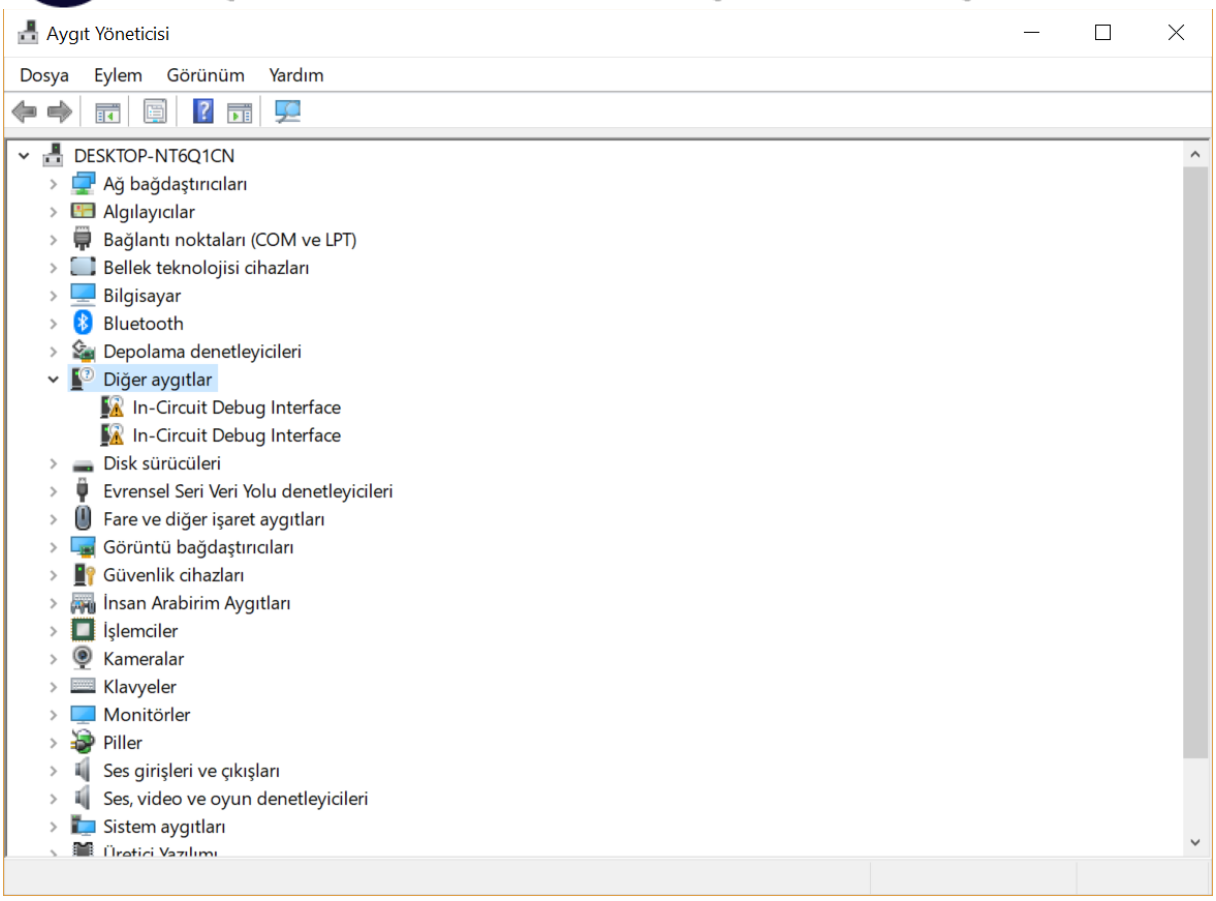


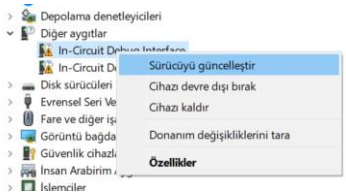
2. Then plug in the USB cable to the "Power/ICDI" port of the microcontroller and select "DEBUG" option using the "Power Select Switch" and then plug it into your computer:

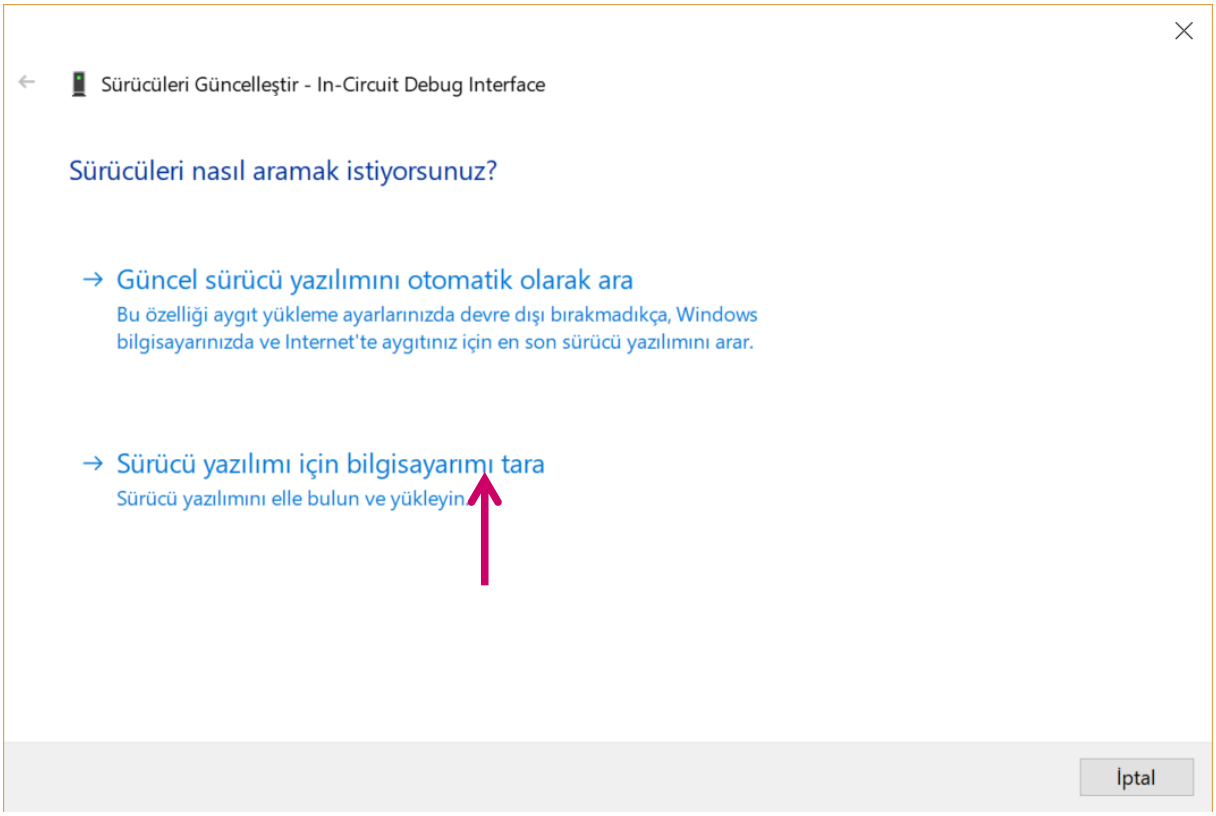


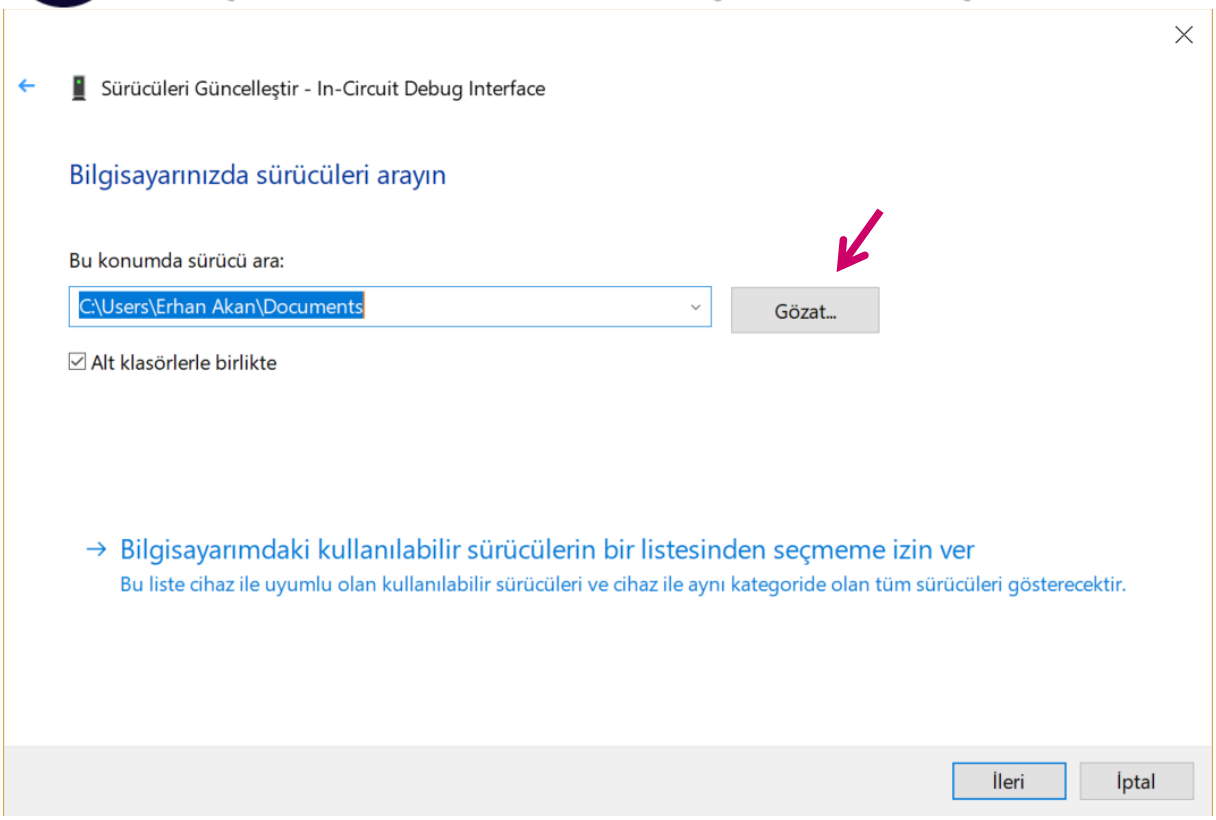
3. The computer should try to recognize the device however, it will fail to detect our hardware.

