

August 21 (Monday)

Organizational Meeting.

1. The "GreenSheet" is posted on the github

Note: Bring your Laptop Computer to the Class.

<https://github.com/hualili/CMPE244>

## Course and Contact Information

Instructor:	Harry Li, Ph.D. Professor, Computer Engineering Dept., San Jose State University
Office Location:	Engineering Building 267A
Telephone:	(408) 924-4060 (650) 400-1116
Email:	hua.li@sjtu.edu
Class Days/Time:	Mondays and Wednesdays, 4:30 pm – 5:45 pm, August 21, 2023
Office Hours:	Mondays and Wednesdays, 3:00 pm – 4:00 pm
Classroom:	Engineering Building Room 295
Prerequisites:	CMPE 180A and CMPE 180D, classified standing, computer science majors or Artificial Intelligence or Computer Engineering or Software Engineering majors only.

2. Emphasis on Posix O.S. Linux OpenSource O.S. & Device Drivers Programming and Development. Scalability & Vertical Solution.

## Course Description

Experiments dealing with advanced embedded software programming concepts, interfacing techniques, hardware organization, and software development using embedded systems. Individual projects.

3. Course Format: In-Person.

Hands-on Class. Prototype System

Optional. NVIDIA Jetson Nano. GPU (128)

4 GB Version      CPU      JetPack

Option 2. Broadcom Piex3B+, Piex4.

Option 3. RISC-V FPGA Dev. Board + FreeRTOS

Selection Decision in 1 week

Option 4. NXP LPC11G24 or

LPC1768, RTOS. NXP

Dev. Forum.

has limited Processing Power.

May Not Meet the Need for Our Project

#### 4. Textbook & References

Set I: Datasheets(s), CPU Datasheet, Developer Guide; Set II: NVIDIA Developer Forum. Set III: PPTs, Sample Code, Handouts in the Class GitHub.

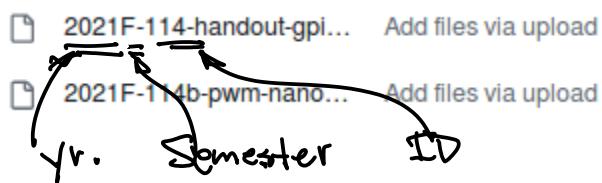
#### Course Materials

Instructor's teaching materials and online resources.

1. Professor's git: <https://github.com/hualili/CMPE244>
2. Jetson NANO Jetpack download <https://developer.nvidia.com/embedded/downloads>

#### Other Equipment / Material

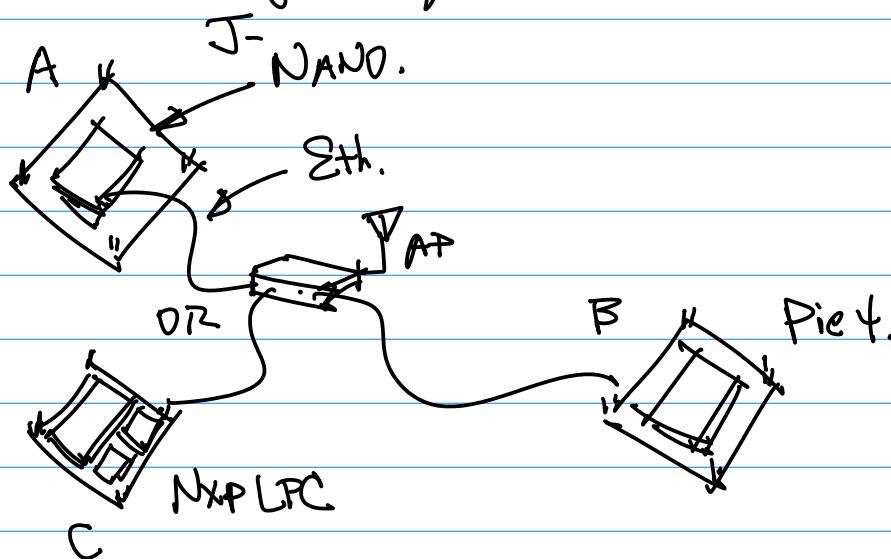
1. Hardware Equipment: You may choose any one of the following options. For detailed selection information, I will cover it in the introduction session of the class. Option 1. Nvidia Jetson NANO Board with minimum 2 GB RAM; or Option 2. Pi 3B+, or Pi 4; Option 3: Nvidia Jetson Tx2 developer kit; or Option 4: LPC1769 CPU Module: [https://www.mouser.com/NXP-Semiconductors/Embedded-Solutions/Engineering-Tools/Embedded-Processor-Development-Kits/Development-Boards-Kits-ARM/\\_/N-cxd2t2P=1z0jm4m&Keyword=LPC1769&FS=True&gclid=Cj0KCQjwqKuKBhCRAIIsACf4XuHyN8WfqtQ24WGgt0MdKd6n-k17c-YNz-r1hTcPt0ErdZN62jrM0mgaAtXZEALw\\_wcB](https://www.mouser.com/NXP-Semiconductors/Embedded-Solutions/Engineering-Tools/Embedded-Processor-Development-Kits/Development-Boards-Kits-ARM/_/N-cxd2t2P=1z0jm4m&Keyword=LPC1769&FS=True&gclid=Cj0KCQjwqKuKBhCRAIIsACf4XuHyN8WfqtQ24WGgt0MdKd6n-k17c-YNz-r1hTcPt0ErdZN62jrM0mgaAtXZEALw_wcB) or Option 5: Samsung ARM11 developer platform.
2. Linux Host Machine (Ubuntu 18.04).



Naming Convention:

A & B  
A & C

Note: Regarding the Selection of  
A Target Platform:



## 5. Grading Policy

Project Assignment (Two Projects)	
Phased	
15% (pts) for the assigned projects.	
15% for the Semester Long Project	
Assignments and projects:	30%
Midterm Exam:	30%
Final Exam:	40%
Total:	100%

August 23rd (Wed)

Introduction

Note: Rm268

Ref:

Datasheets.



bcm



lpc



nvda



sam

Broadcom

Pi e

Linux O.S.

NXP

LPC1769

RTOS

IP Stack

Micro Web Server

Jetson

NAND.

JetPack O.S.

Linux (Ubuntu)

+ Additional  
Packages.

