INDIAN INSTITUTE OF ENGINEERING SCIENCE AND TECHNOLOGY, SHIBPUR

Intelligent Embedded System Design
(under KEIL and Arm environment)

By

Anupam Sanidhya

Examination Roll Number : **510817049** of **2017-21**

under the supervision of

Dr. Prasun Ghosal

A report submitted in fulfilment of the requirements for the
mini project of Bachelor of Technology in Information Technology (5th Semester)

Department of Information Technology

Indian Institute of Engineering Science and Technology, Shibpur

P.O. Botanic Garden, Howrah 711103, WB, India

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Certificate of Approval

This is to certify that the thesis synopsis entitled **"Intelligent Embedded System Design (under KEIL and ARM environment)"** is a record of bona fide work carried out by Mr. Anupam Sanidhya under my supervision and guidance.

The report has fulfilled the requirements for the completion of mini project of degree of Bachelor of Technology in Information Technology from Indian Institute of Engineering Science and Technology, Shibpur, India.

He has duly completed the required course/research work with sincerity and the work has reached the standard necessary for submission.

Signed:

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DEPARTMENT OF INFORMATION TECHNOLOGY
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FORWARD

I would like to forward the report entitled **Intelligent Embedded System Design (under KEIL and ARM environment** towards the examination committee as a record of bona fide work carried out by **Anupam Sanidhya** under my supervision and guidance.

In my opinion, the work for the report is satisfactory and it has reached the standard necessary for the submission in the fifth semester of *Bachelor of Technology* in *Information Technology* of Indian Institute of Engineering Science and Technology, Shibpur.

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Professor and Dean (Academic Affairs) [Acting]
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as and when required.

Finally, I cordially thank my team members and fellow classmates of Information Technology, Indian Institute of Engineering Science and Technology, my parents and all others who have been attached to this phase of the development of the project directly or otherwise.

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INDIAN INSTITUTE OF ENGINEERING SCIENCE AND TECHNOLOGY, SHIBPUR

Intelligent Embedded System Design (under KEIL and ARM environment)

Department of Information Technology
Bachelor of Technology in Information Technology
by Anupam Sanidhya

Motivation of the Project

Embedded systems aim at interacting with the real world and thus they provide a huge scope for practical real world applications. They are currently being used in various spheres of our lives and can be integrated with various machines like toys, airplanes, audio equipments, cars, robots, appliances.

The motivation for this project was to design intelligent car parking system using an embedded system and ultrasonic sound sensors to prevent car damages by facilitating precision rear parking.

Objective

The objective was to understand the working of an Intelligent embedded system such as an ARM and KEIL based microcontroller MCBSTM32F400 using Keil MDK-ARM™ (Microcontroller Development Kit) which features the industry standard ARM compiler, the µVision® 5 IDE, analysis tools, and the fully functional Keil RTX RTOS.

Hence, by using the aforementioned microcontroller, an intelligent parking system is designed which uses two ultrasonic sensors to sense the distance between the car and the objects nearby for an efficient parking. It also uses it's gyroscope and camera for real time precision.

Introduction

An embedded system is a small computer that forms part of a larger system or machine. Its purpose is to control the device and interact with real world elements and to allow users to perform various operations accordingly thus providing us with a large scale of functionalities. They tend to have one or a limited number of tasks that they can perform.

Examples of embedded systems include :

- central heating systems
- engine management systems in vehicles
- IoT applications
- domestic appliances, such as dishwashers, TVs and digital phones
- digital watches
- electronic calculators
- GPS systems
- fitness trackers

What is Arm Processor

An ARM processor is one of the families of CPUs based on the RISC (reduced instruction set computer) architecture developed by Advanced RISC Machines (ARM). RISC is a microprocessor that is designed to perform a smaller number of types of computer instructions so that it can operate at a higher speed.

RISC are built to perform a smaller number of types of computer instructions so that it can operate at a higher speed.

This makes ARM processors quite efficient and thus are extensively used in consumer electronic devices such as smartphones, tablets, multimedia players and other mobile devices.

Components Used

The follow components were used :

- Keil MCBSTM32F400 Evaluation Board
- Segger J-Link Edu adapter
- Connecting Cables
- Laptop
- KEIL MDK-ARM™ (Microcontroller Development Kit) with µVision® 5 IDE

KEIL MCBSTM32F400 Evaluation Board

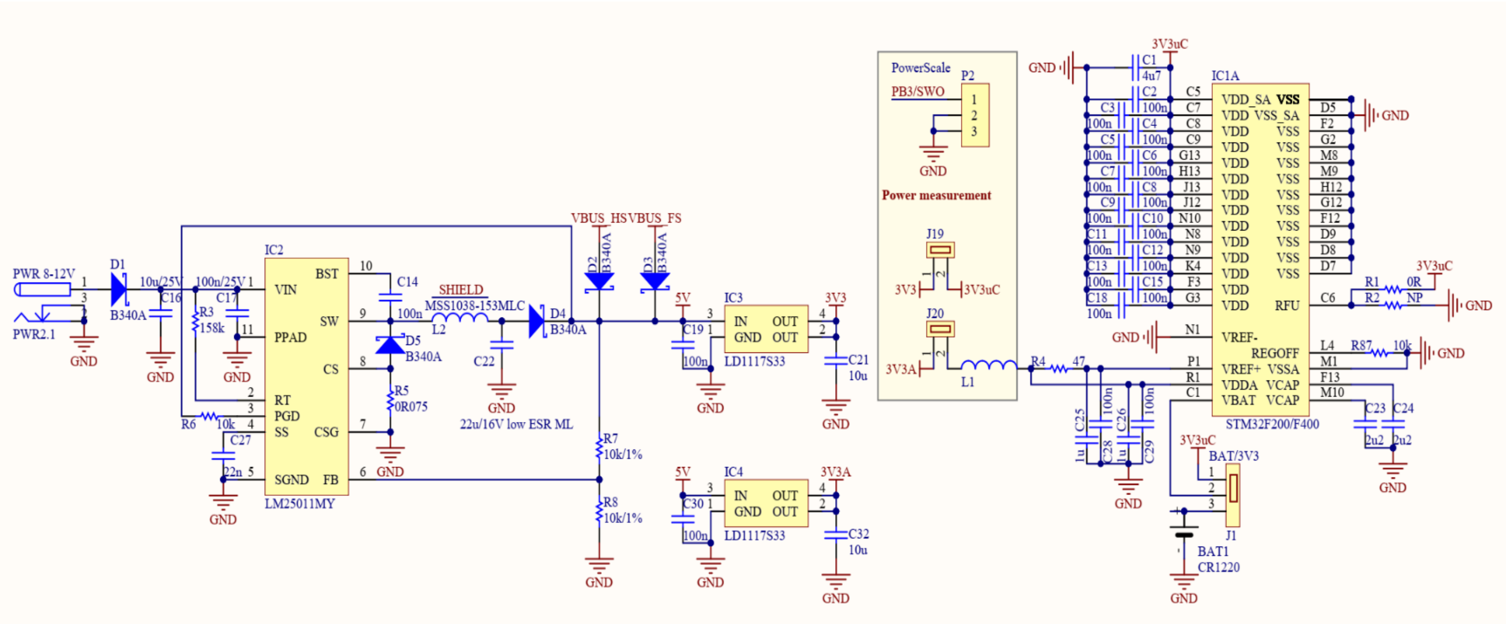
168MHz STM32F407IG ARM Cortex™-M4 processor-based MCU in 176-pin BGA

Features :

- On-Chip Memory: 1MB Flash & 192KB RAM
- External Memory: 8MB NOR Flash, 512MB NAND Flash, 2MB SRAM, 8KB I2C EEPROM with NFC interface
- 2.4 inch Color QVGA TFT LCD with resistive touchscreen
- USB 2.0 Full Speed - USB, USB-OTG, & USB Host
- 1 CAN Interface
- Serial/UART Port
- MicroSD card interface
- 5 position Joystick
- 3 position Accelerometer and Gyroscope
- Analog to Digital Converter

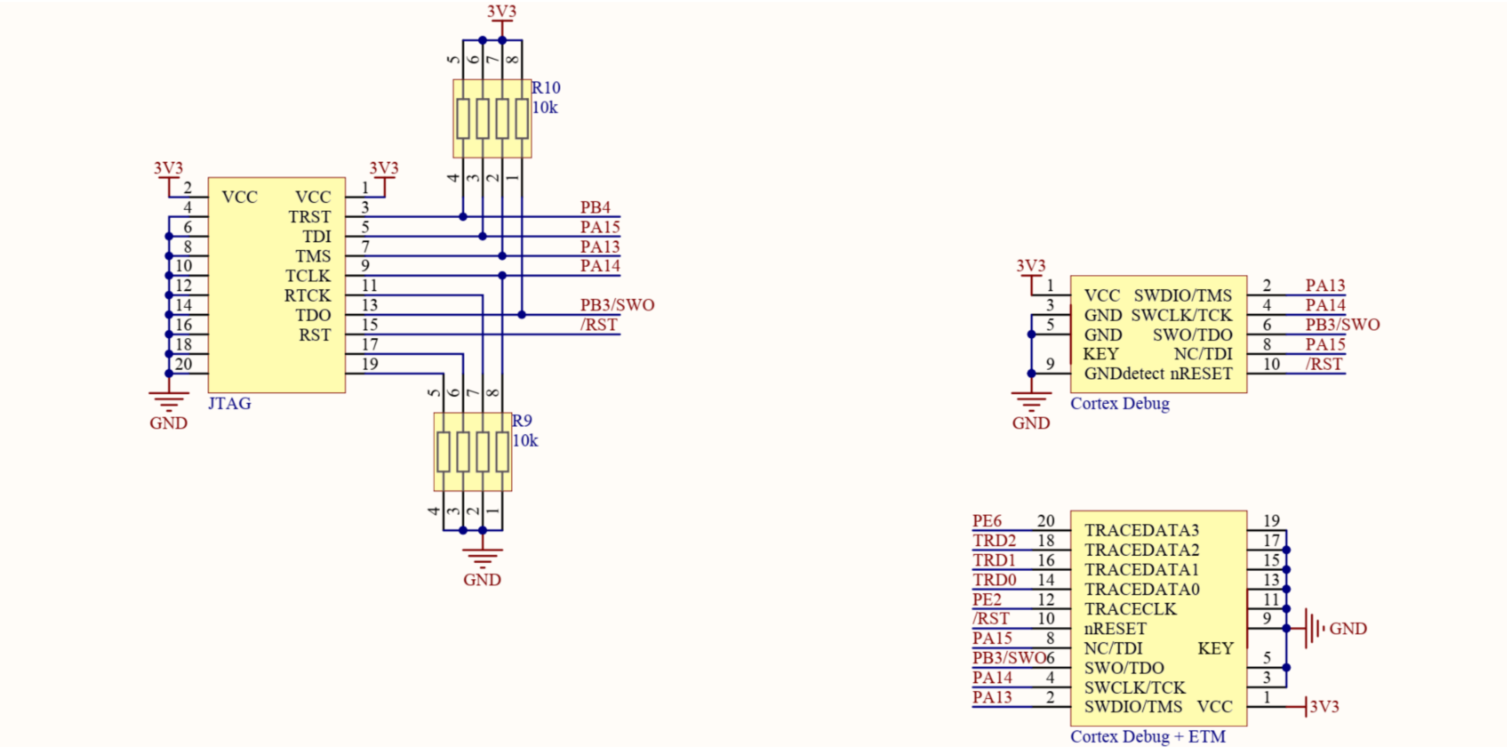
- Audio CODEC with Line-In/Out and Speaker/Microphone
- Digital Microphone
- Digital VGA camera
- Push-Buttons for Reset, Wakeup, Tamper and User
- 8 LEDs directly connected to port pins
- Power Supply via :
  - High Speed and Full Speed USB (micro) connectors
  - Power jack (8V-12V) with Voltage Regulator capable to supply both USB host interfaces (500mA each
- Debug interface connectors :
  - 20 pin JTAG (0.1 inch connector)
  - 10 pin Cortex debug (0.05 inch connector)
  - 20-pin Cortex debug + ETM Trace (0.05 inch connector