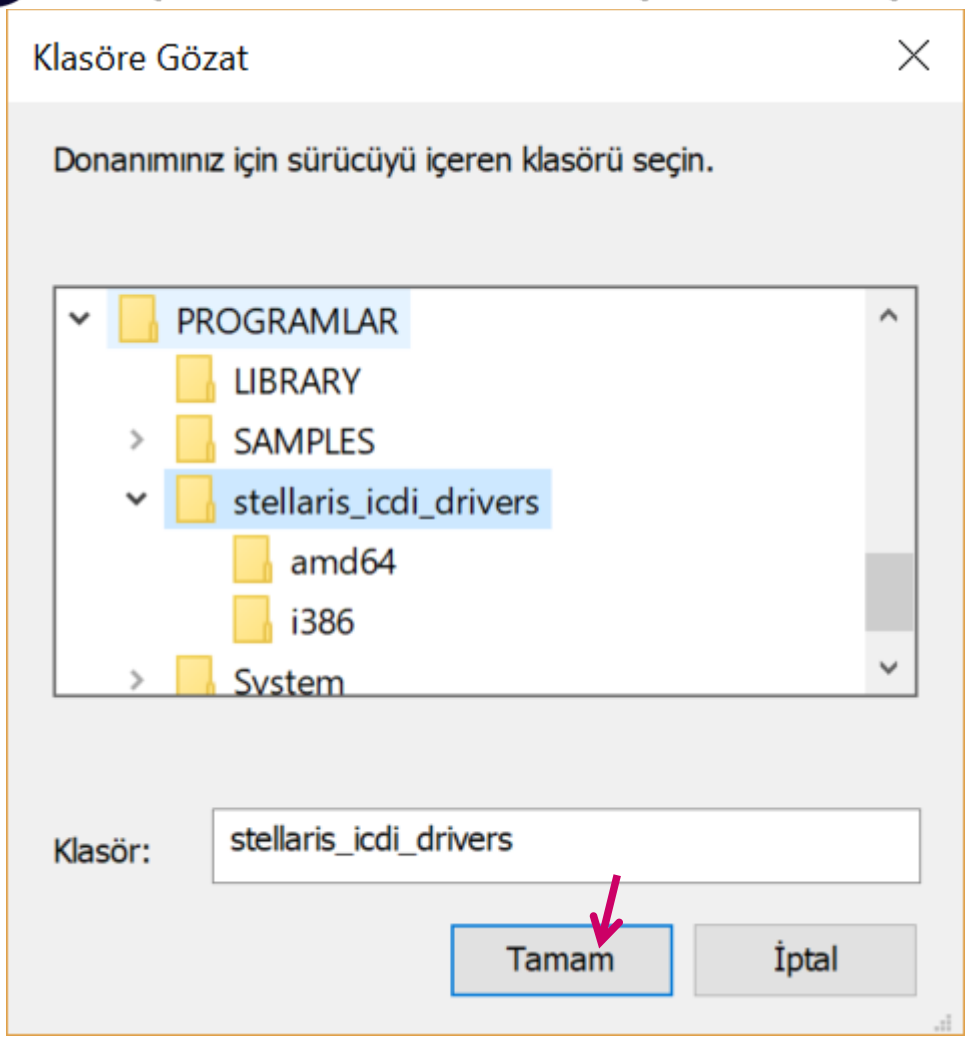
4. Then open the "Device Manager" of Windows OS and follow the pictures below:

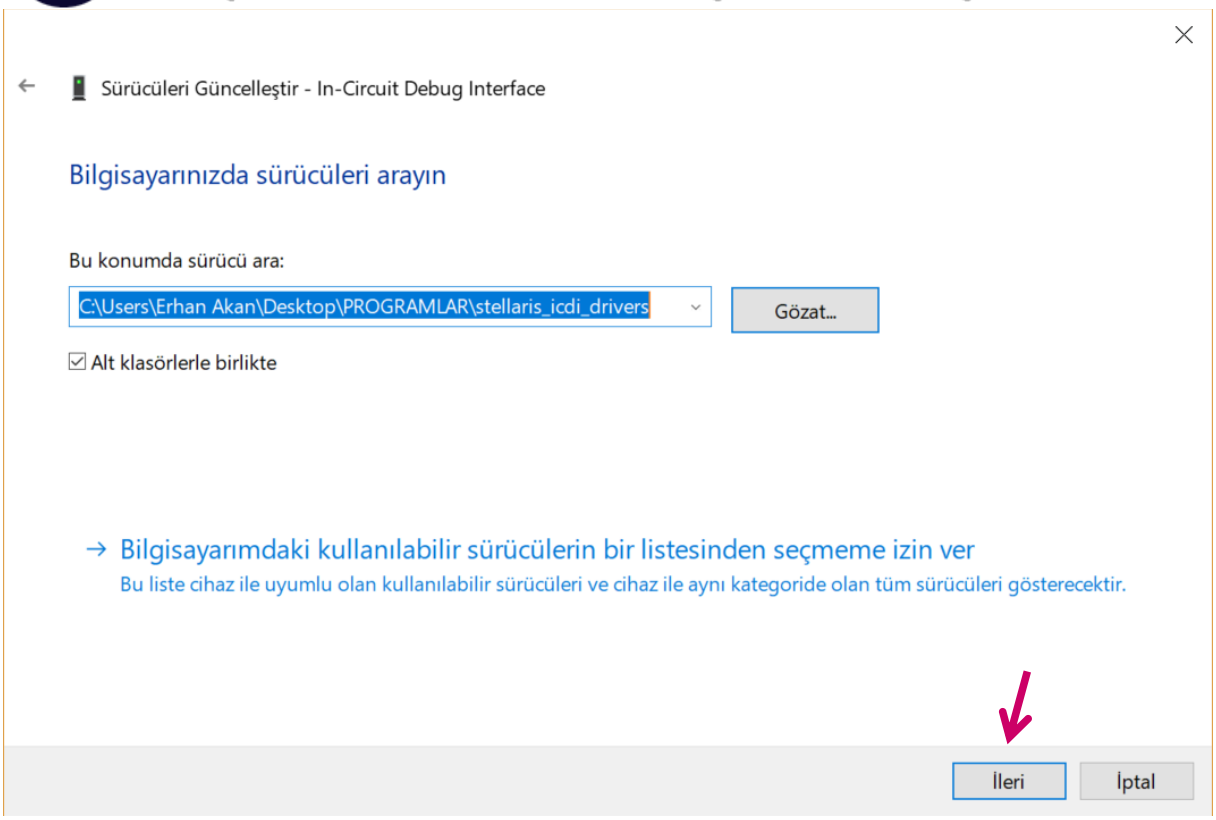

Aygıt Yöneticisi
Dosya
Eylem
Görünüm
Yardım
DESKTOP-NT6Q1CN
Ağ bağdaştırıcıları
Algılayıcılar
Bağlantı noktaları (COM ve LPT)
Bellek teknolojisi cihazları
Bilgisayar
Bluetooth
Depolama denetleyicileri
Diğer aygıtlar
In-Circuit Debug Interface
In-Circuit Debug Interface
Disk sürücüleri
Evrensel Seri Veri Yolu denetleyicileri
Fare ve diğer işaret aygıtları
Görüntü bağdaştırıcıları
Güvenlik cihazları
İnsan Arabirim Aygıtları
İşlemciler
Kameralar
Klavyeler
Monitörler
Piller
Ses girişleri ve çıkışları
Ses, video ve oyun denetleyicileri
Sistem aygıtları

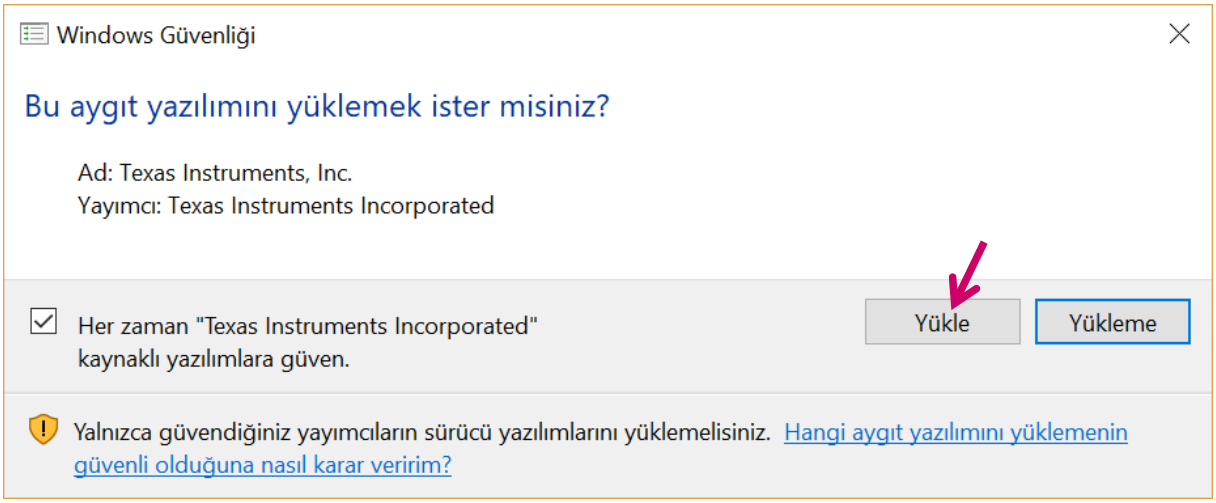

Depolama denetleyicileri
Diğer aygıtlar
In-Circuit Debug Interface
In-Circuit D
Disk sürücüleri
Evrensel Seri Ve
Fare ve diğer işa
Görüntü bağda
Güvenlik cihazla
İnsan Arabirim
İşlemciler
Sürücüyü güncelleştir
Cihazı devre dışı bırak
Cihazı kaldır
Donanım değişikliklerini tara
Özellikler