Samsung

ARM11

2021F-107-lpc-cpu-  
UM10360.pdf

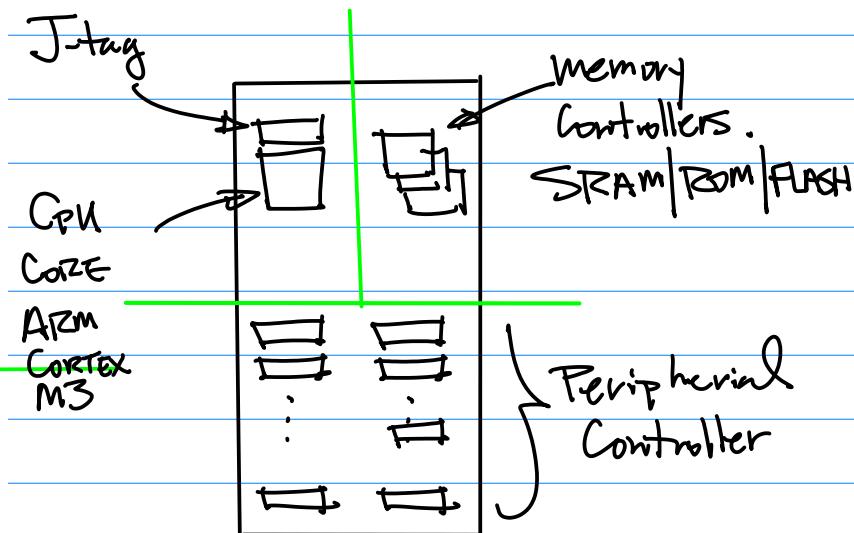
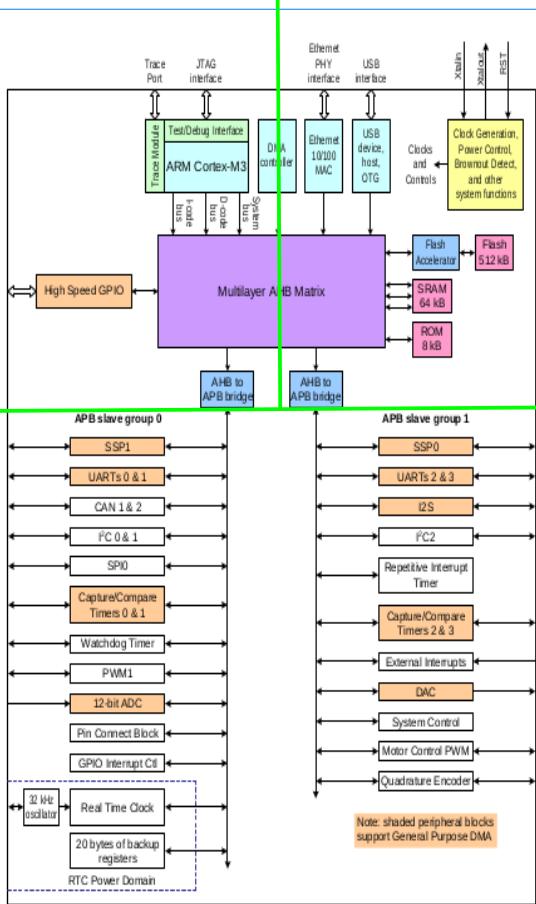
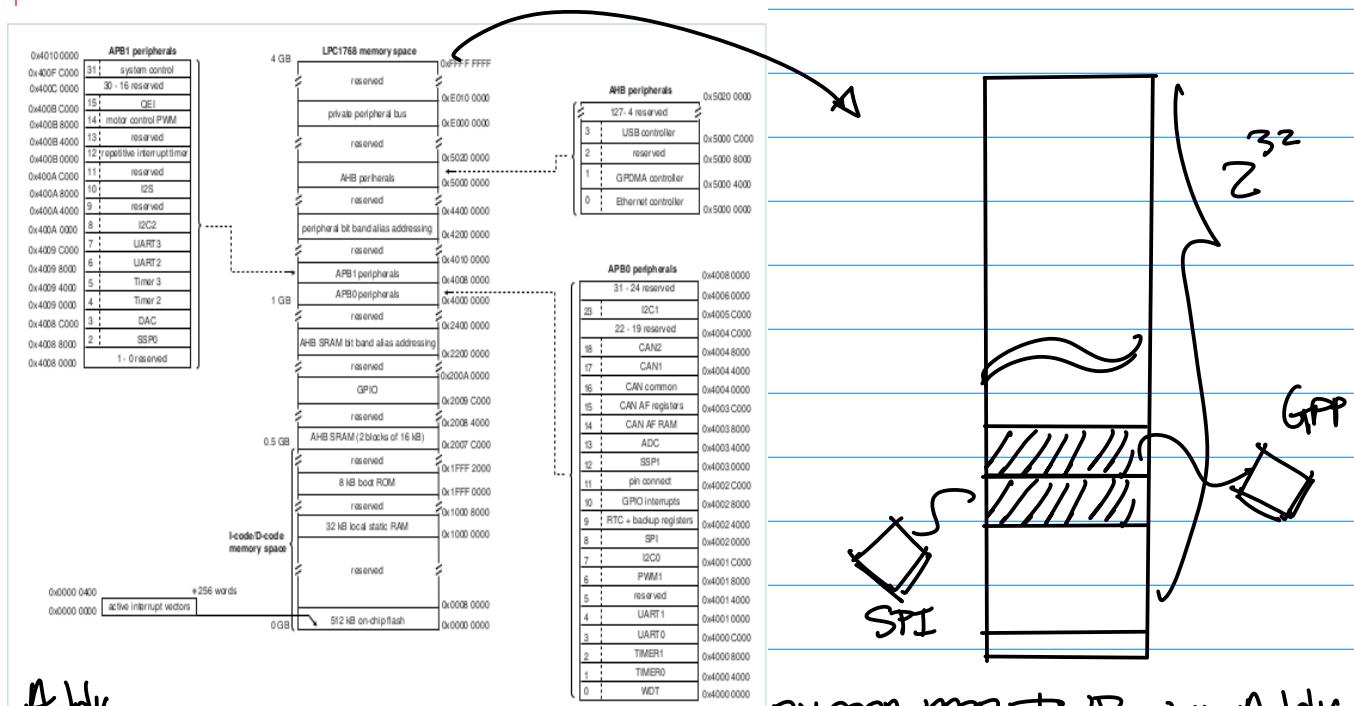


Fig. 1

Note: The CPU Block Diagram for LPC1769 is a Sample for the Rest of the target platforms.

e.g. Pic34 ; Sam's ARM 11 ;  
NVIDIA Jetson NANO

Note 2 :



Addrs.

$$\begin{aligned} Z^{32} &= Z^0 \cdot Z^1 \cdot Z^2 \cdot Z^3 \\ 1024 &: : : 4 \\ 1K &: : : \\ 1\text{ meg.} &: : : \\ 1\text{ G.} &: : : \end{aligned}$$

4 G Addresses.

Example: "B", Sam's CPU  
ARM11

Fig. 2

0x0000-0000 - PWR-up Addr.

Datasheets.