Power

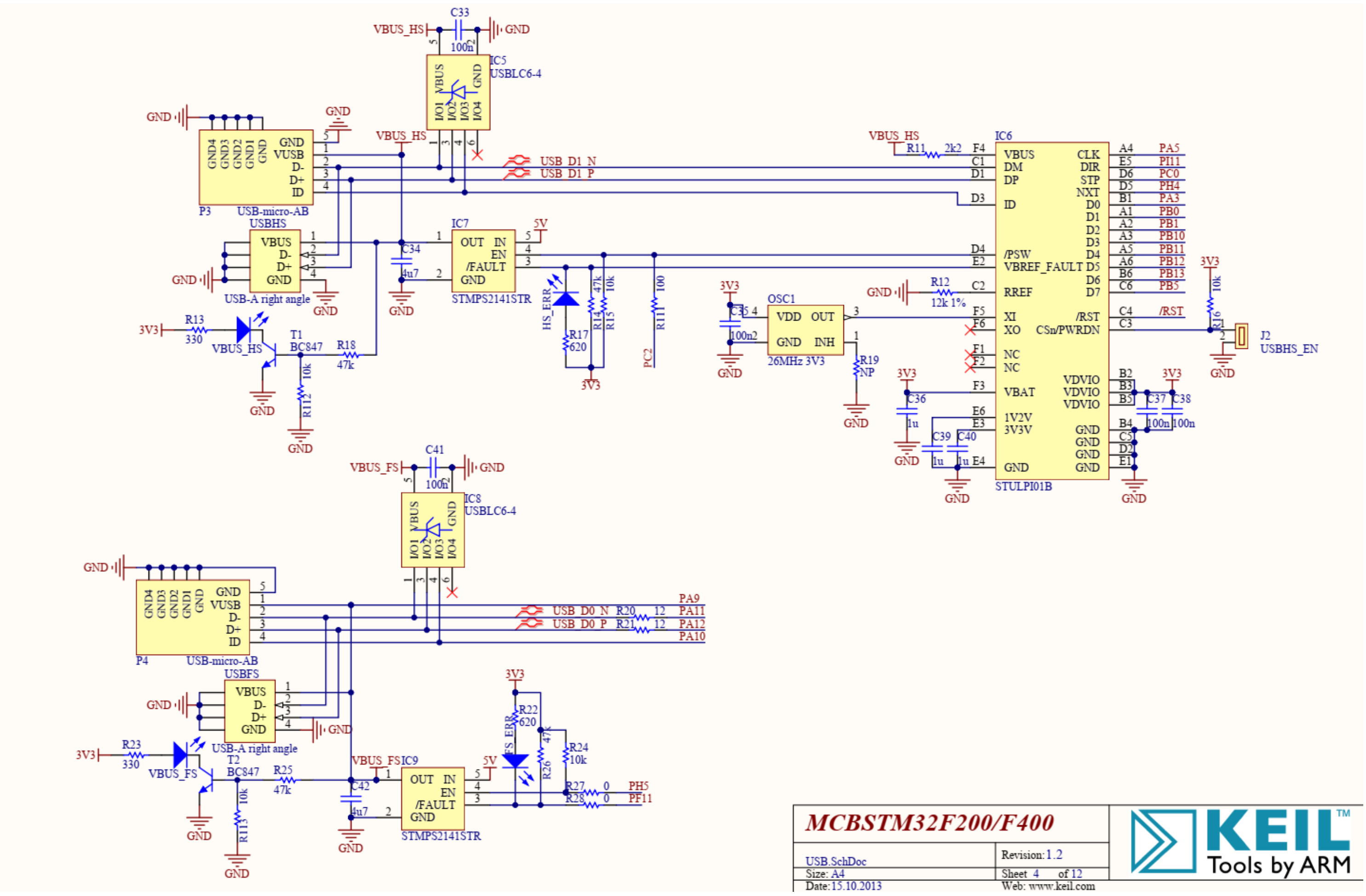


uC

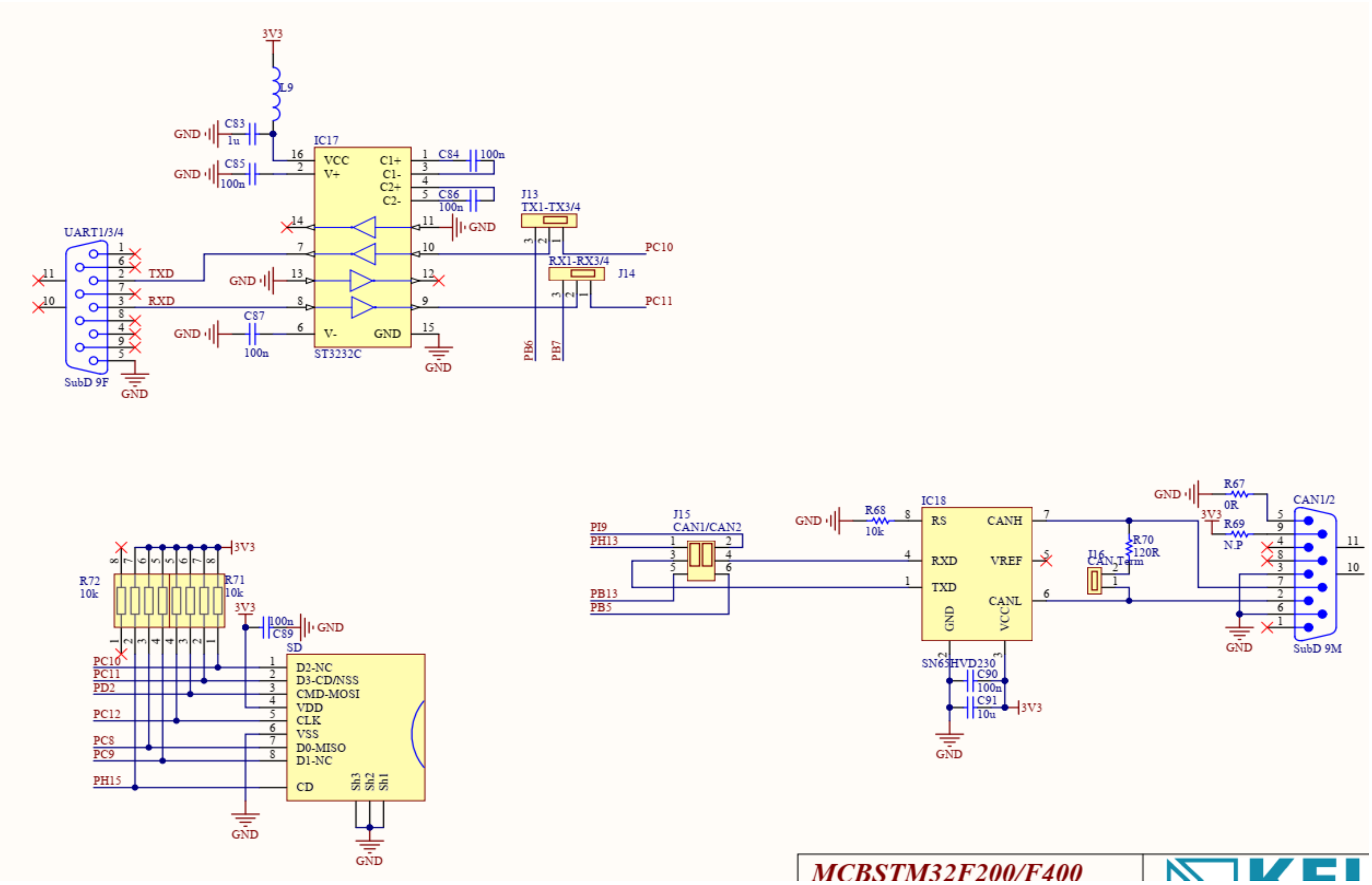
Debug


3V3
R10
10k
VCC
TRST
TDI
TMS
TCLK
RTCK
TDO
RST
JTAG
GND
PB4
PA15
PA13
PA14
PB3/SWO
/RST
R9
10k
VCC SWDIO/TMS
GND SWCLK/TCK
GND SWO/TDO
KEY NC/TDI
GNDdetect nRESET
Cortex Debug
PA13
PA14
PB3/SWO
PA15
/RST
PE6
TRD2
TRD1
TRD0
PE2
/RST
PA15
PB3/SWO
PA14
PA13
TRACEDATA3
TRACEDATA2
TRACEDATA1
TRACEDATA0
TRACECLK
nRESET
NC/TDI
KEY
SWO/TDO
SWCLK/TCK
SWDIO/TMS
VCC
Cortex Debug + ETM