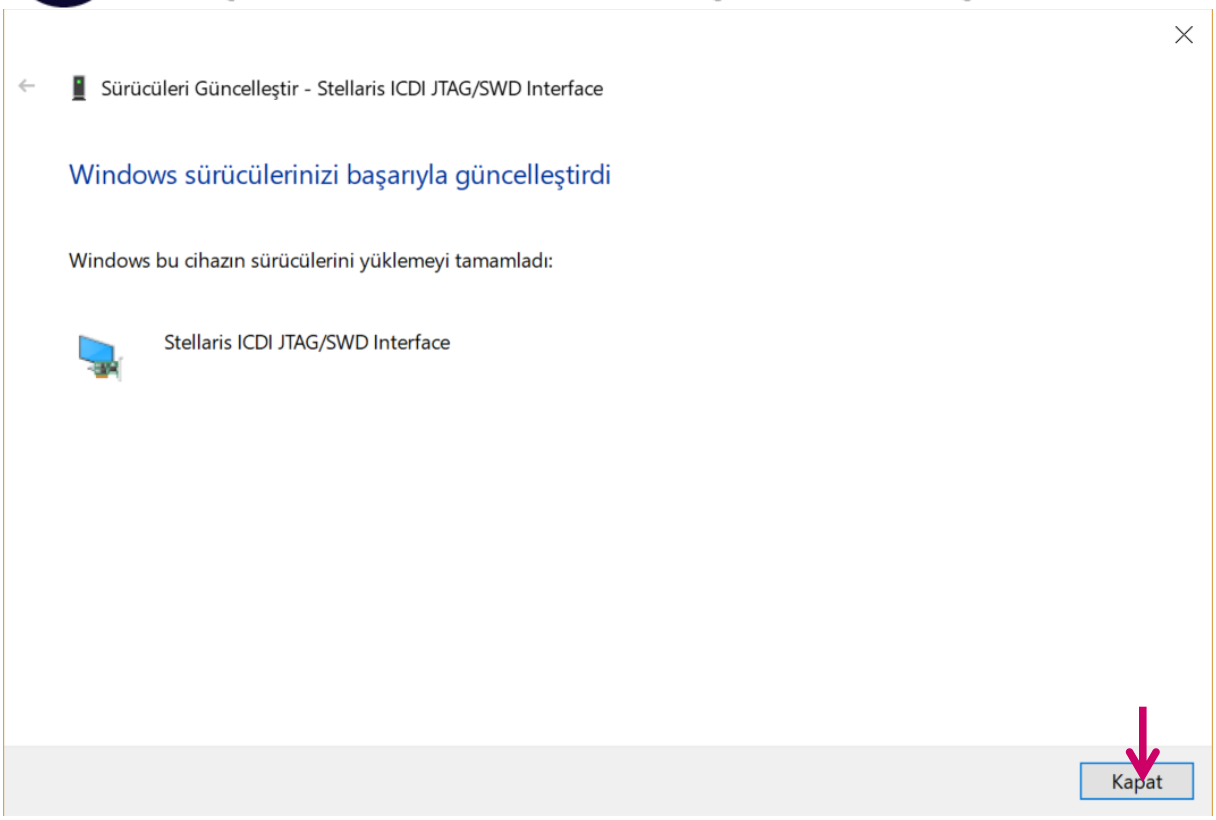

Sürücüleri Güncelleştir - In-Circuit Debug Interface
Sürücüleri nasıl aramak istiyorsunuz?
→ Güncel sürücü yazılımını otomatik olarak ara
Bu özelliği aygıt yükleme ayarlarınızda devre dışı bırakmadıkça, Windows bilgisayarınızda ve Internet'te aygıtınız için en son sürücü yazılımını arar.
→ Sürücü yazılımı için bilgisayarımı tara
Sürücü yazılımını elle bulun ve yükleyin.
İptal


Sürücüleri Güncelleştir - In-Circuit Debug Interface
Bilgisayarınızda sürücüleri arayın
Bu konumda sürücü ara:
C:\Users\Erhan Akan\Documents
Gözat...
Alt klasörlerle birlikte
Bilgisayarımdaki kullanılabilir sürücülerin bir listesinden seçmeme izin ver
Bu liste cihaz ile uyumlu olan kullanılabilir sürücüleri ve cihaz ile aynı kategoride olan tüm sürücüleri gösterecektir.
İleri
İptal

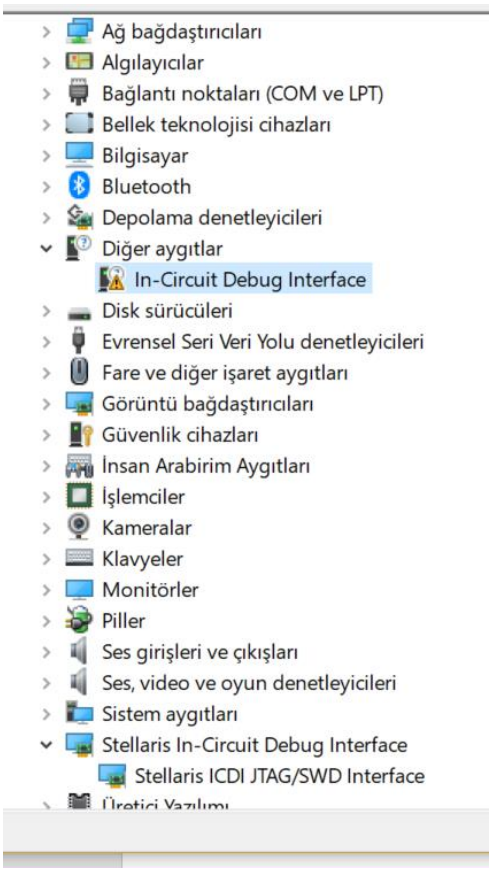

Klasöre Gözat
Donanımınız için sürücüyü içeren klasörü seçin.
PROGRAMLAR
LIBRARY
SAMPLES
stellaris_icdi_drivers
amd64
i386
System
Klasör:
stellaris_icdi_drivers
Tamam
İptal


Sürücüleri Güncelleştir - In-Circuit Debug Interface
Bilgisayarınızda sürücüleri arayın
Bu konumda sürücü ara:
C:\Users\Erhan Akan\Desktop\PROGRAMLAR\stellaris_icdi_drivers
Gözat...
Alt klasörlerle birlikte
Bilgisayarımdaki kullanılabilir sürücülerin bir listesinden seçmeme izin ver
Bu liste cihaz ile uyumlu olan kullanılabilir sürücüleri ve cihaz ile aynı kategoride olan tüm sürücüleri gösterecektir.
İleri
İptal


Windows Güvenliği
Bu aygıt yazılımını yüklemek ister misiniz?
Ad: Texas Instruments, Inc.
Yayımcı: Texas Instruments Incorporated
Her zaman "Texas Instruments Incorporated" kaynaklı yazılımlara güven.
Yükle
Yükleme
Yalnızca güvendiğiniz yayımcıların sürücü yazılımlarını yüklemelisiniz. Hangi aygıt yazılımını yüklemenin güvenli olduğuna nasıl karar veririm?