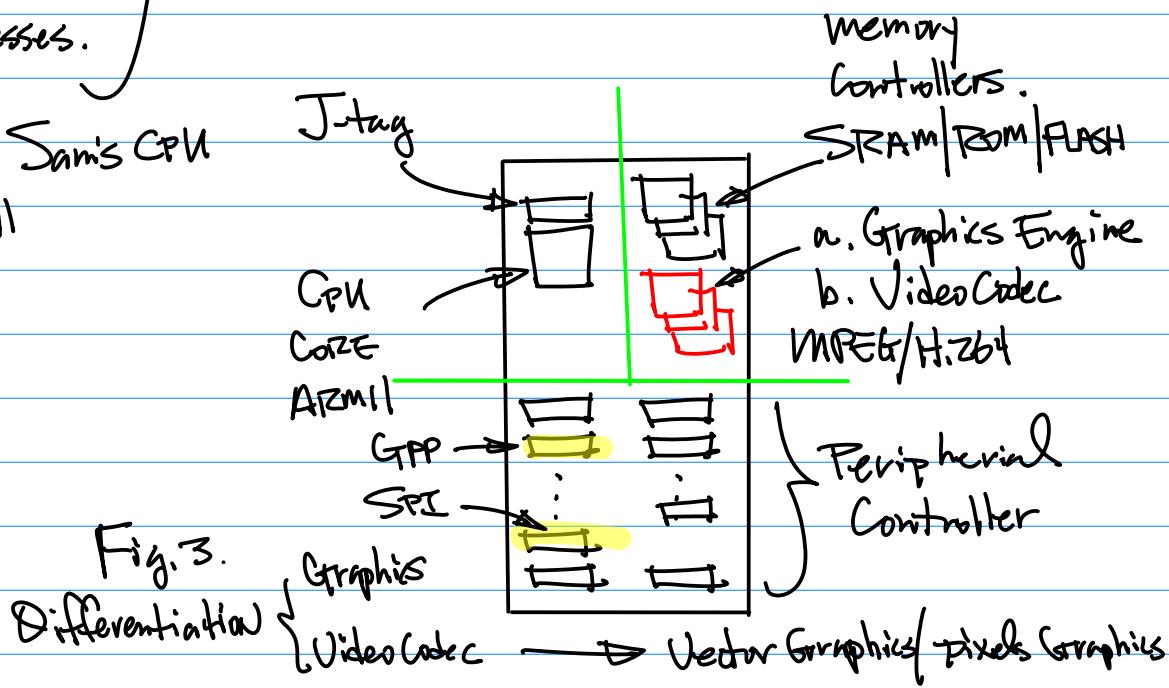
2021F-105-#0-cpu-arm11-  
2018S-29-CPU\_S3C6410X.  
pdfLocate the page with the top level  
Description of the CPU Architecture

Fig. 3.