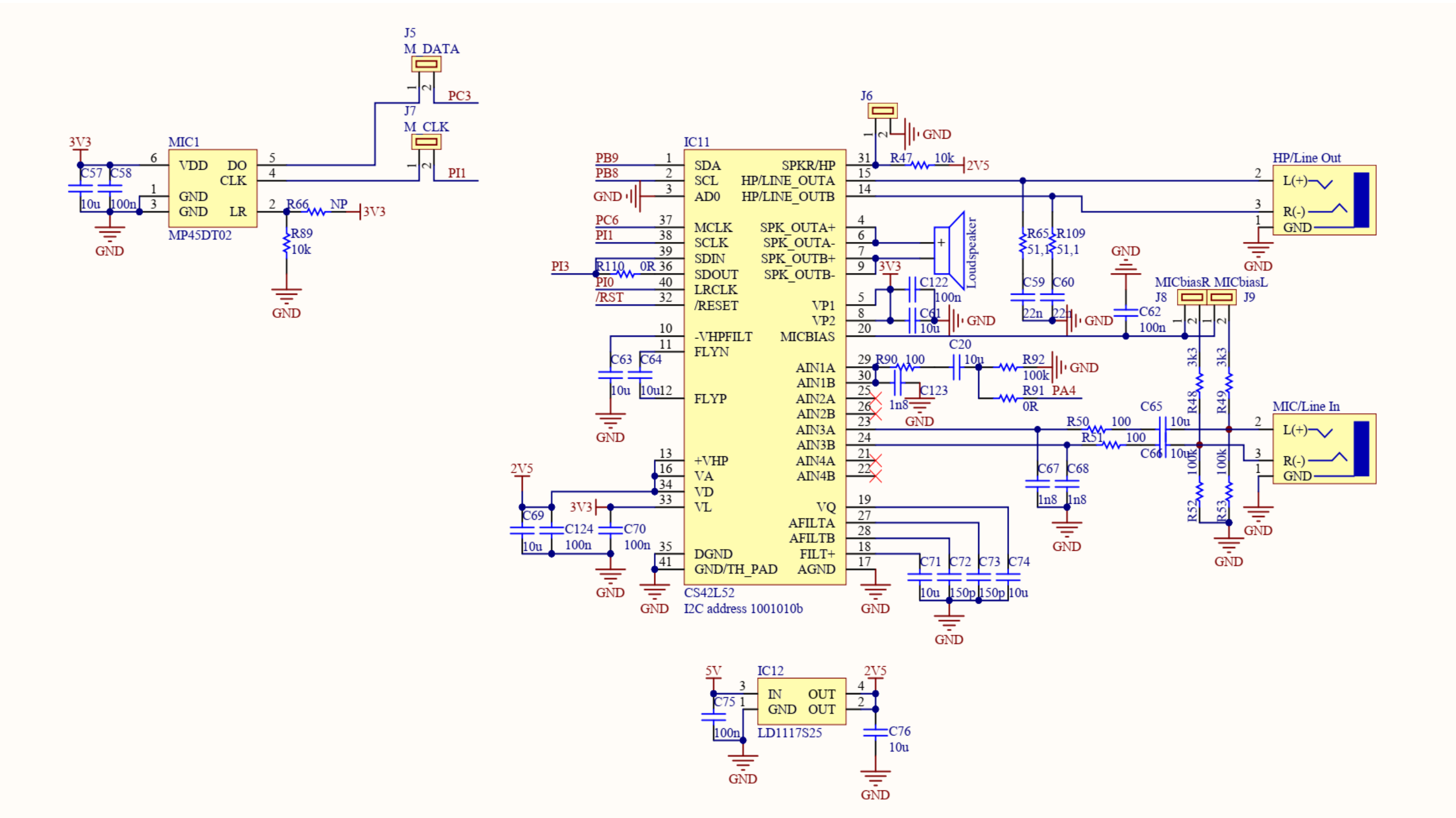
USB


VBUS_HS
C33
100n
GND
IC5
USBLC6-4
USB-micro-AB
USBHS
USB-A right angle
IC7
STMPS2141STR
OUT IN
EN
/FAULT
GND
HS_ERR
R17
620
R14
47k
R15
10k
R11
100
PC2
R13
330
VBUS_HS
T1
BC847
R18
47k
R112
10k
USB_D1_N
USB_D1_P
VBUS_HS
R11
2k2
IC6
STULPI01B
VBUS
DM
DP
ID
/PSW
VBREF_FAULT
RREF
XI
XO
NC
VBAT
1V2V
3V3V
GND
CLK
DIR
STP
NXT
/RST
CSn/PWRDN
VDVIO
PA5
PI11
PC0
PH4
PA3
PB0
PB1
PB10
PB11
PB12
PB13
PB5
/RST
R16
10k
J2
USBHS_EN
OSC1
26MHz 3V3
VDD OUT
GND INH
R12
12k 1%
R19
NP
C35
100n2
C36
1u
C39
1u
C40
1u
C37
100n
C38
100n
VBUS_FS
C41
100n
IC8
USBLC6-4
USB-micro-AB
USBFS
USB-A right angle
R23
330
VBUS_FS
T2
BC847
R25
47k
R113
10k
USB_D0_N
USB_D0_P
R20
12
R21
12
PA9
PA11
PA12
PA10
VBUS_FS
IC9
C42
4u7
STMPS2141STR
FS_ERR
R22
620
R26
47k
R24
10k
R27
0
R28
0
PH5
PF11
MCBSTM32F200/F400
USB.SchDoc
Size: A4
Date: 15.10.2013
Revision: 1.2
Sheet 4 of 12
Web: www.keil.com
KEIL
Tools by ARM