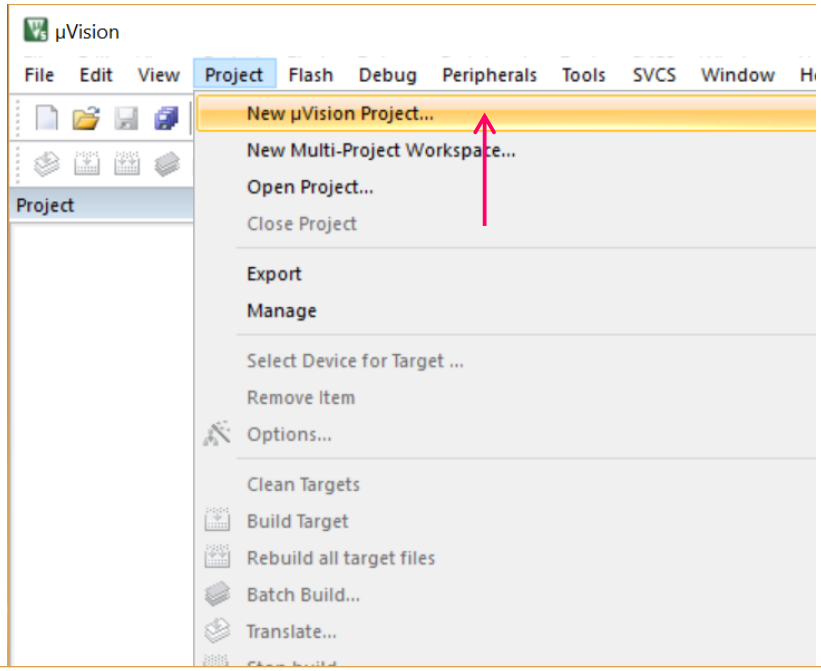


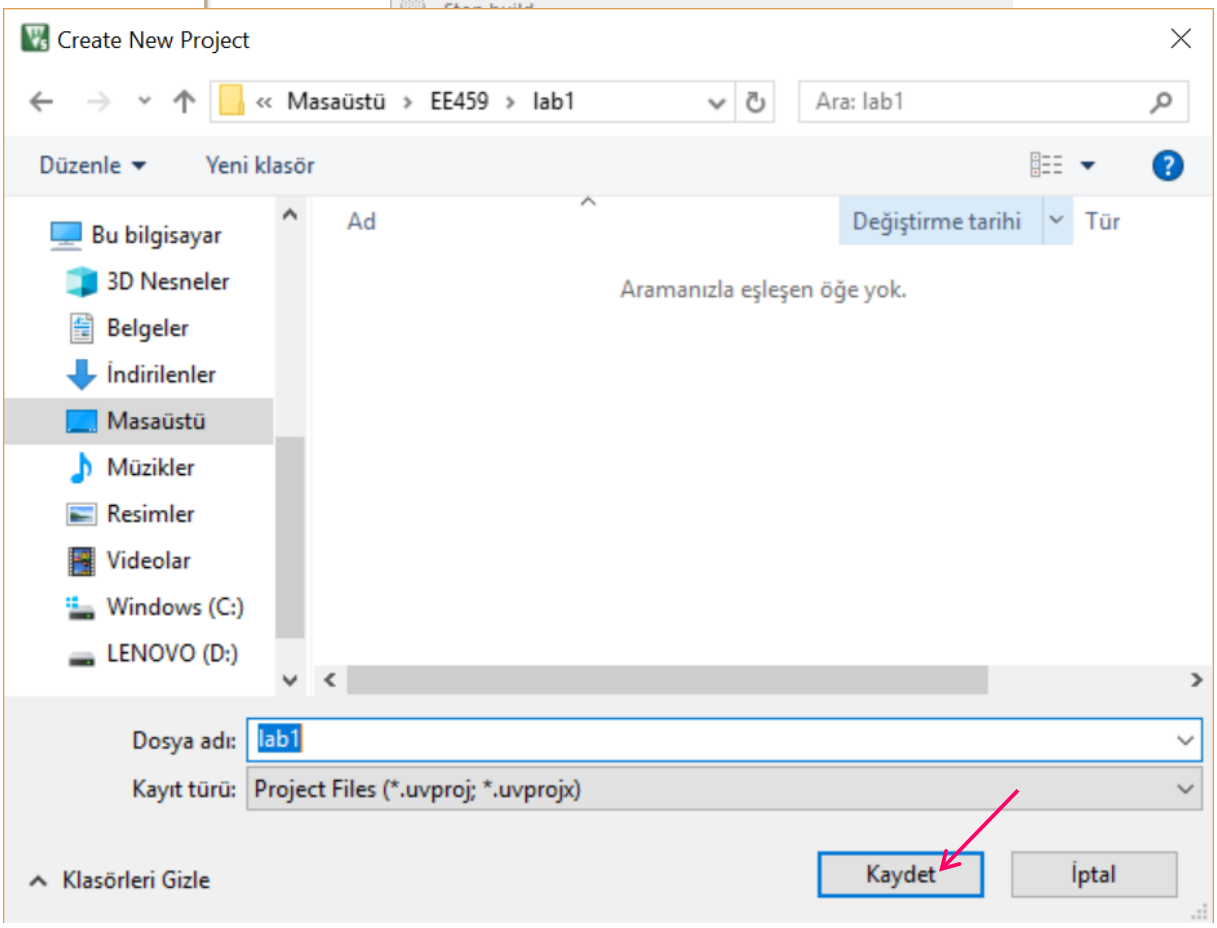
5. Do the same for the remaining device below:

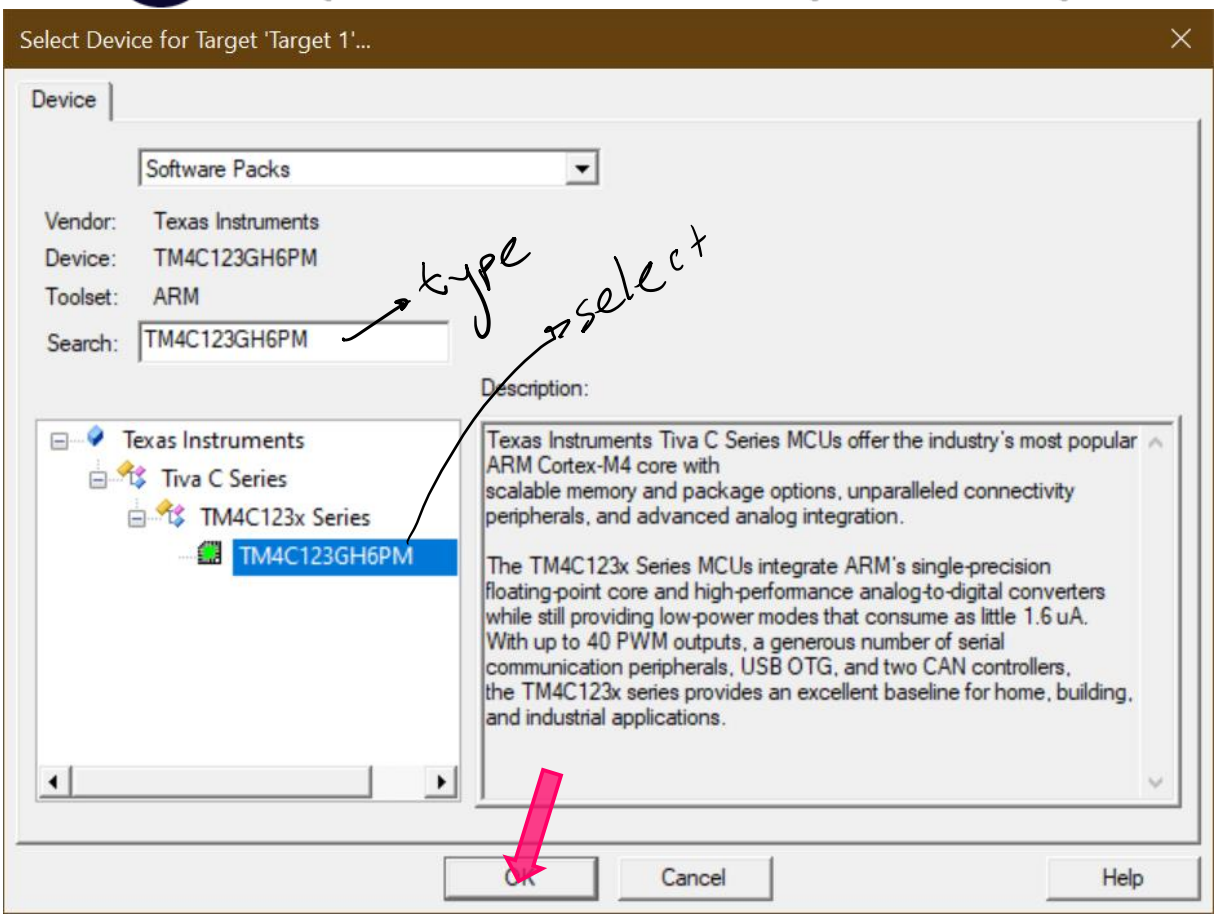


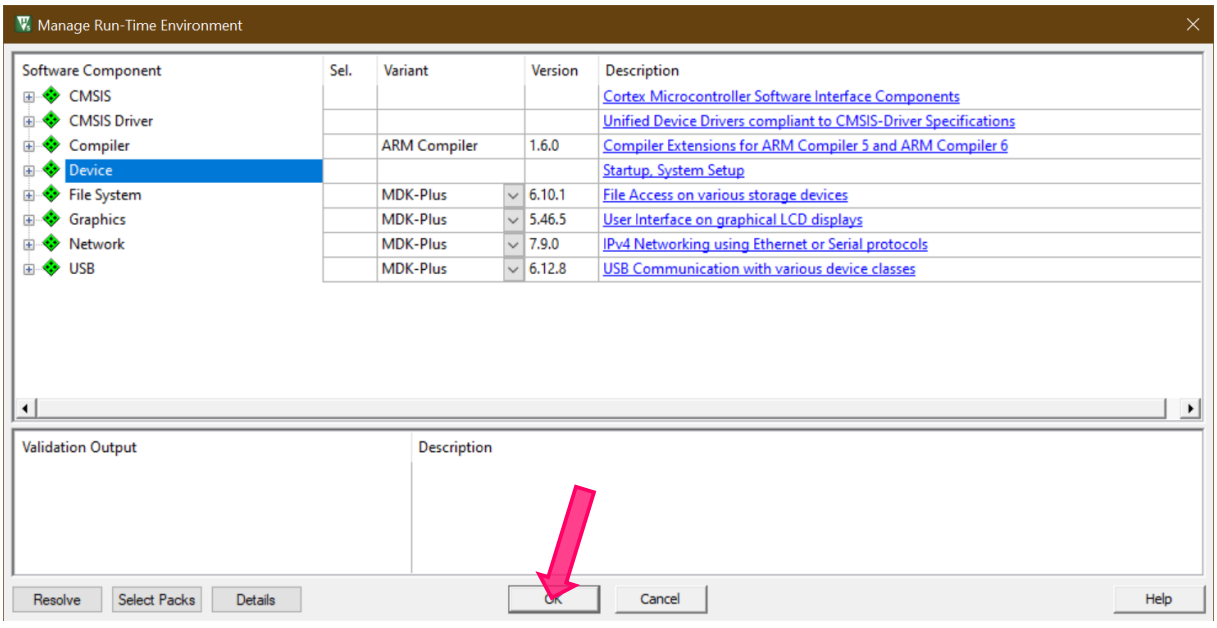
Creating a New Project

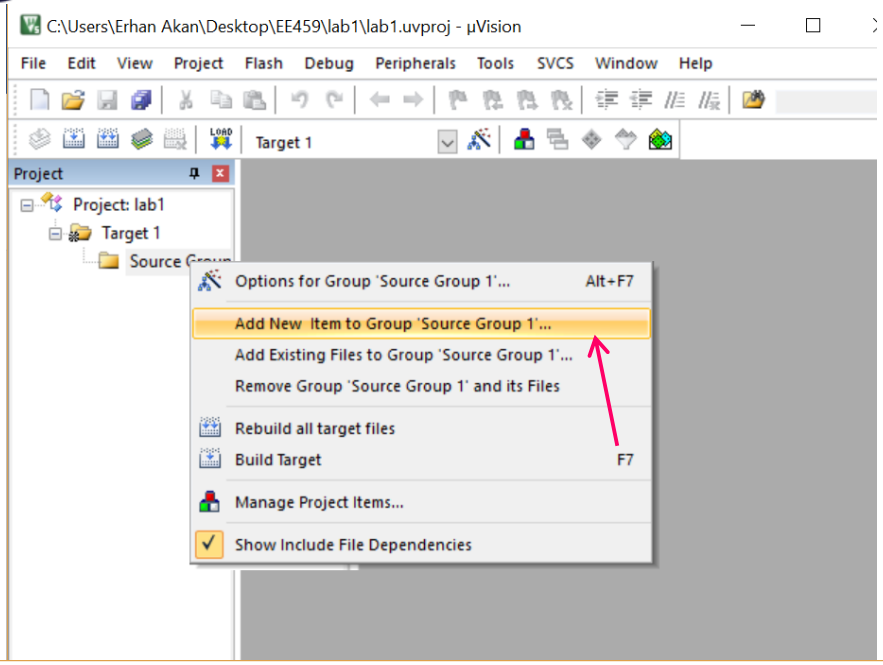
1. Run uVision and follow the instructions below:

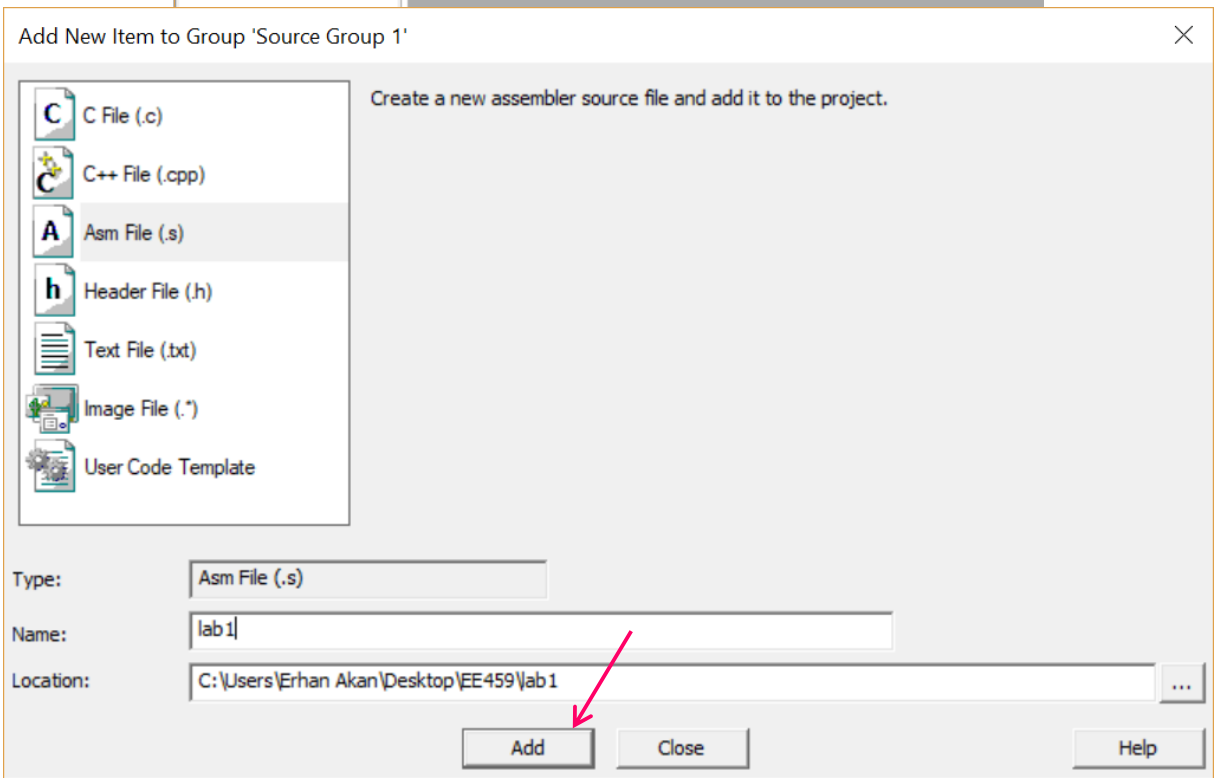


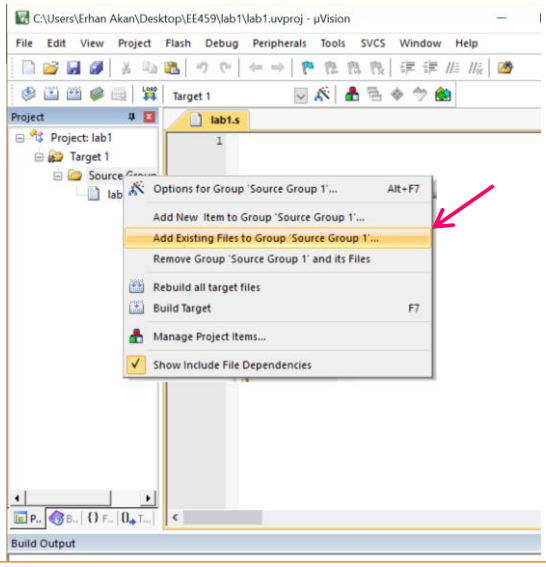


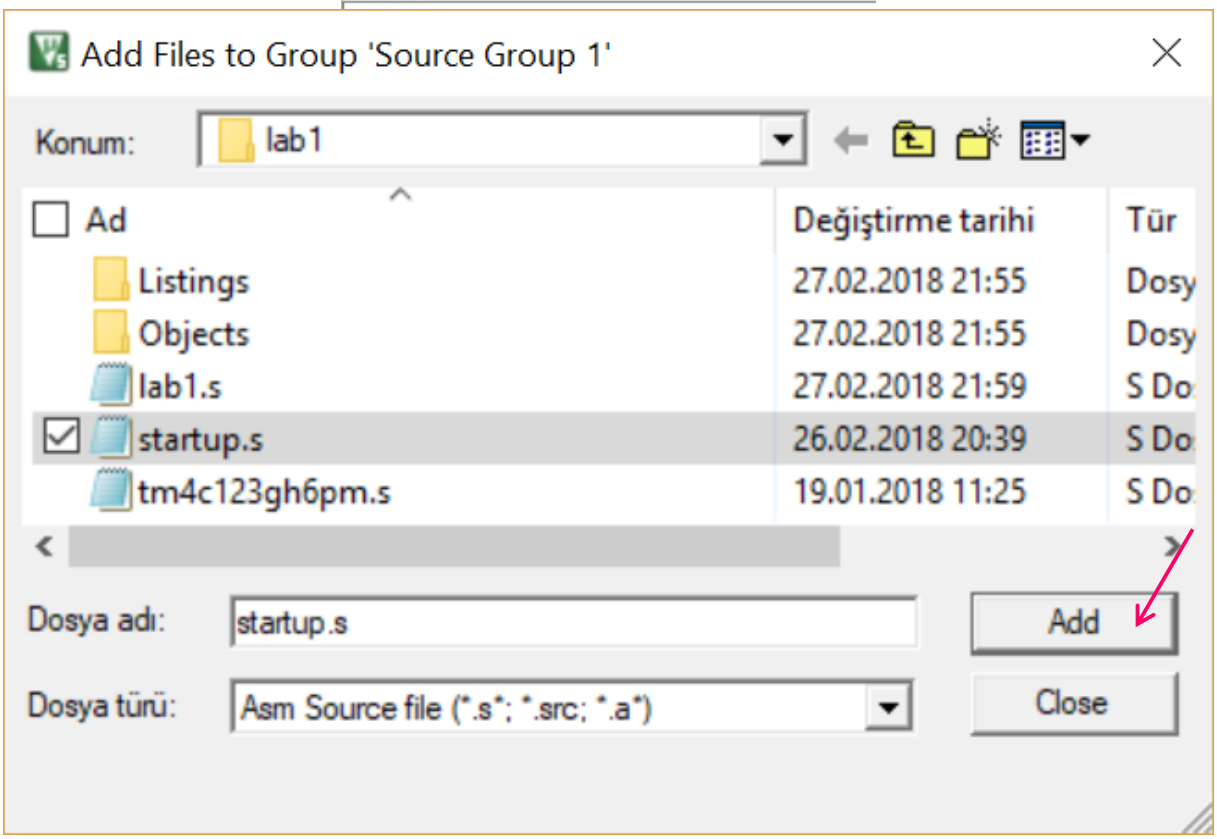

Select Device for Target 'Target 1'...
Device
Software Packs
Vendor: Texas Instruments
Device: TM4C123GH6PM
Toolset: ARM
Search: TM4C123GH6PM
type
select
Description:
Texas Instruments
Tiva C Series
TM4C123x Series
TM4C123GH6PM
Texas Instruments Tiva C Series MCUs offer the industry's most popular ARM Cortex-M4 core with scalable memory and package options, unparalleled connectivity peripherals, and advanced analog integration.
The TM4C123x Series MCUs integrate ARM's single-precision floating-point core and high-performance analog-to-digital converters while still providing low-power modes that consume as little 1.6 uA. With up to 40 PWM outputs, a generous number of serial communication peripherals, USB OTG, and two CAN controllers, the TM4C123x series provides an excellent baseline for home, building, and industrial applications.
OK
Cancel
Help