Differentiation

Example: Connection to (Embedded) Software Architecture

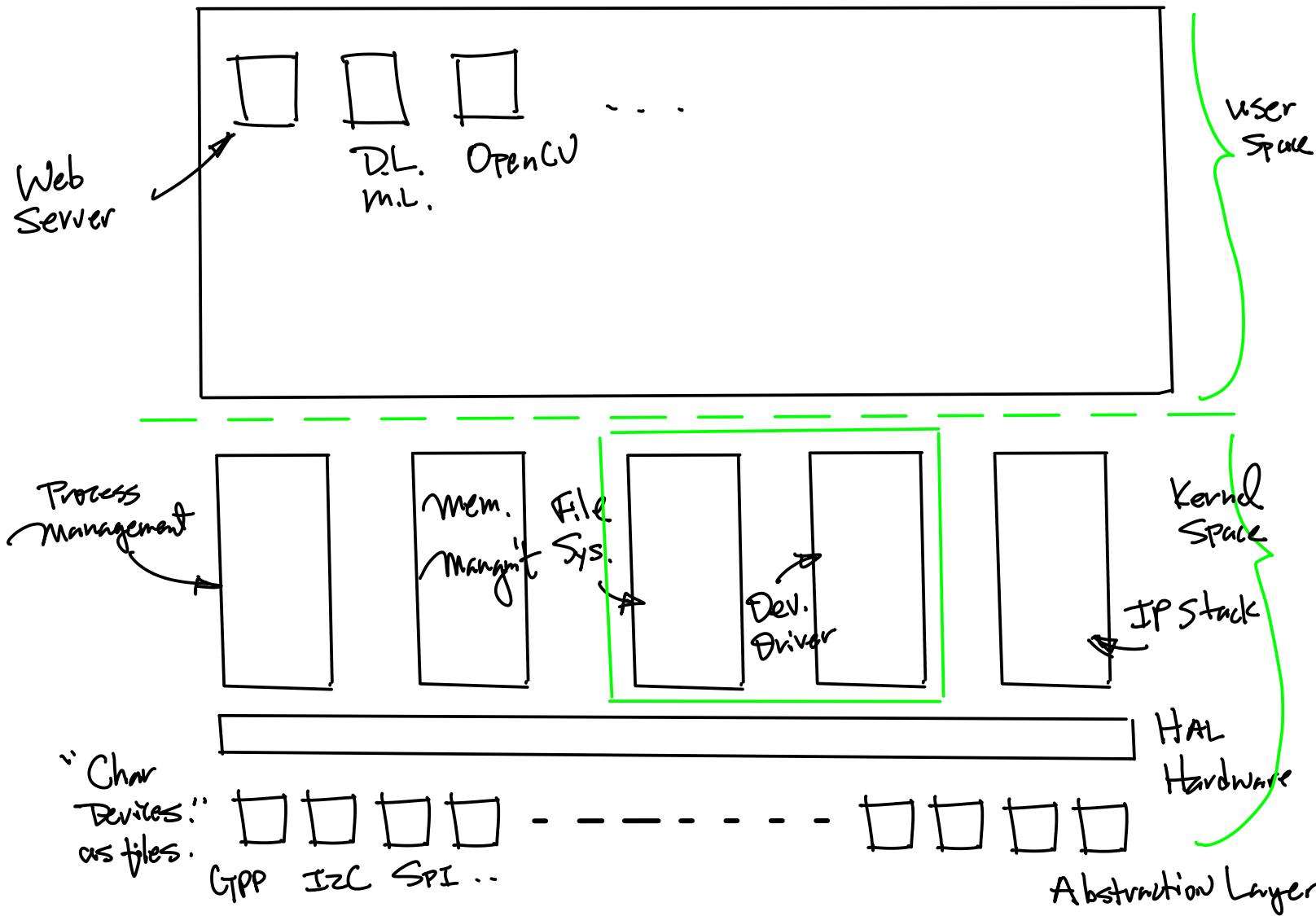


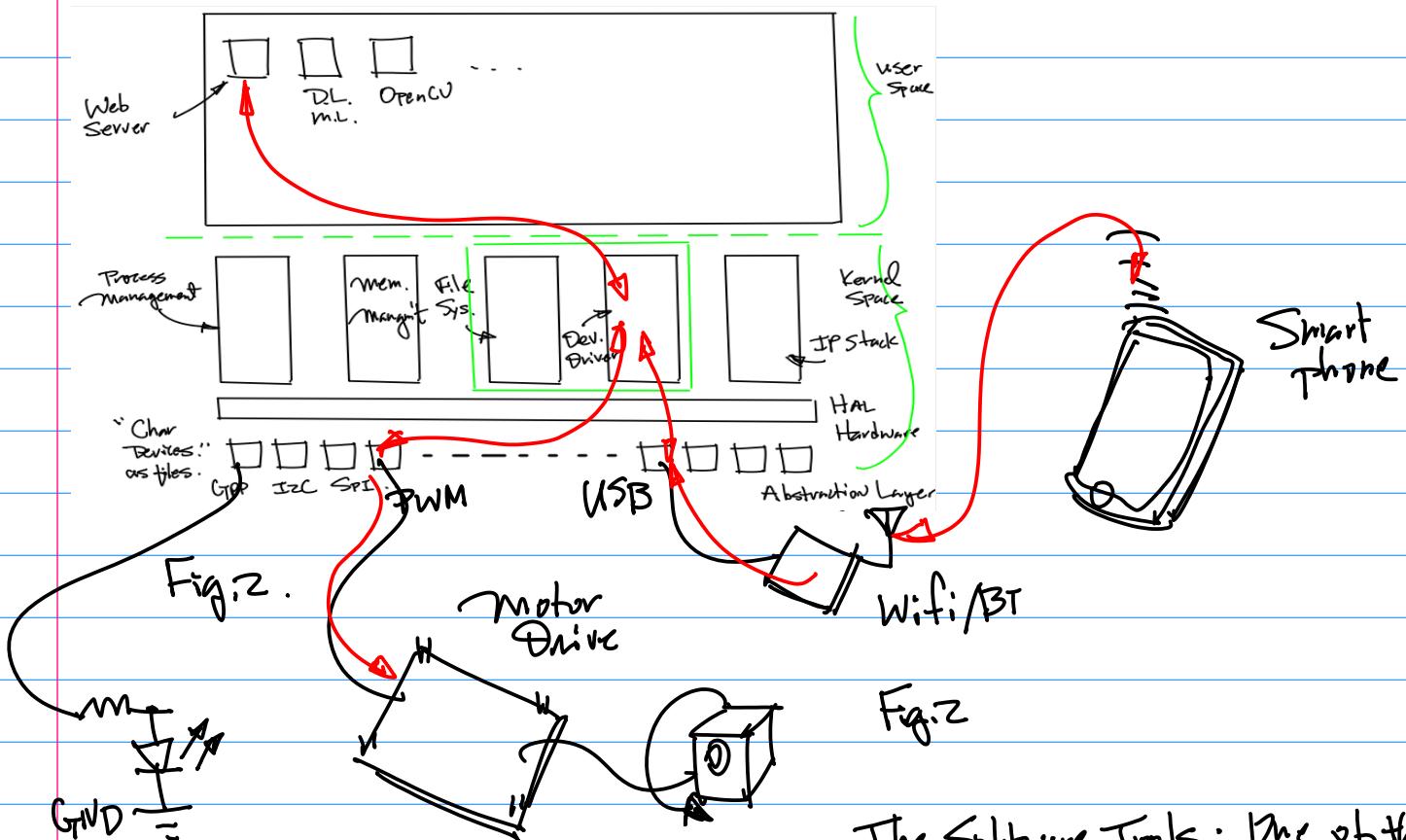
Fig.1.

Note: Data Size for 1080P  
Image OR 720P

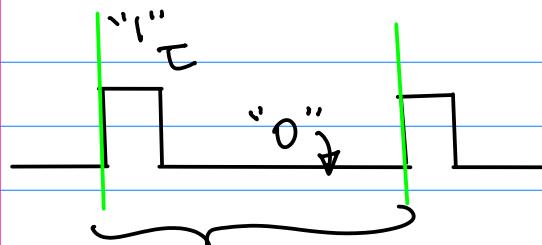
August 28 (Monday)  
Note: 1<sup>o</sup> Brief Description D.V.  
the Scope of Semester-Long  
Project.

- Embedded Software; Kernel D.S.
- Device Driver → APPS for iPhone/Android phone
- 2<sup>o</sup> CANVAS is up.
- Honesty pledge
- 3<sup>o</sup> Target platform → Minor upgrade to Enable RTC by Adding On-Board Battery

Example: Continuation of the  
Introduction/Embedded Software Architecture.



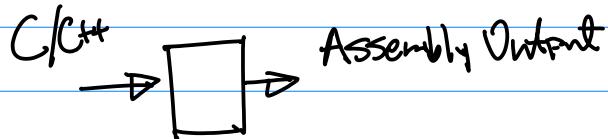
Note: PWM — Pulsewidth Modulation.



$T$  One Period

$$\left\{ \begin{array}{l} \text{Duty Cycle} = \frac{T}{f_{\text{PWM}}} \dots (1) \\ f_{\text{PWM}} \dots (2) \end{array} \right.$$

The Software Tools: One of them  
is open source gcc, or g++  
Compiler.



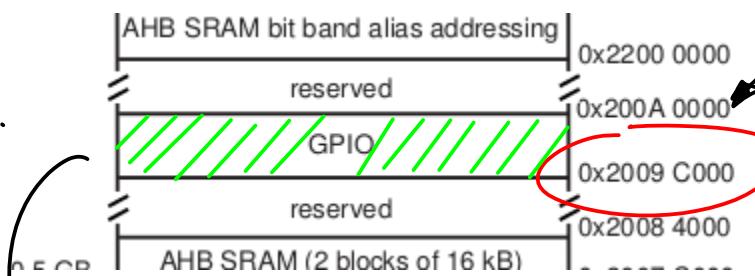
Porting. → Match to the Core  
(ISA: Instruction Set Architecture)  
Device Drivers Customization.

✓ Peripheral Controller  
A Set of Special Purpose Registers.

Most Likely this SPR has  
the paddr in the Block.

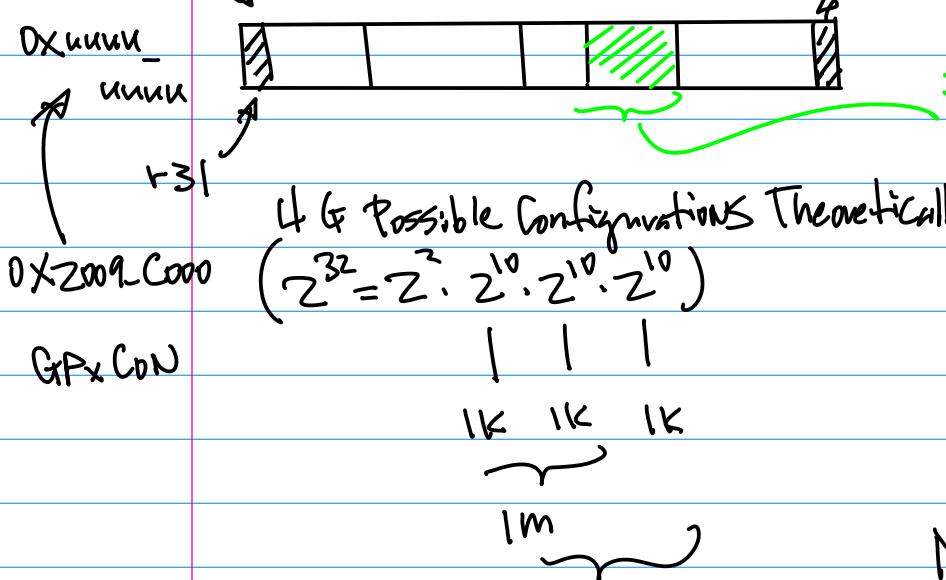
Identify A peripheral controller, GPP

Fig. 3.