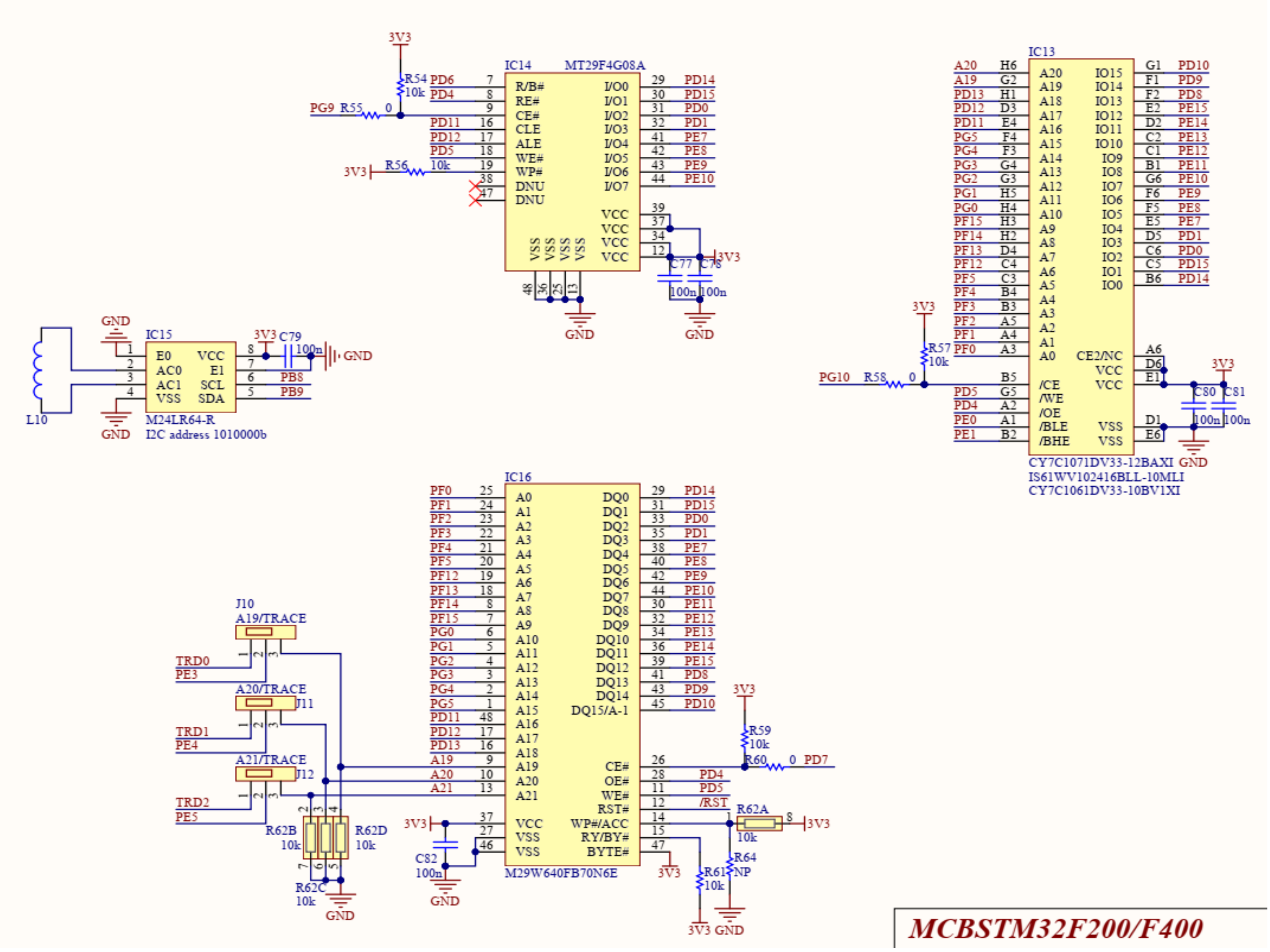
SD-CAN_RS32



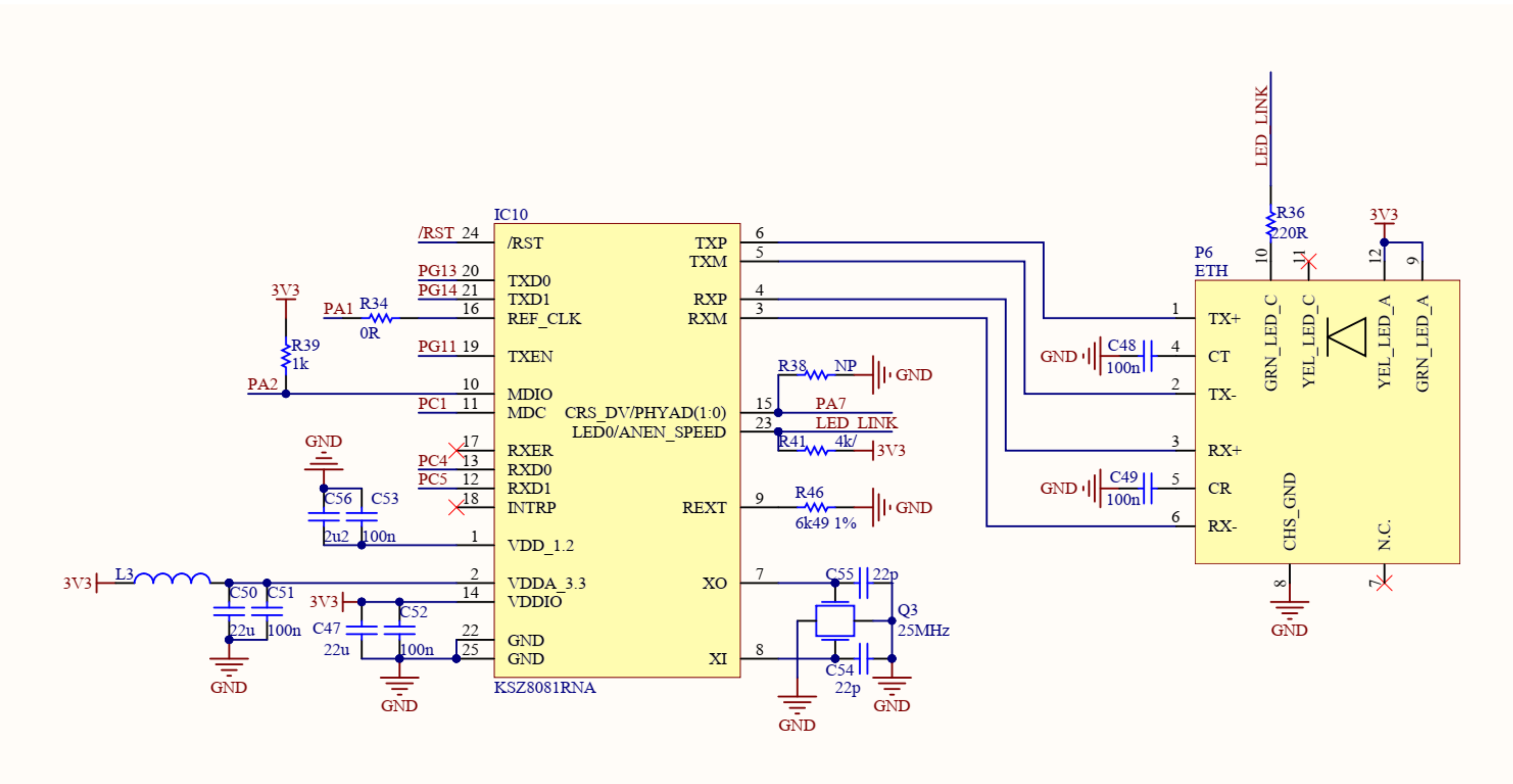
Audio



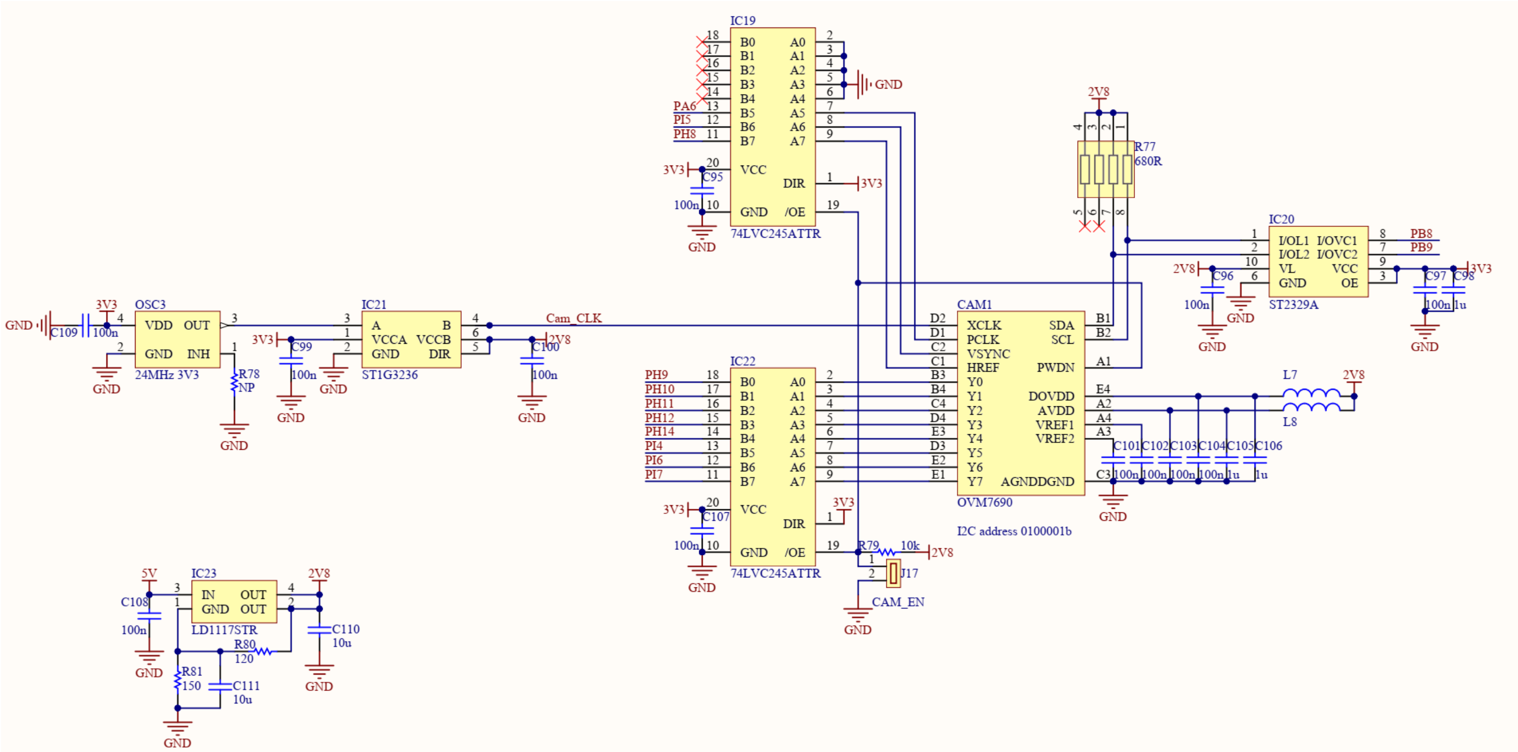
Memory



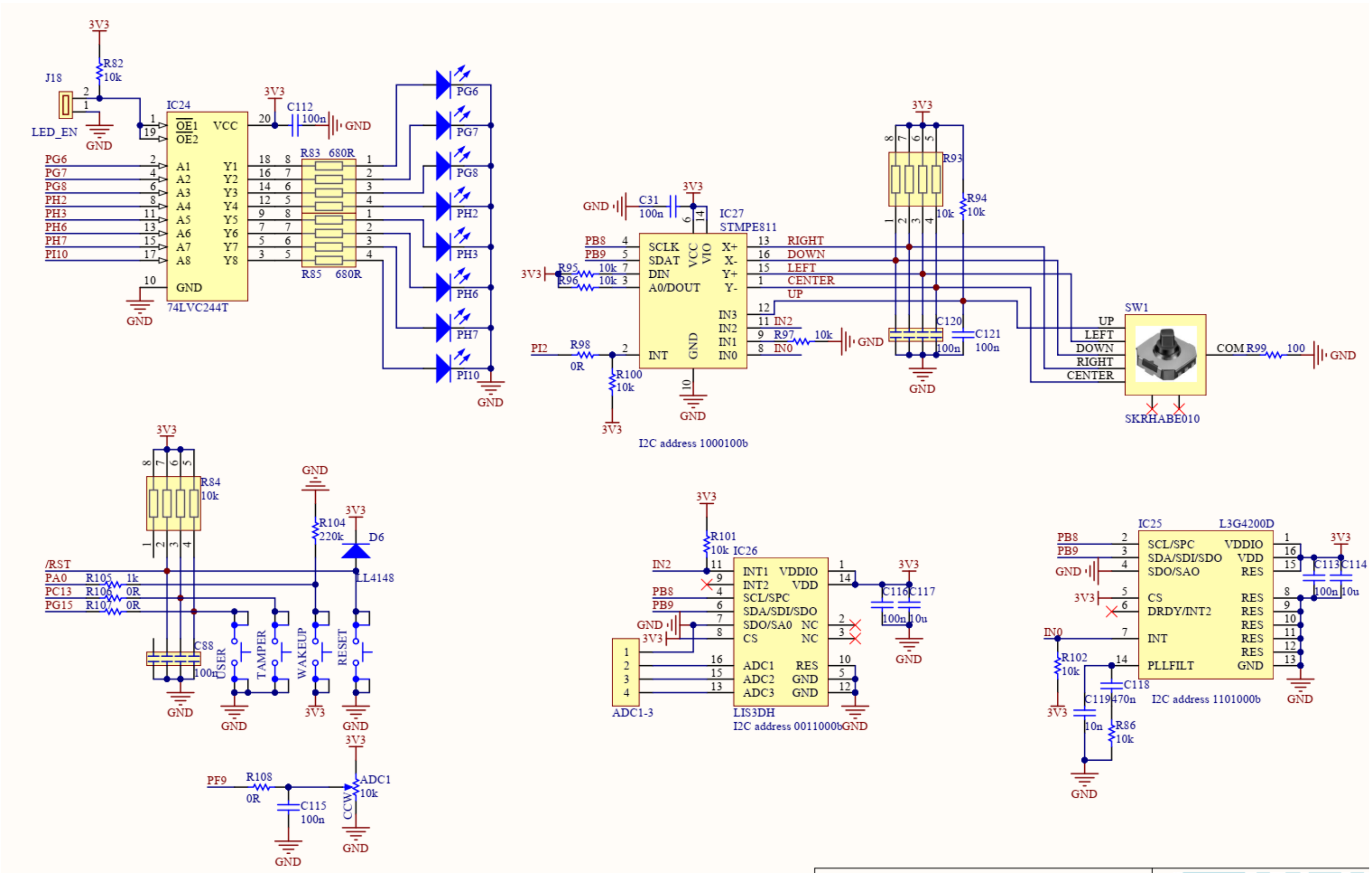
Ethernet



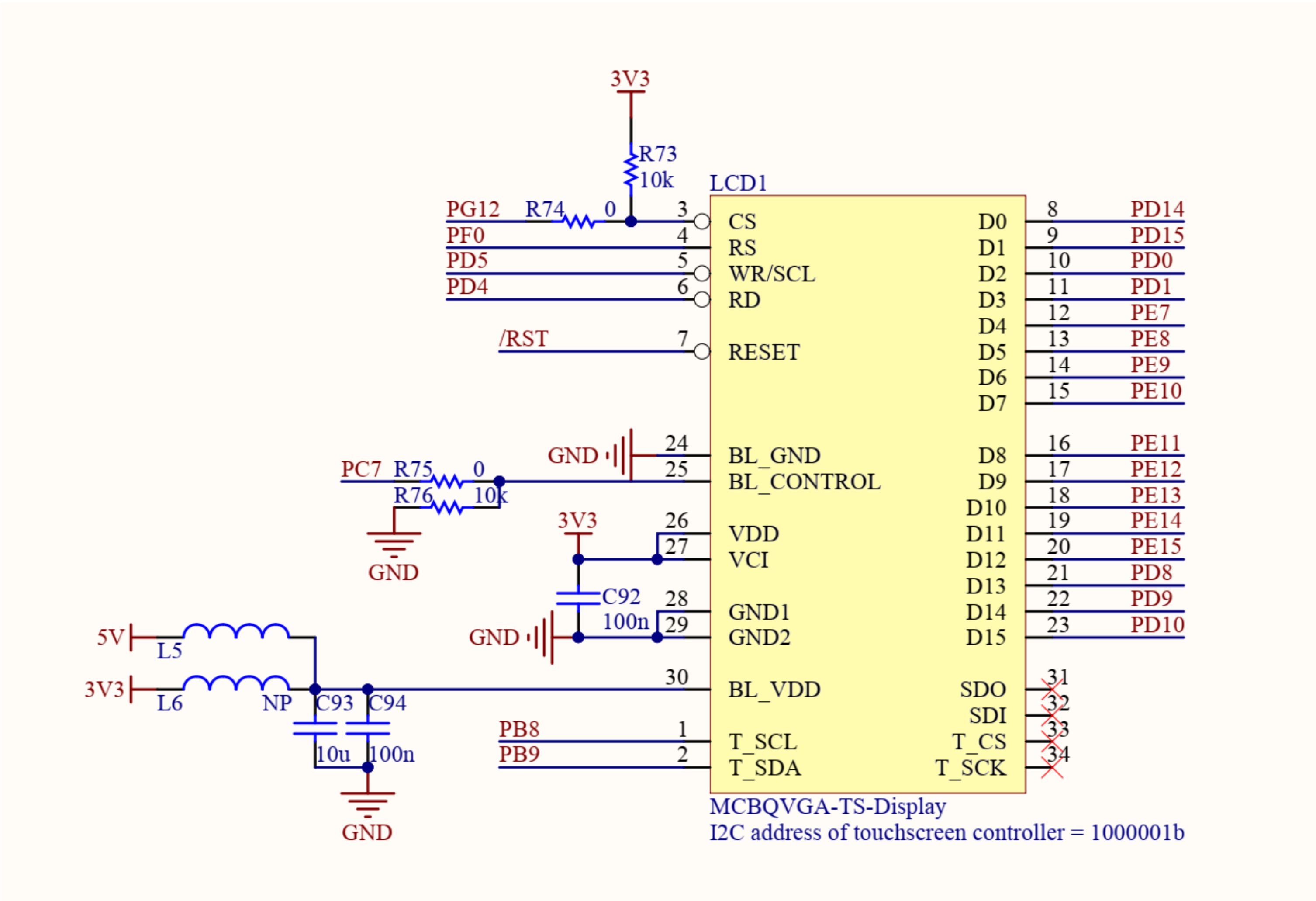
Camera



LED Switch-TEMP

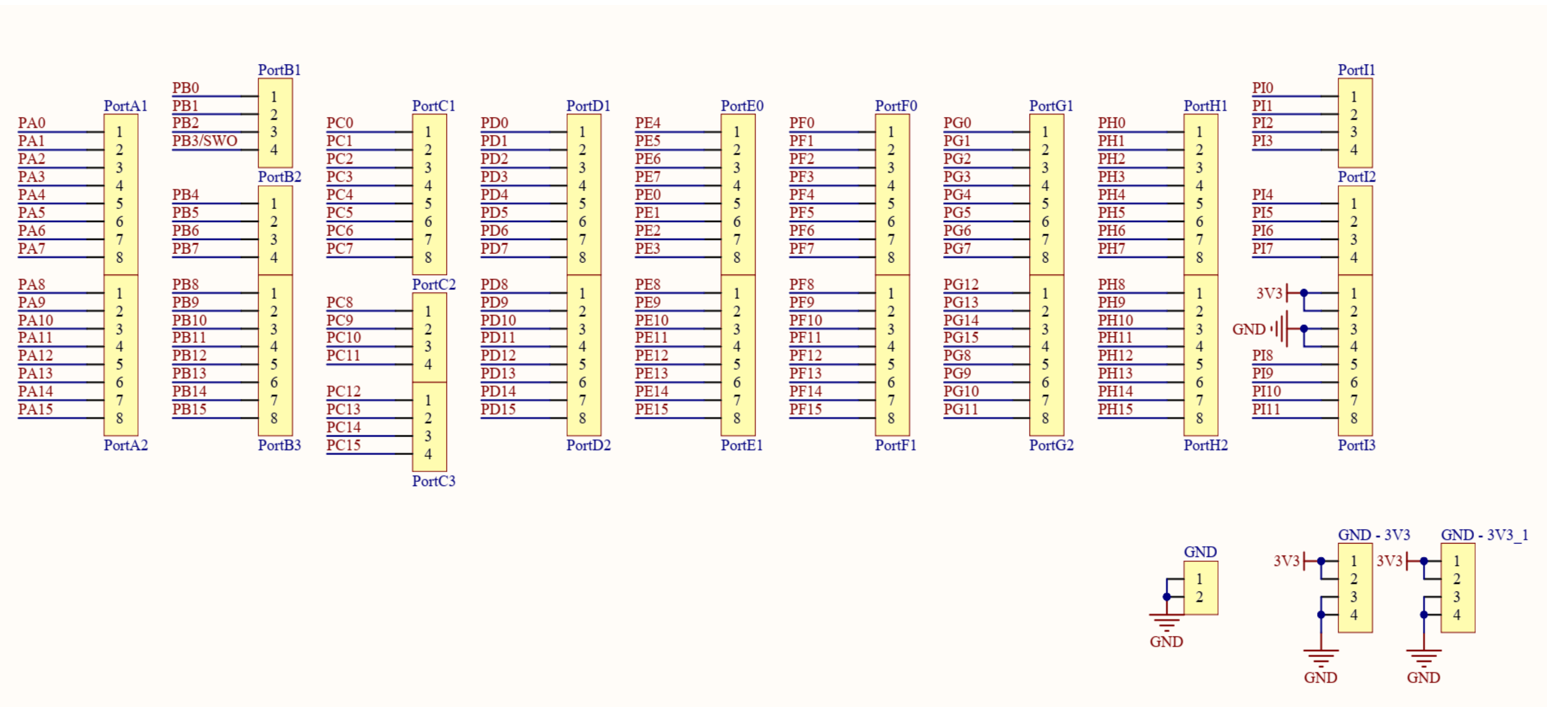


LCD



3V3
R73
10k
LCD1
PG12
R74
0
PF0
PD5
PD4
/RST
CS
RS
WR/SCL
RD
RESET
D0
D1
D2
D3
D4
D5
D6
D7
PD14
PD15
PD0
PD1
PE7
PE8
PE9
PE10
GND
PC7
R75
R76
10k
BL_GND
BL_CONTROL
D8
D9
D10
D11
D12
D13
D14
D15
PE11
PE12
PE13
PE14
PE15
PD8
PD9
PD10
3V3
VDD
VCI
C92
100n
GND1
GND2
5V
L5
3V3
L6
NP
C93
C94
10u
100n
BL_VDD
SDO
SDI
T_CS
T_SCK
PB8
PB9
T_SCL
T_SDA
MCBQVGA-TS-Display
I2C address of touchscreen controller = 1000001b

Headers



PortA1
PortA2
PortB1
PortB2
PortB3
PortC1
PortC2
PortC3
PortD1
PortD2
PortE0
PortE1
PortF0
PortF1
PortG1
PortG2
PortH1
PortH2
PortI1
PortI2
PortI3
PB3/SWO
GND - 3V3
GND - 3V3_1

Segger J-Link Edu Adapter

The J-lINK debug adapter connects PC’s USB port to the JTAG or Cortex™ Debug connector on the target board allowing to download and analyze embedded programs running on target hardware.