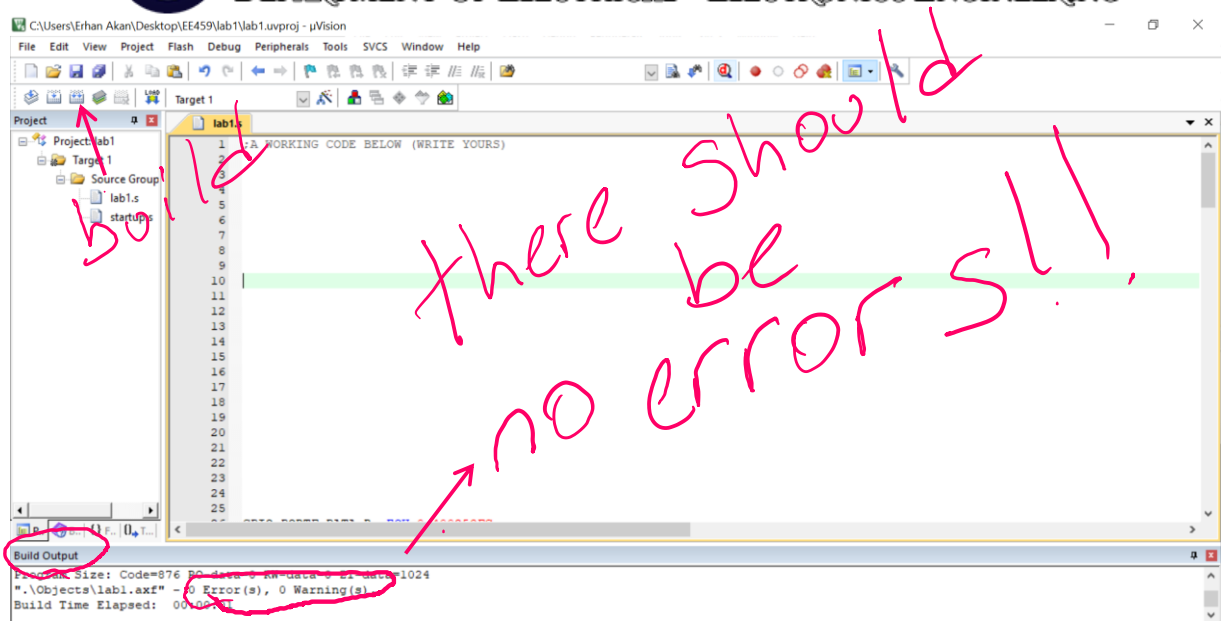

Manage Run-Time Environment
Software Component
Sel.
Variant
Version
Description
CMSIS
Cortex Microcontroller Software Interface Components
CMSIS Driver
Unified Device Drivers compliant to CMSIS-Driver Specifications
Compiler
ARM Compiler
1.6.0
Compiler Extensions for ARM Compiler 5 and ARM Compiler 6
Device
Startup, System Setup
File System
MDK-Plus
6.10.1
File Access on various storage devices
Graphics
MDK-Plus
5.46.5
User Interface on graphical LCD displays
Network
MDK-Plus
7.9.0
IPv4 Networking using Ethernet or Serial protocols
USB
MDK-Plus
6.12.8
USB Communication with various device classes
Validation Output
Description
Resolve
Select Packs
Details
OK
Cancel
Help


C:\Users\Erhan Akan\Desktop\EE459\lab1\lab1.uvproj - µVision
File Edit View Project Flash Debug Peripherals Tools SVCS Window Help
Target 1
Project
Project: lab1
Target 1
Source Group
Options for Group 'Source Group 1'... Alt+F7
Add New Item to Group 'Source Group 1'...
Add Existing Files to Group 'Source Group 1'...
Remove Group 'Source Group 1' and its Files
Rebuild all target files
Build Target F7
Manage Project Items...
Show Include File Dependencies


Add New Item to Group 'Source Group 1'
C File (.c)
C++ File (.cpp)
Asm File (.s)
Header File (.h)
Text File (.txt)
Image File (.*)
User Code Template
Create a new assembler source file and add it to the project.
Type: Asm File (.s)
Name: lab1
Location: C:\Users\Erhan Akan\Desktop\EE459\lab1
Add
Close
Help

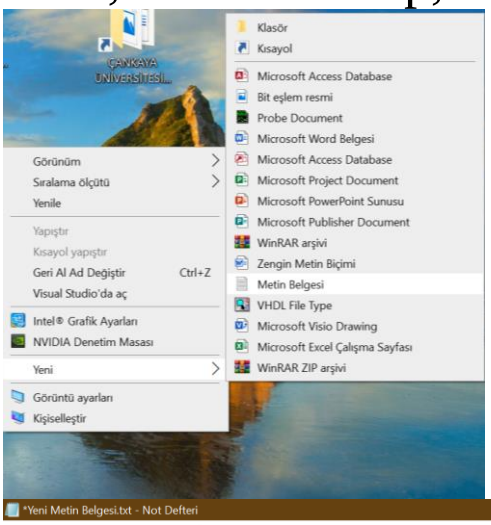

C:\Users\Erhan Akan\Desktop\EE459\lab1\lab1.uvproj - µVision
File Edit View Project Flash Debug Peripherals Tools SVCS Window Help
Target 1
Project
Project: lab1
Target 1
lab1.s
Options for Group 'Source Group 1'... Alt+F7
Add New Item to Group 'Source Group 1'...
Add Existing Files to Group 'Source Group 1'...
Remove Group 'Source Group 1' and its Files
Rebuild all target files
Build Target F7
Manage Project Items...
Show Include File Dependencies
Build Output

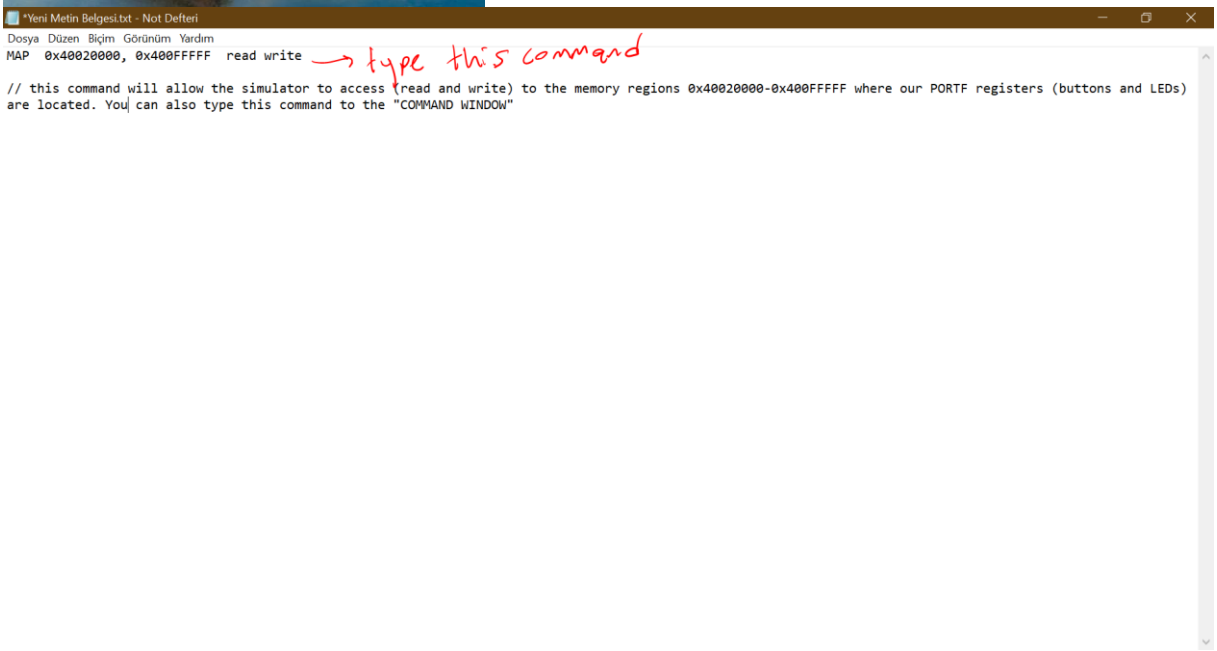

Add Files to Group 'Source Group 1'
Konum:
lab1
Ad
Değiştirme tarihi
Tür
Listings
27.02.2018 21:55
Dosy
Objects
27.02.2018 21:55
Dosy
lab1.s
27.02.2018 21:59
S Do
startup.s
26.02.2018 20:39
S Do
tm4c123gh6pm.s
19.01.2018 11:25
S Do
Dosya adı:
startup.s
Add
Dosya türü:
Asm Source file (*.s*; *.src; *.a*)
Close



Note that, if there are some errors, you should check them one by one from the “build output” window and correct them all.

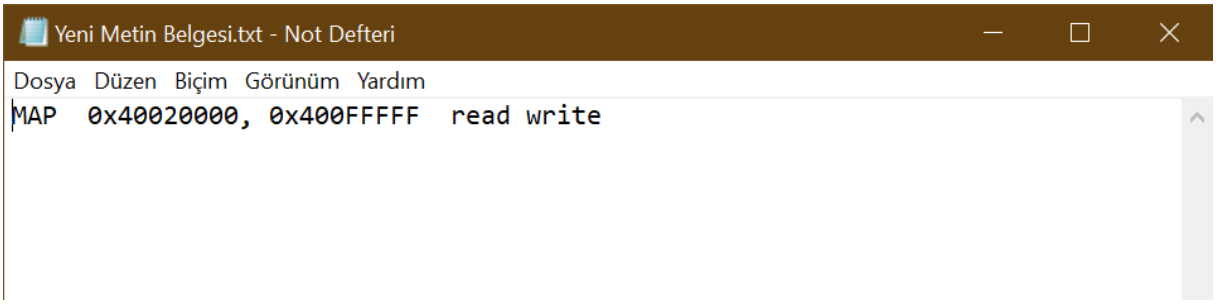
Now, at the desktop, create a txt file





Just type
MAP 0x40020000, 0x400FFFFF read write

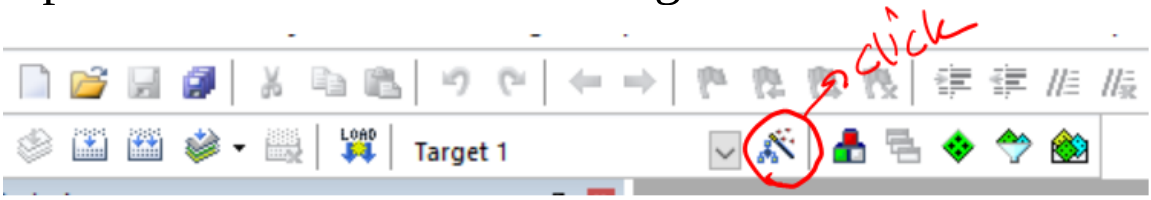
And save this notepad file.