→ Memory is designated for  
SPR's (Special Purpose Registers)

## Control & Configuration Register



It has its unique address. (at the multiple of 4).

Write 32 bits unsigned Data as Init & Config pattern to Select the GPP & the pin as output.

## Next. Naming Convention.

August 30 (Wed)

Note: 1<sup>o</sup> CANVAS is up.

Honesty Pledge to Be Signed  
And Submit on CANVAS  
By this Friday 11:59 pm.

2<sup>o</sup> Please Bring the target platform to the Class. Next Wednesday.

3<sup>o</sup> (Written Requirements) <sup>in 2 weeks</sup>

Bring up your target platform  
By Downloading Kernel OS.

Image to A micro-SD Card,  
then boot the System.

then Screen Capture with your personal identifier, Submit it on CANVAS.

4<sup>o</sup> Create A ChatGPT Account, Python interface to ChatGPT (3.5) API.

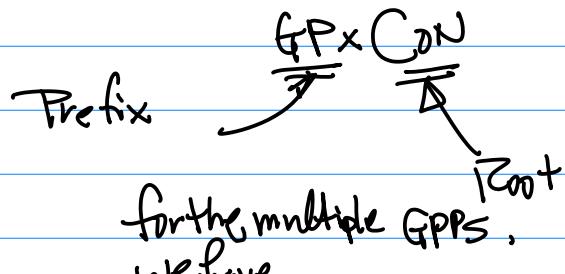
Example: Continued.

Naming Convention of the Control & Configuration Register.

By John Hennessy . Golden Rules

Uniformity, "3+3"  
Regularity,  
Orthogonality Naming Convention

Prefix + Root  
3 letters 3 letters.

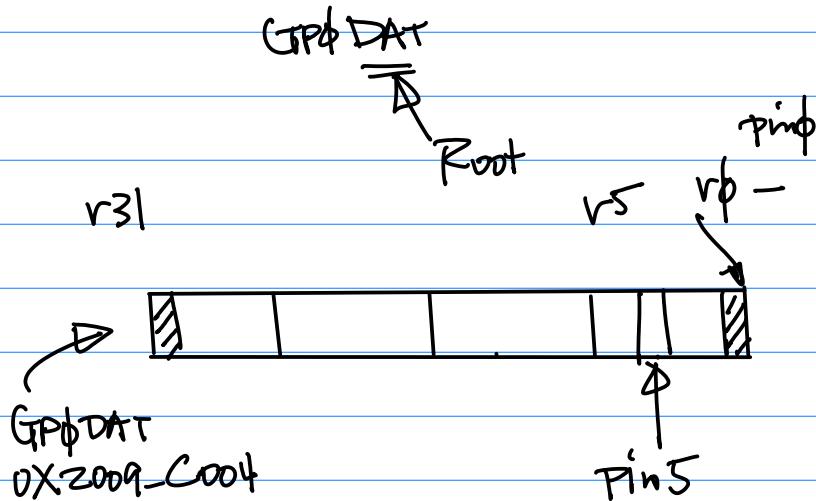


for the multiple GPPS,  
we have

GPPCON, GPICON, etc.

Suppose we want to use GP0 pin 5 as an output to turn on/off LED.

Design 2nd SPR.



place "1" @ r5 to Output logical high.  
"0" ..  
Low.

#define GP0CON  
GP0DAT ..

Porting Porting  
gcc/g++ → ARM → CORTEX

Porting ↓  
Board

Sept 6 (Wed).

Note: 1° Target Board  
Inspection:

Purpose: J41 Connector

RTC Battery      2021F-114~  
Ref: on the github.

Harry Li, Ph.D.

2021F-114-gpio-nano-v2-h1-2021-10-20.pdf

160.87% □

## NVIDIA Jetson Nano J41 Header Pinout

<https://www.jetsonhacks.com/nvidia-jetson-nano-j41-header-pinout/>

Note: I2C and UART pins are connected to hardware and should not be reassigned. By default, all other pins (except power) are assigned as GPIO. Pins labeled with other functions are recommended functions if using a different device tree.

1. take Pin 1 Vcc (3.3V) and Pin 39 GND to test out LED, make sure you can light up a LED with 220 Ohm resistor in series.

Sysfs GPIO	Name	Pin	Pin	Name	Sysfs GPIO
	3.3 VDC Power	1	2	5.0 VDC Power	
	I2C_2_SDA I2C Bus 1	3	4	5.0 VDC Power	
	I2C_2_SCL I2C Bus 1	5		GND	
gpio216	AUDIO_MCLK	7	8	UART_2_TX /dev/ttyTHS1	
	GND	9	10	UART_2_RX /dev/ttyTHS2	
gpio50	UART_2_RTS	11	12	I2S_4_SCLK	gpio79
gpio14	SPI_2_SCK	13	14	GND	
gpio194	LCD_TE	15	16	SPI_2_CS1	gpio232
	3.3 VDC Power	17	18	SPI_2_CS0	gpio15
gpio16	SPI_1_MOSI	19	20	GND	
gpio17	SPI_1_MISO	21	22	SPI_2_MISO	gpio13
gpio18	SPI_1_SCK	23	24	SPI_2_CS0	gpio19
	GND	25	26	SPI_1_CS1	gpio20