Keil MDK-ARM™ (Microcontroller Development Kit)

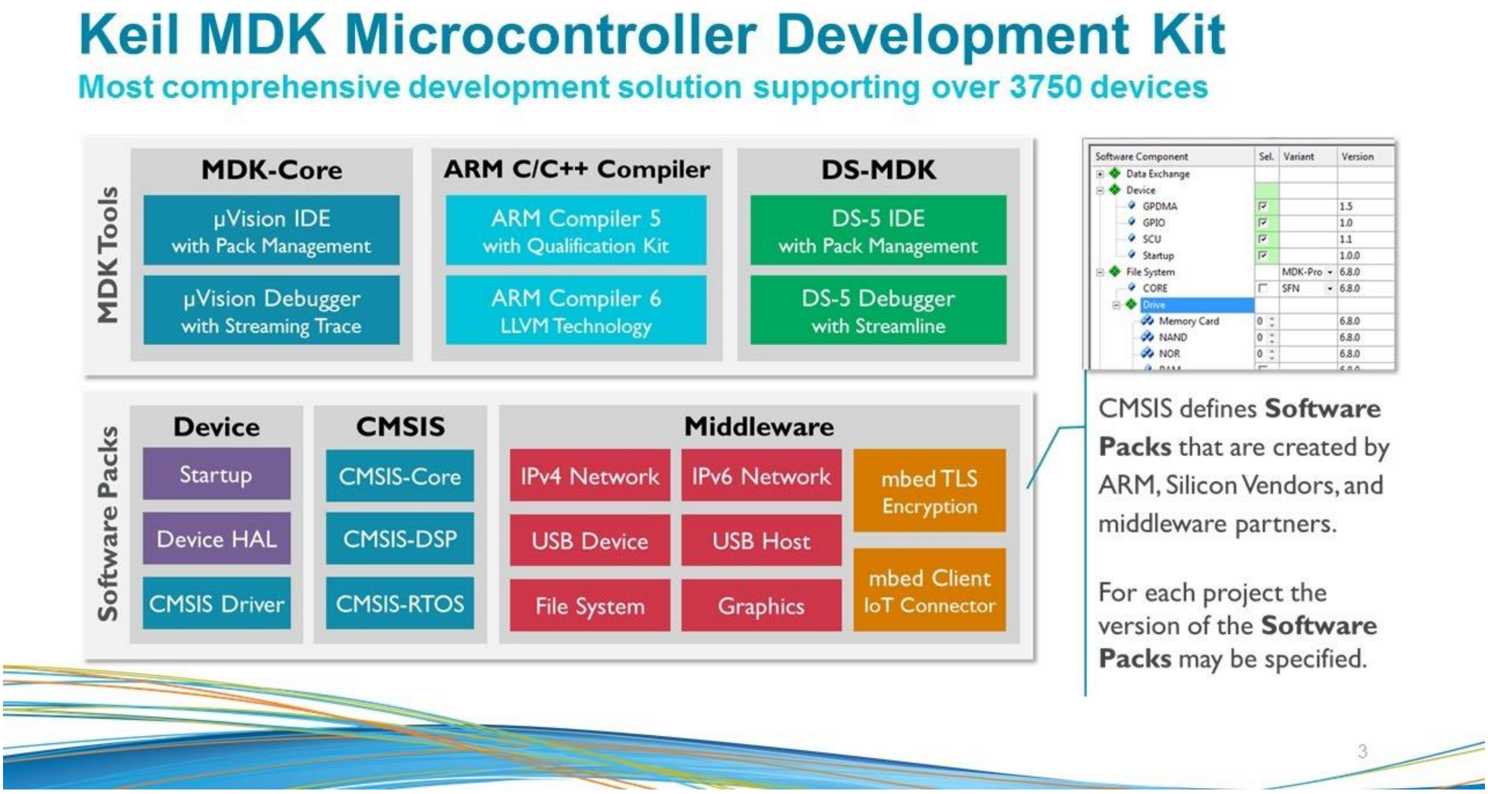
Keil MDK-ARM™ is the complete software development environment for a wide range of ARM Cortex-M based microcontroller devices. MDK includes the µVision® IDE and debugger, ARM C/C++ compiler, and essential middleware components..

The µVision® IDE combines project management, run-time environment, build facilities, source code editing, and program debugging in a single powerful environment.

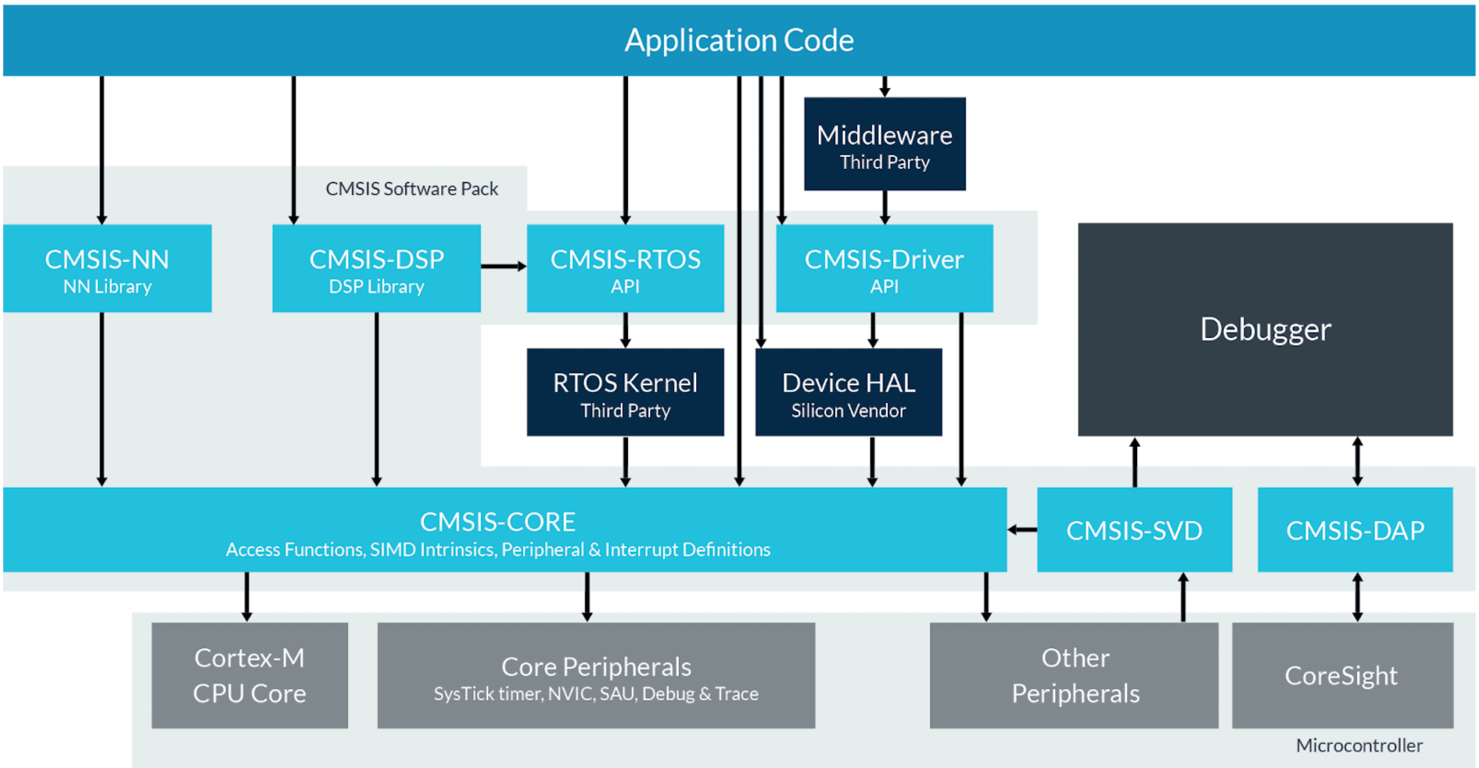
The µVision® debugger provides a single environment used to test, verify and optimize application code.

It provides a single environment in which the application code may be tested, verified, and optimized.

Overview of the Keil MDK- ARM™



CMSIS (Cortex Microcontroller Software Interface Standard)

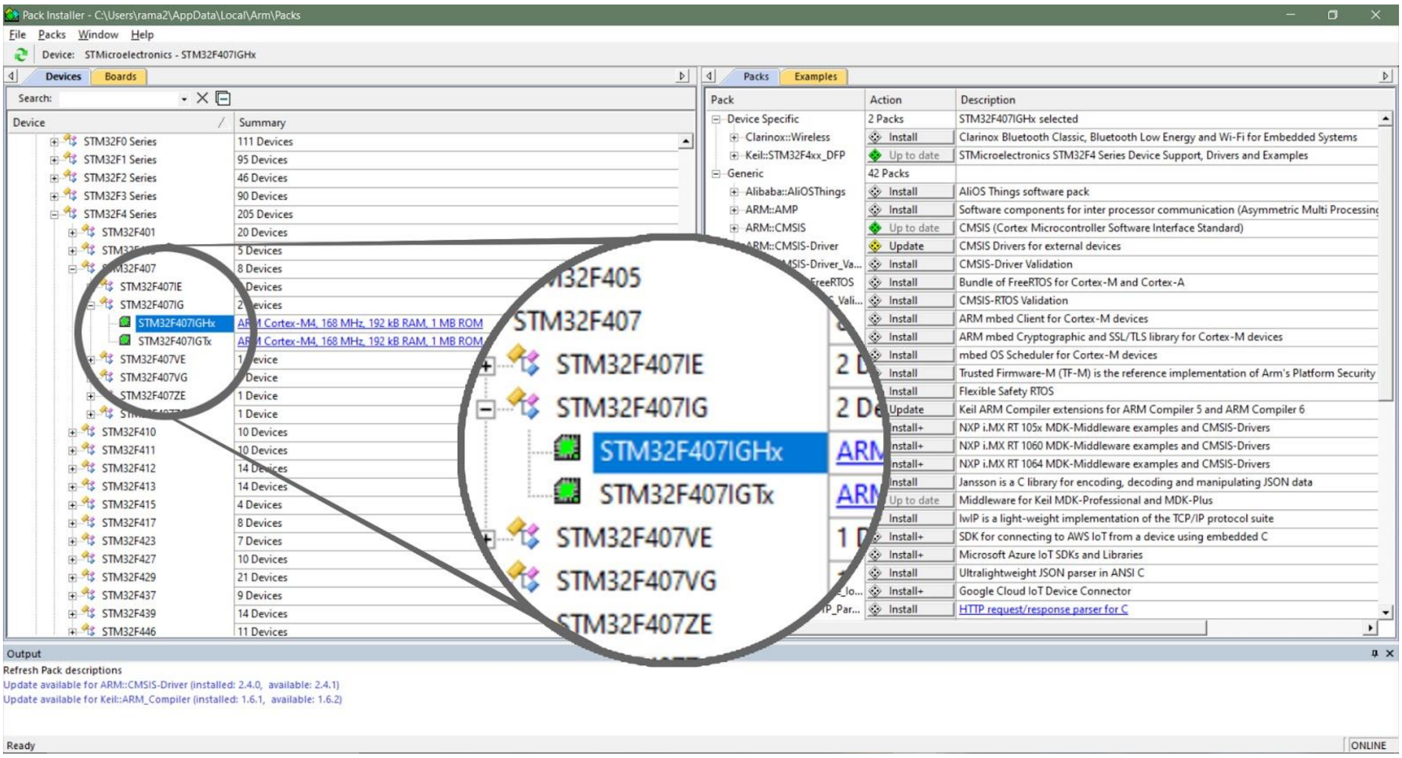


The Cortex Microcontroller Software Interface Standard (CMSIS) provides a ground-up software framework for embedded applications that run on Cortex-M based microcontrollers. CMSIS enables consistent and simple software interfaces to the processor and the peripherals, simplifying software reuse, reducing the learning curve for microcontroller developers.