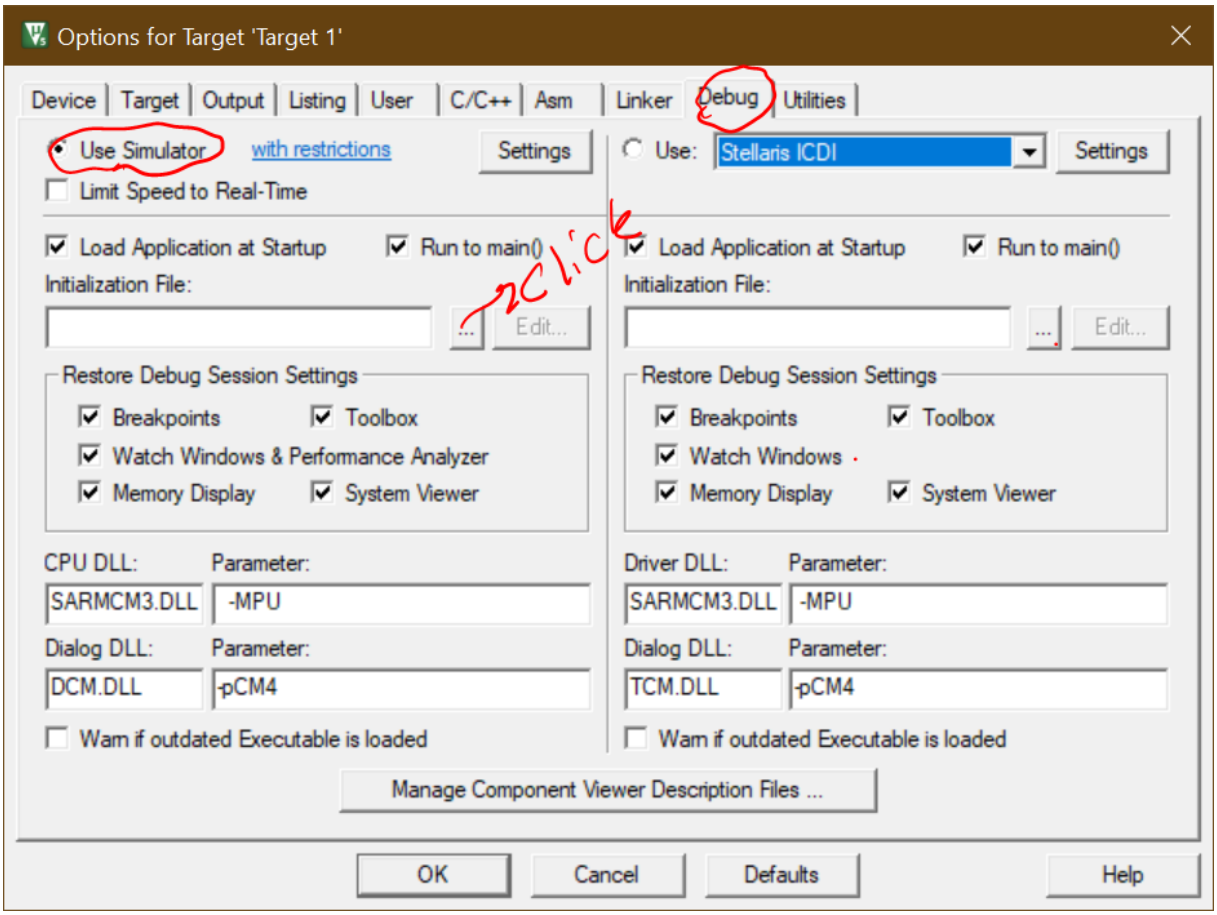


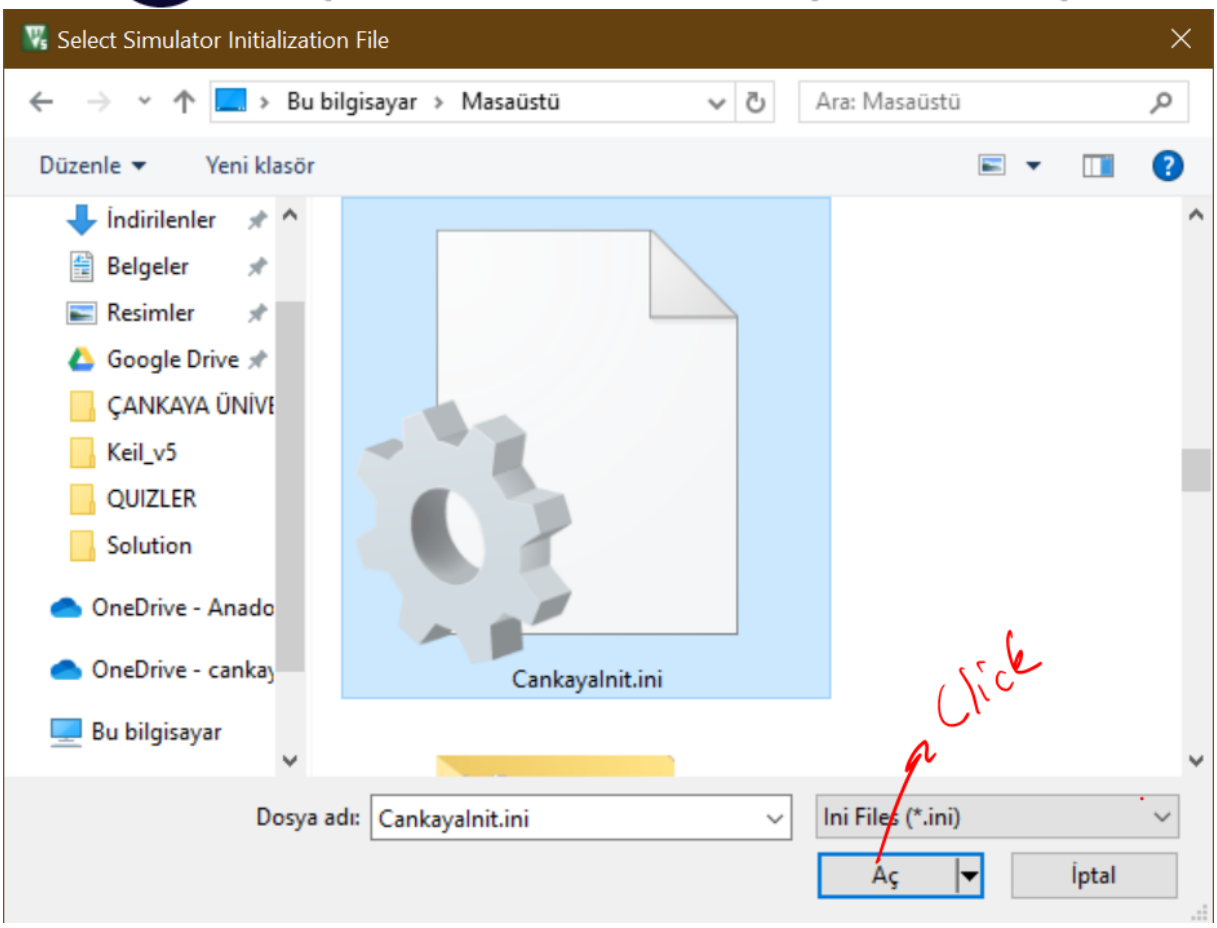
Then Don’t forget to change file extension into the “.ini”

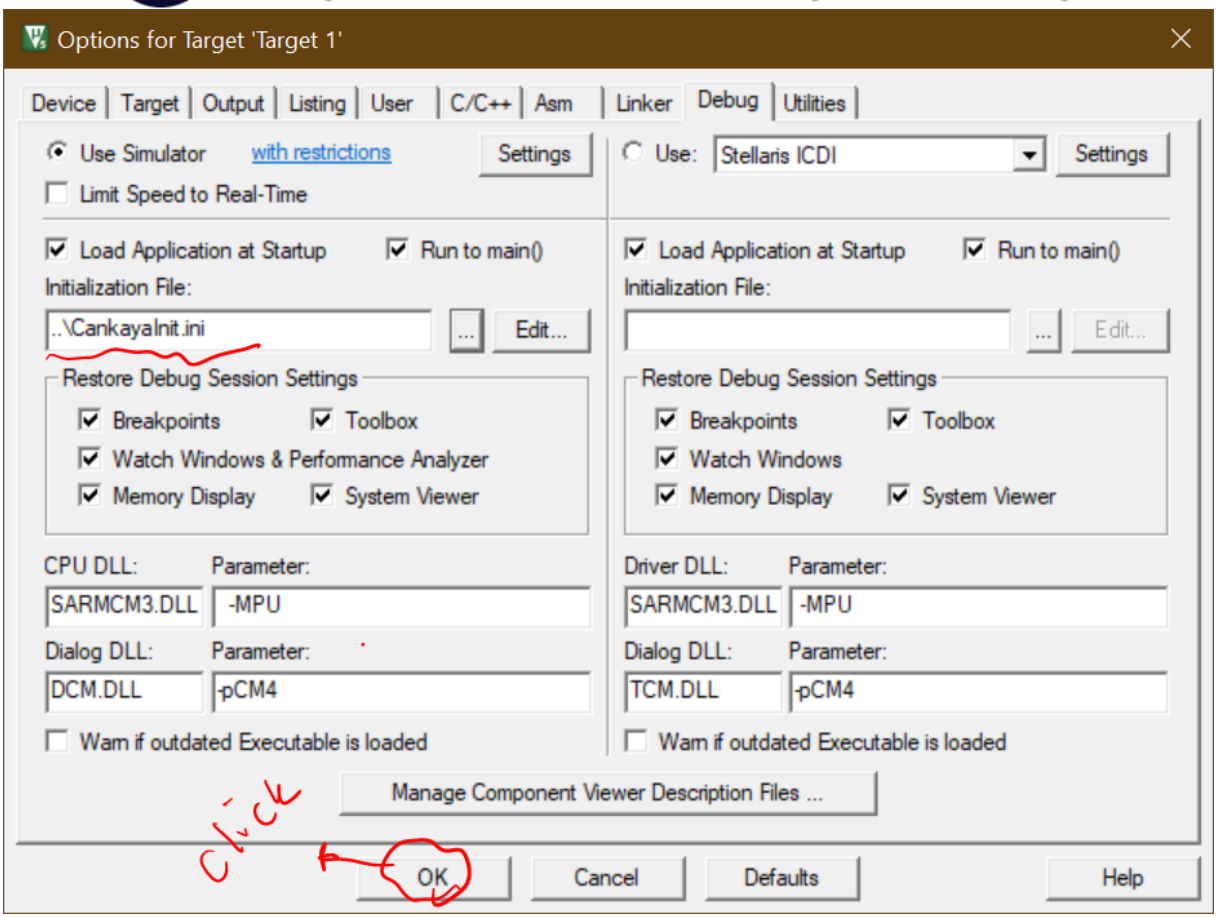
The file should look like that

Open Keil and do the followings:





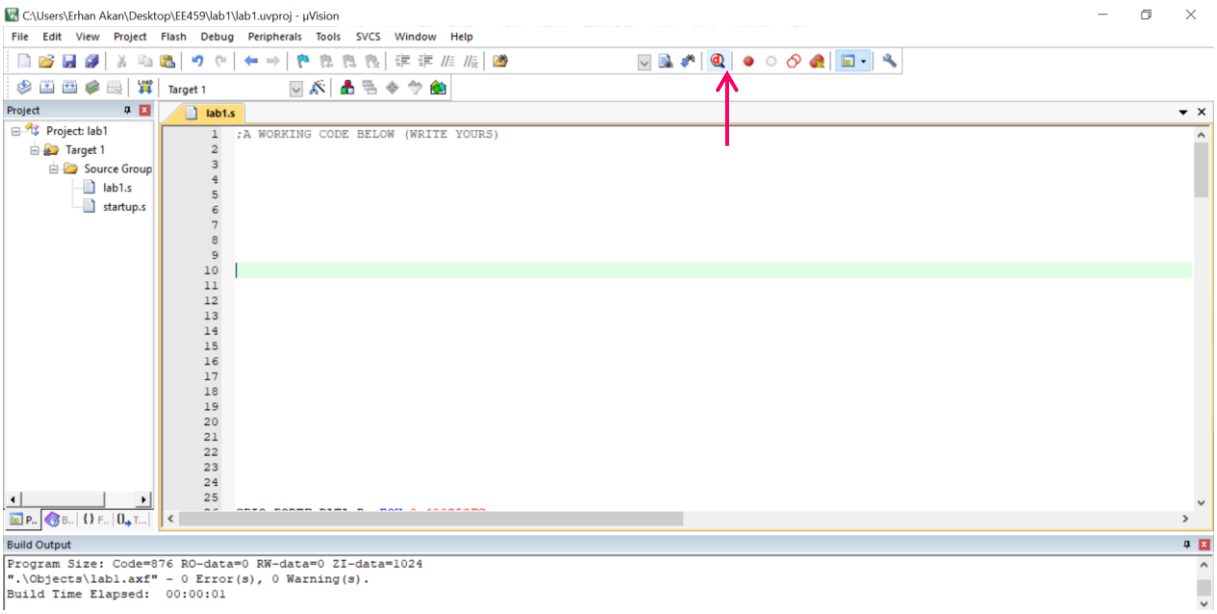

Select Simulator Initialization File
Bu bilgisayar › Masaüstü
Ara: Masaüstü
Düzenle
Yeni klasör
İndirilenler
Belgeler
Resimler
Google Drive
ÇANKAYA ÜNİVE
Keil_v5
QUIZLER
Solution
OneDrive - Anado
OneDrive - canka
Bu bilgisayar
Cankayalnit.ini
Click
Dosya adı: Cankayalnit.ini
Ini Files (*.ini)
Aç
İptal

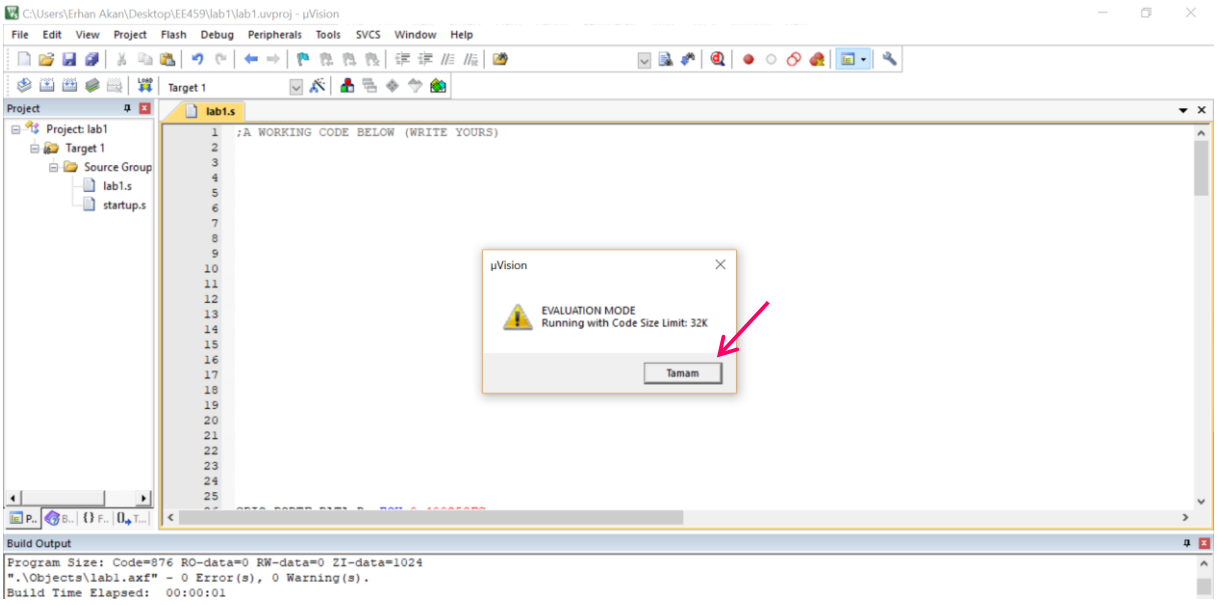


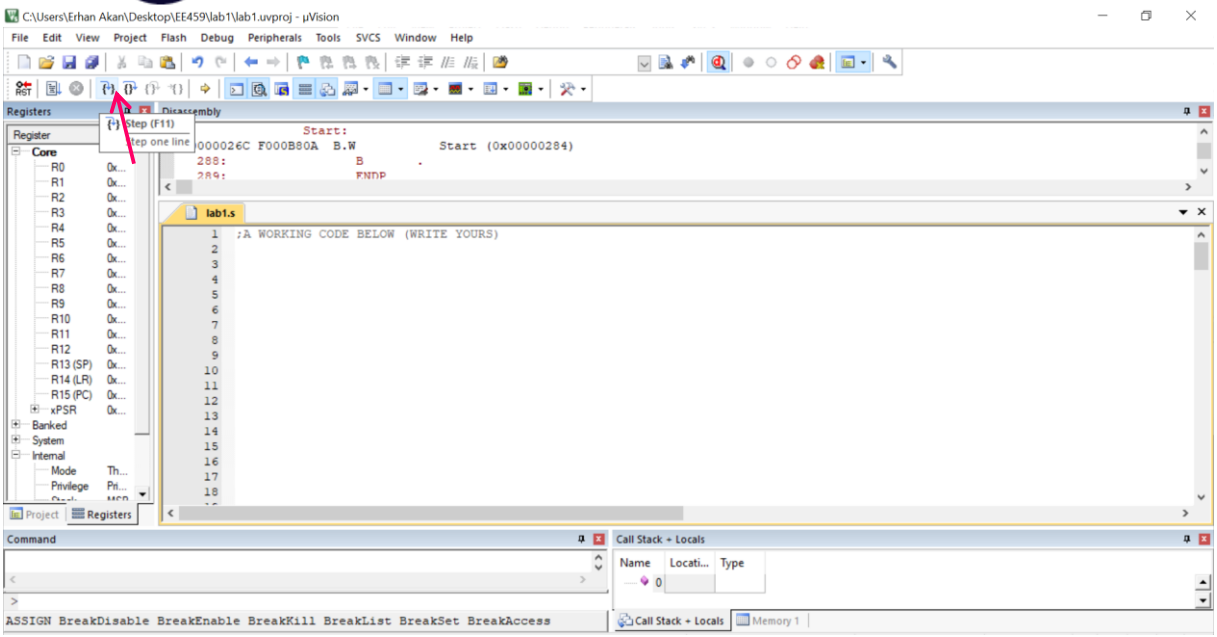
NOW, YOU WILL HAVE THE PERMISSION TO WRITE OR READ INTO/FROM THIS ADRESS REGION

Debugging Your Code

1. Follow the steps below:






C:\Users\Erhan Akan\Desktop\EE459\lab1\lab1.uvproj - µVision
File Edit View Project Flash Debug Peripherals Tools SVCS Window Help
Registers
Register
Core
R0
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
R13 (SP)
R14 (LR)
R15 (PC)
xPSR
Banked
System
Internal
Mode
Privilege
Step (F11)
Step one line
Disassembly
Start:
0000026C F000B80A B.W Start (0x00000284)
288:
289:
lab1.s
;A WORKING CODE BELOW (WRITE YOURS)
Project
Registers
Command
ASSIGN BreakDisable BreakEnable BreakKill BreakList BreakSet BreakAccess
Call Stack + Locals
Name
Locati...
Type
Call Stack + Locals
Memory 1