Note: 1° Power Pins

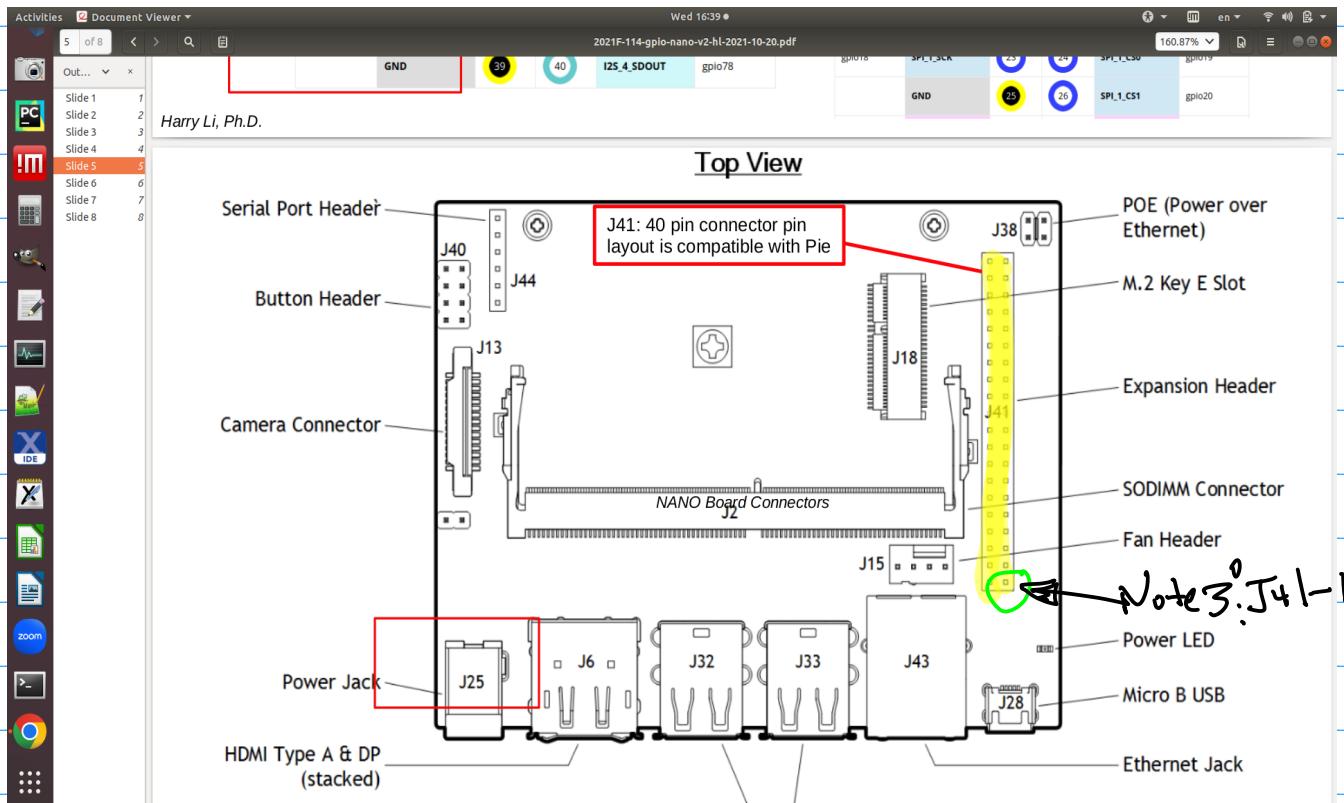
{ GND : b19/25/39  
Vout: 3.3VDC/5VDC  
Pin 1, Pin 2, 4.  
Vin: J25 (5A or higher  
@ 5VDC)

Note 2° GPIO

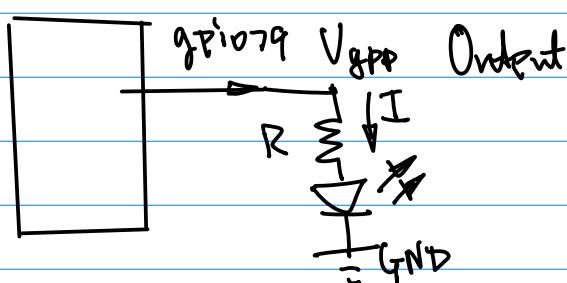
J41-P2  
J41-40

CPU Functionality

gpio79  
gpio78



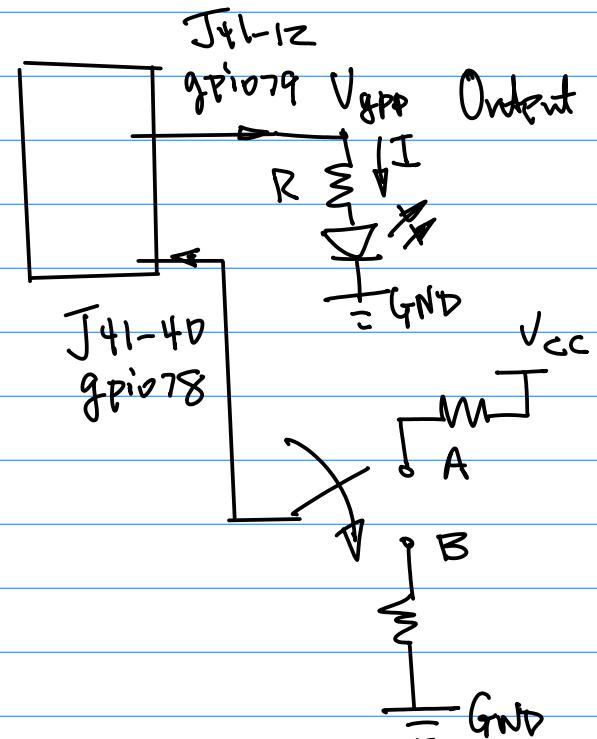
Note 4<sup>o</sup>: GPIO Input/Output Testing Ckt  
Build the following Testing Ckt.



Let  $I = 4 \text{ mA}$ ,  $V_{\text{LED}} \approx 1.8 \text{ V}$

$$V_{\text{GPP},\text{H}} = IR + V_{\text{LED}} \dots (1)$$

w/o Resistor With Proper Selected LED.

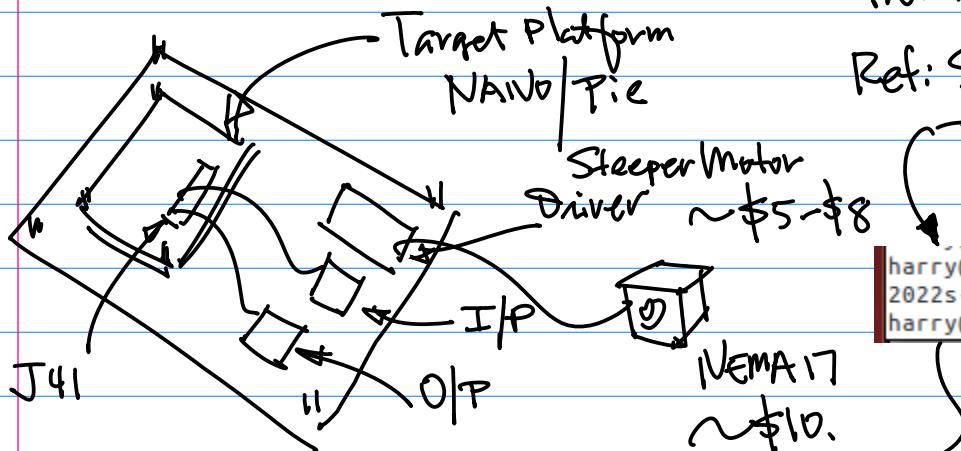


GPIO J41 Pins	CPU Functionality	Note
J41-12	gpio79	Output
J41-40	gpio78	Input

User Space Code  
Kernel Space Code

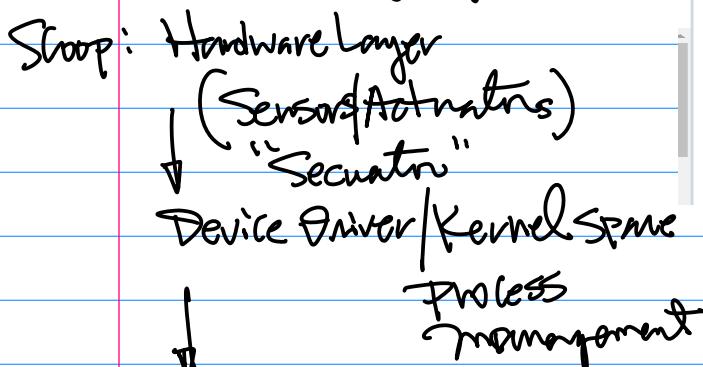
Take a Reference Design  
from Arm11, Samsung CPU.