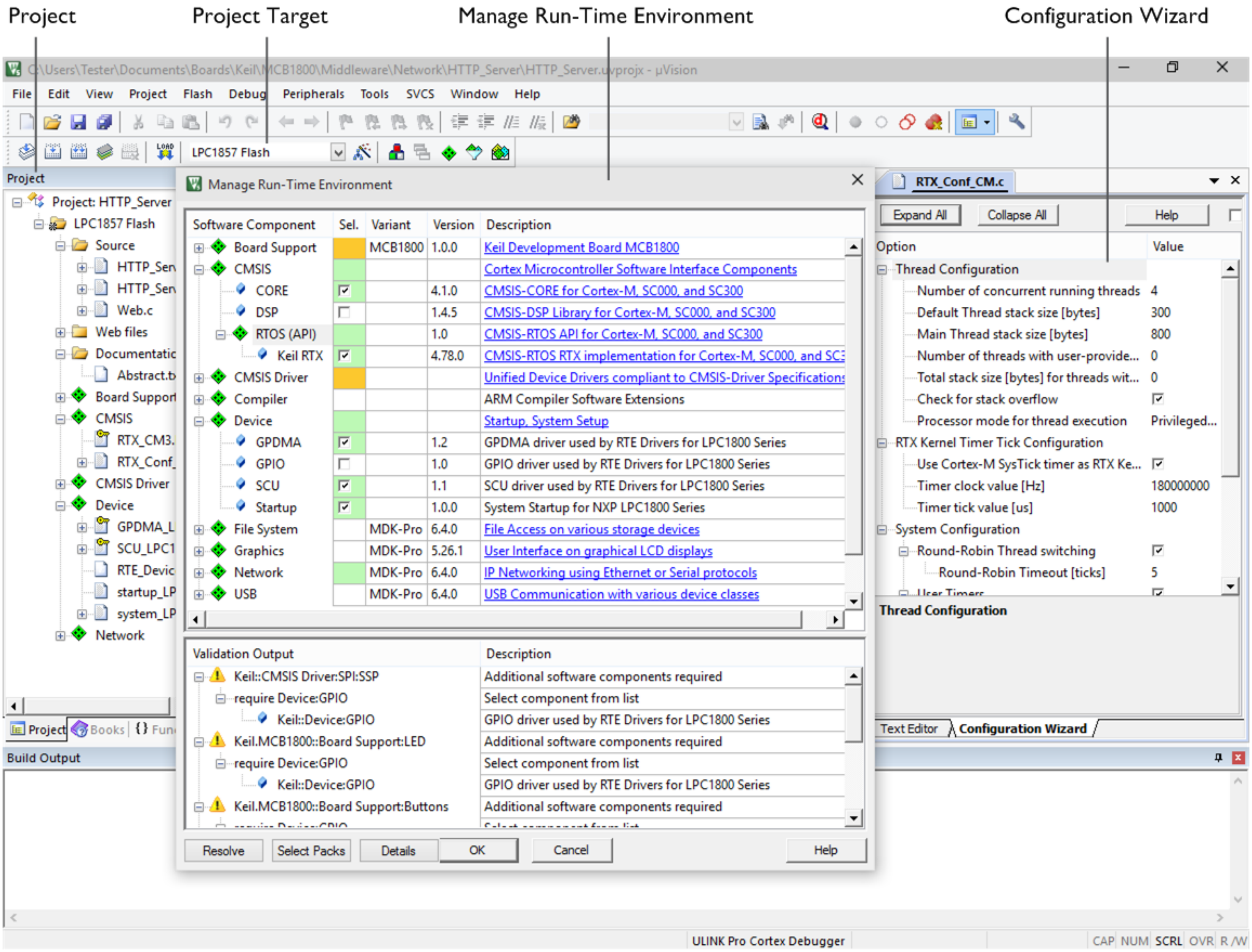
CMSIS-CORE: Defines the API for the Cortex-M processor core and peripherals and includes a consistent system startup code. The software components **::CMSIS:CORE** and **::Device:Startup** are all that is needed to create and run applications on the native processor that uses exceptions, interrupts, and device peripherals.

CMSIS-RTOS2: Provides a standardized real-time operating system API and enables software templates, middleware, libraries, and other components that can work across supported RTOS systems.

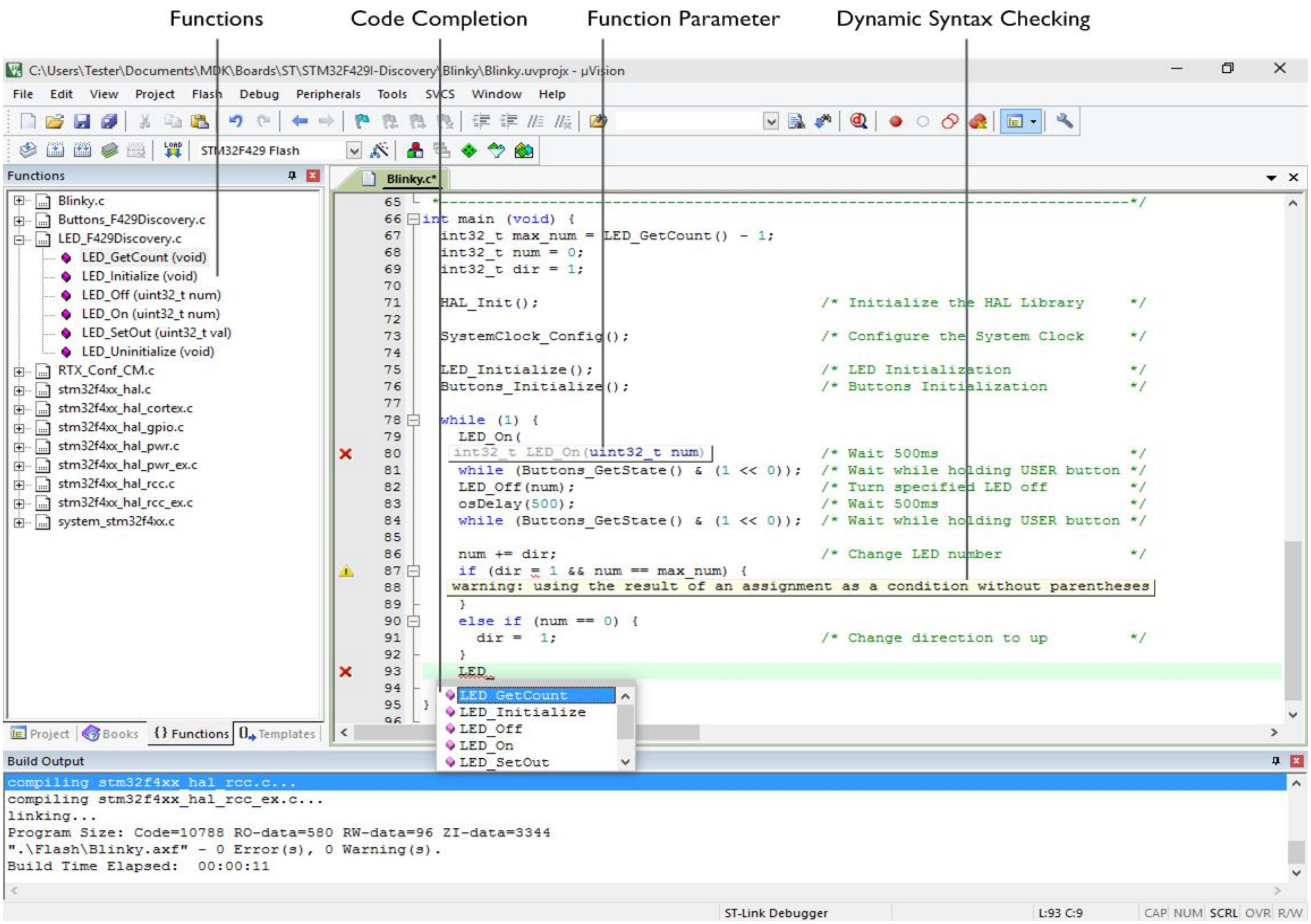
µVision® IDE (Installation of Board Drivers)