Ref: Sample code has been  
Posted on the github.



```
harry@harry-laptop:/opt/FriendlyARM/min
2022s-104d-userSpace-gpio.c led led.c
harry@harry-laptop:/opt/FriendlyARM/min
```

Note: Form 2 person Team for  
A Semester Long Project.



↓  
Web Server

↓  
Smartphone APPs.

ChatGPT 3.5 API + Python Interface

Example: Sample Code for GPIO Device  
Driver

[CMPE242-Embedded-Systems- / 2022s / 2022s-104d-userSpace-gpio.c](#)

hualili Add files via upload

Code Blame 37 lines (30 loc) · 642 Bytes Code 55% faster with GitHub

```
1 #include <stdio.h>
2 #include <stdlib.h>
3 #include <unistd.h>
4 #include <sys/ioctl.h>
5 #include <sys/types.h>
6 #include <sys/stat.h>
7 #include <fcntl.h>
```

Sept. 11 (Monday)

Notel: Homework Due in 1½ weeks.

To Be Posted on Line today;

a. Bring up the target, Screen Capture with Personal Identifier.

b. GPIO Testing (Python + Hardware Circuit). (1) Input Testing (KT).

Output Testing (KT). (2) Coding:

Python.

Note 2: B.o.M. (Bill of Material)

for the class/Project

a. Motor (Stepper Motor, NEMA.

17



Nema17  
Stepper Motor  
\$8.99  
Amazon.com

(2) BLDC  
Brushless DC  
motor

c. Smartphone (iPhone

OR Android phone

Swift Mac OS. as Development  
platform.

Ubuntu Linux.  
18.04.

NVIDIA JetPack (OS.)

Note:

With GPIO Testing

Ckt.

(Work-In-  
progress)

Target  
Board

NVIDIA Jetson Nano Bread Board/

OR Wine Wrapping  
Board.



350W Brushed  
Electric Motor



10 Inch Hub  
Motor 1000w, ...



48V 500W  
Wheel Motor ...

b. Motor Drive Unit.



EASON  
Stepper Motor  
\$9.69  
Amazon.com



SparkFun  
Electronics ...  
\$12.09  
DigiKey



WWZMDiB  
A4988 Stepper  
\$7.99  
Amazon.com



Pololu  
Corporation  
\$8.49  
DigiKey



[STEPPERONLINE](#)  
[CNC Stepper Motor](#)  
[Driver 1.0-4.2A](#)  
20-50VDC 1/128

## Example: Continuation on Linux D.D.

on ARM-11 (Samsung). Note! userSpace Code Samples, Kernel Space code

```
linux
harry@harry-laptop:/opt/FriendlyARM/mini6410$ cd linux/
harry@harry-laptop:/opt/FriendlyARM/mini6410/linux$ ls
arm-qte-4.7.0      examples          u-boot-mini6410
arm-qt-extended-4.4.3  linux-2.6.38    x86-qte-4.6.1
arm-qtopia          rootfs_qtopia_qt4  x86-qt-extended-4.4.3
busybox-1.17.2     rootfs_qtopia_qt4-s x86-qtopia
harry@harry-laptop:/opt/FriendlyARM/mini6410/linux$
```

Ref. Sample code on github.

```
harry@harry-laptop:/opt/FriendlyARM/mini6410/linux/examples/leds$ ls
2022s-104d-userSpace-gpio.c  led  led.c  led.c~  Makefile  Makefile~
harry@harry-laptop:/opt/FriendlyARM/mini6410/linux/examples/leds$
```

```
22
23      fd = open("/dev/leds0", 0);
24  if (fd < 0) {
25      fd = open("/dev/leds", 0);
26  }
27  if (fd < 0) {
28      perror("open device leds");
29      exit(1);
30  }
31
32      ioctl(fd, on, led_no);
33  close(fd);
34 }
```

Note1: "Char" Device. Open the Device just like a file.

Kernel (OS. Image)  
path to the Device.  
The Device Driver can be either integrated as the whole kernel image or module (installed/removed)

Note2 for passing control parameter(s) to the Device for Control Action.