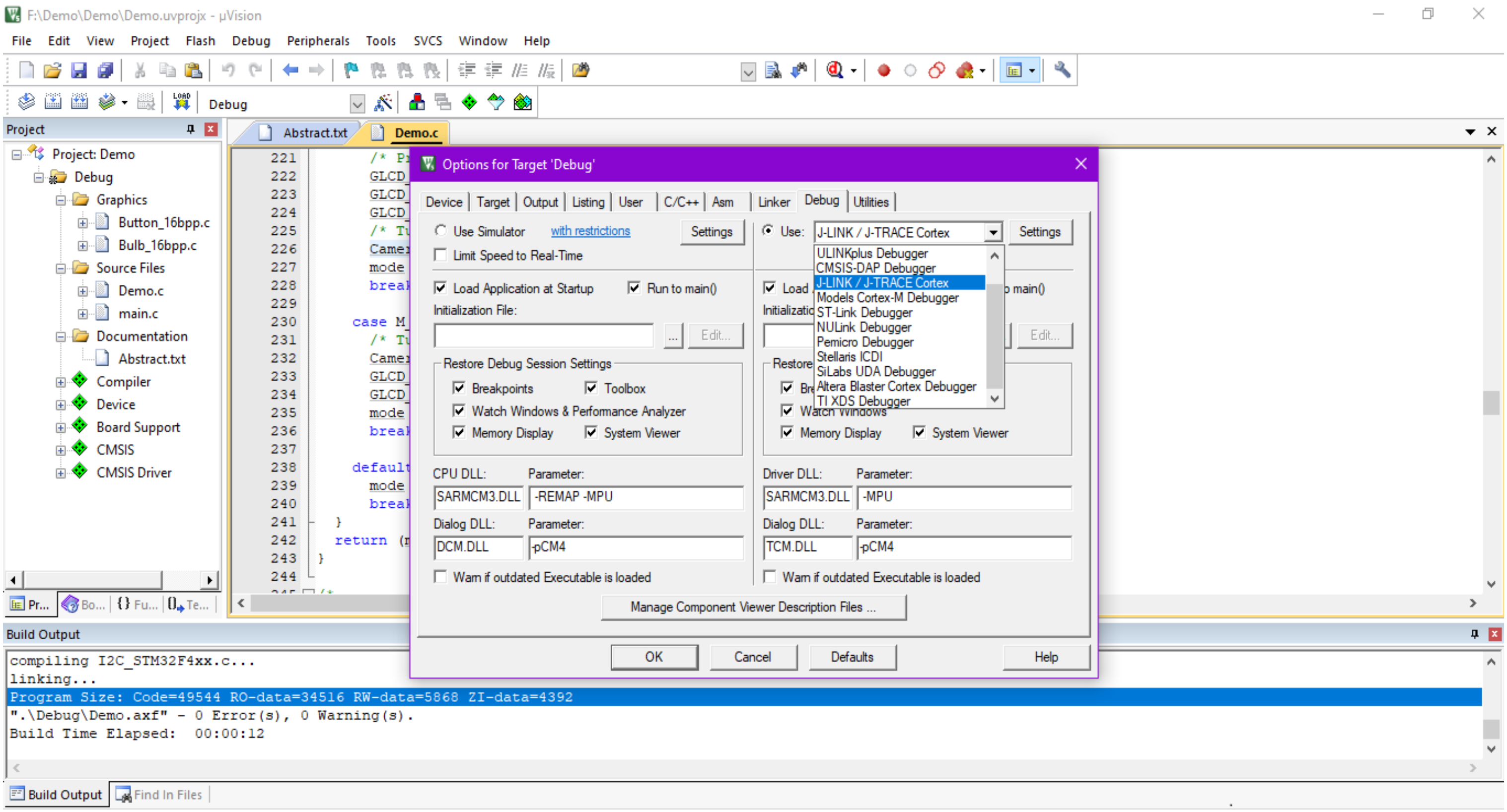
µVision® IDE (Creation of Project)



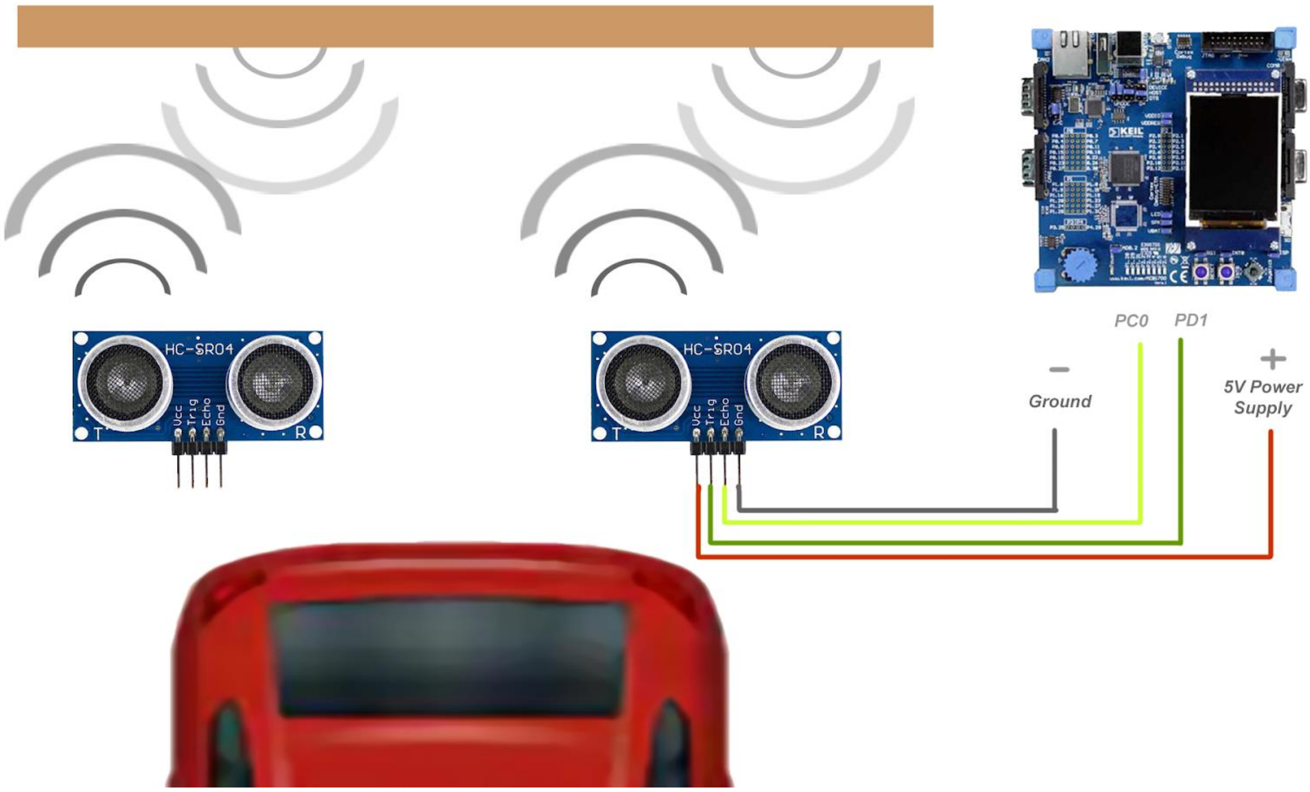
µVision® IDE



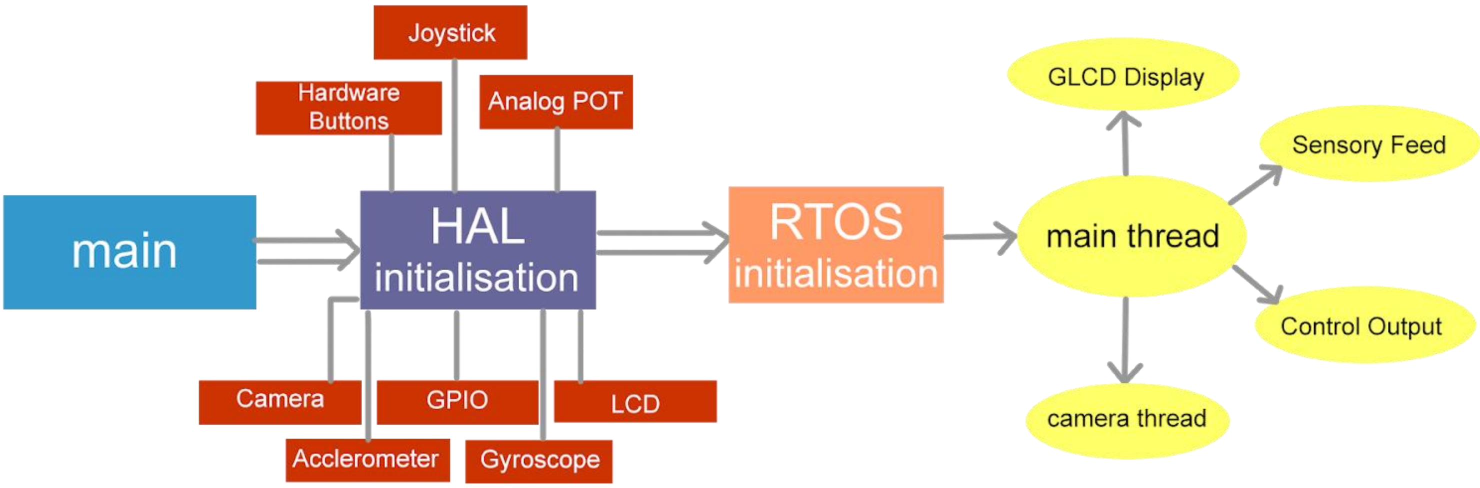
µVision® IDE (Selection of Target Debugger)



Abstract : Intelligent Self Parking System



Block Diagram of Operation



Communicating with the Hardware

In order to communicate with the hardware several library functions were used to access the hardware's functionalities. For different hardware components there are several interfaces available like , LED interface , Buttons interface, Joystick interface, Graphic LCD interface, Gyroscope interface, Accelerometer interface, Touchscreen interface and Camera interface, GPIO (General Purpose I/O) interface etc. .

Challenges

- Lack of information in documentation
- Complexity of hardware level details
- Too many boards, thus very few get widely used and supported. Resulting in very small support community.
- Not a great IDE (Browsing through dependencies in KEIL IDE is mostly manual and cumbersome). No support for external IDEs like Eclipse or Visual Studio.
- Difficult to learn for beginners. It is much easier to work and develop with Arduino or Raspberry Pi for such applications at lower cost.

Conclusion

- Till now we have learnt how to interact with the µVision® IDE and the Microcontroller Development Kit as well as how to use various libraries to interact with the hardware drivers. It provided us several interfaces to interact with the hardware components and use real time data and interaction with the physical world to perform various tasks. This microcontroller can thus be used as an intelligent embedded system and included as a part of our daily lives.

Future Scopes

- Building the sensor system and attaching it to the back of a car.
- Controlling the driving mechanism of the car using the microcontroller by building the logic on data we gather (distance data from 2 sensors) and providing camera feedback to user.
- Incorporating sensor data from accelerometer and gyroscope to achieve fine tune car control.
- Providing system for sending emergency signal in case of accidents. (Rapid deceleration observed by accelerometer in the direction on car head).

References

- Getting started with MDK Create applications with µVision® for ARM® Cortex®-M microcontrollers
- Udemy Embedded Systems Programming on ARM Cortex-M3M4 Processor
- STM32F400 Datasheet from www.st.com