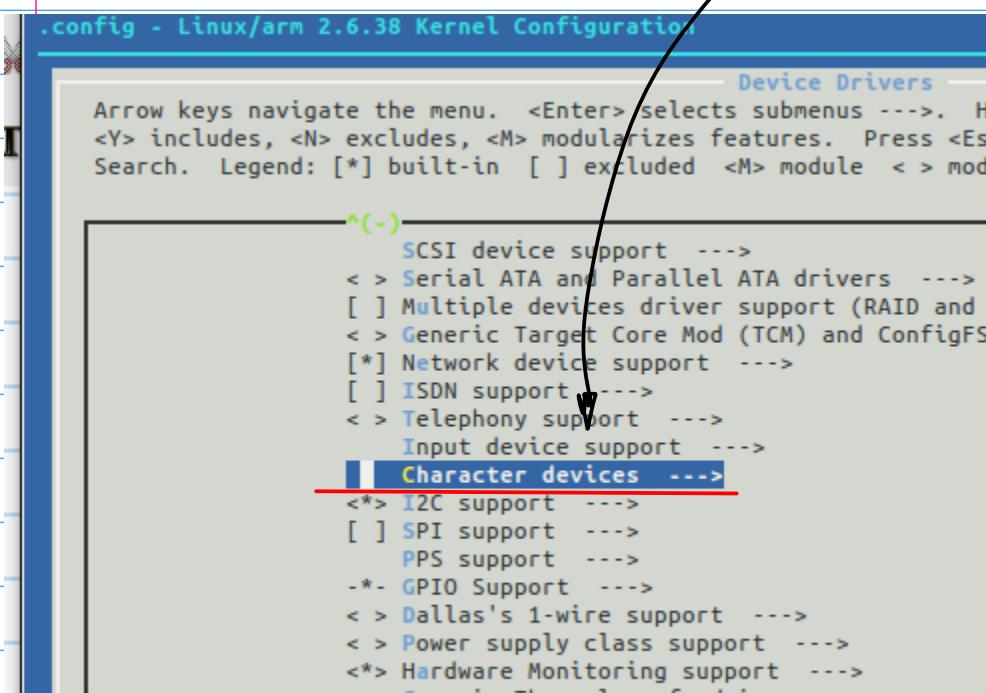
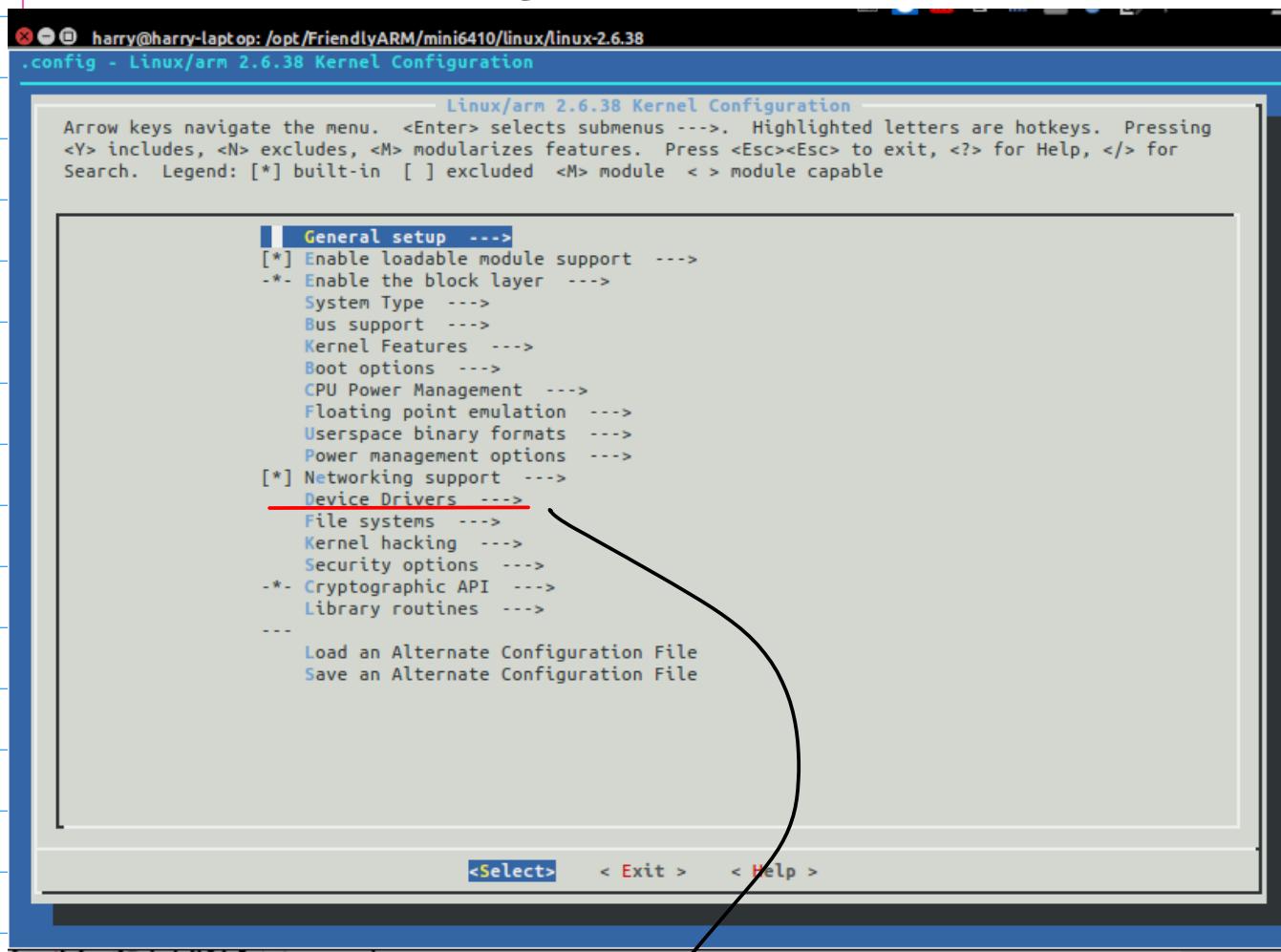
Note3. Close it, when done!

Build

Kernel image using

"menuconfig" → NVDA, Broadcom, Smart phones  
Embedded

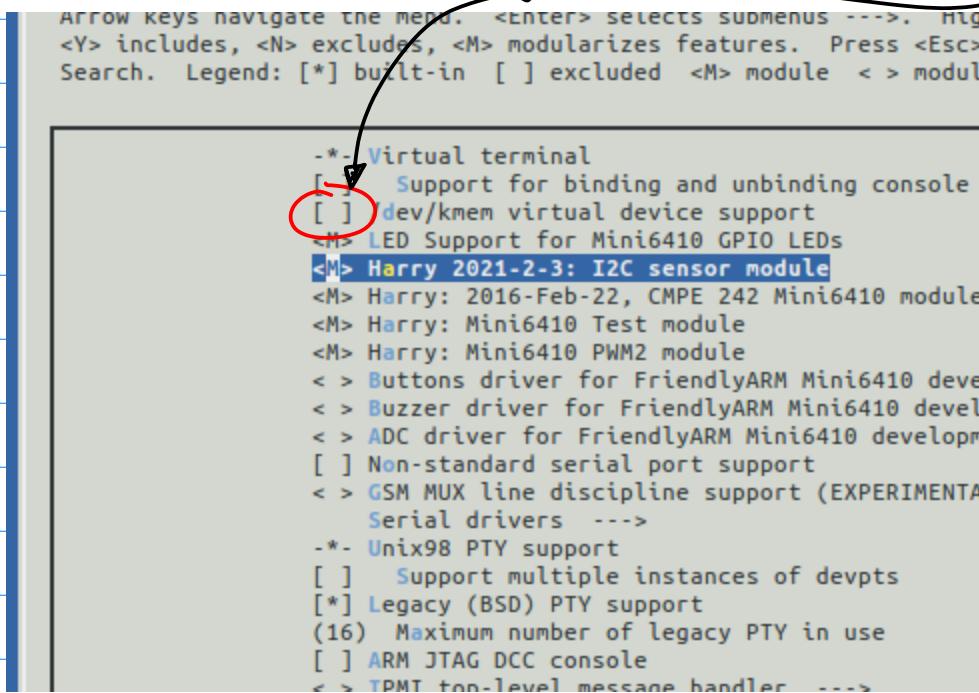
Android.



Note 4. menutools controls how the Kernel Image is built.  
 Here, the "Char" Device Driver can be Selected / Deselected.  
 b. Use "Space Bar" to toggle between 3 options.

```
Arrow keys navigate the menu. <Enter> selects submenus ---. Hig
<Y> includes, <N> excludes, <M> modularizes features. Press <Esc>
Search. Legend: [*] built-in [ ] excluded <M> module < > modul

```



(Non | M | \*)  
↓  
Module  
Integrated Kernel Image

Note 5. Folder for the "Char" D.D., The "gpio" (leds) Device Driver

```
harry@harry-laptop:/opt/FriendlyARM/mini6410/linux/linux-2.6.38/drivers$ cd char
harry@harry-laptop:/opt/FriendlyARM/mini6410/linux/linux-2.6.38/drivers/char$ ls
20-2021S-9-mini6410_pwmHarry.c  ip2          misc.c        rtc.i
2q                           ipmi         misc.o        scc.i
agg                          isicom.c    mmtimer.c    scx2i
amiserial.c                  istallion.c modules.builtin ser_i
apm-emulation.c              Kconfig      modules.order moxa.c
applicom.c                   lp.c         moxa.h       moxa.h
applicom.h                   Makefile     mspec.c      mspec.c
bfin_jtag_comm.c             Makefile-backup mwave        mxser.c
bfin-otp.c                   mbcs.c      mxser.h      mxser.h
briq_panel.c                mbcs.h      nozomi.c    nsc_gpio.c
bsr.c                        mem.c       nvram.c      nwbutton.c
built-in.o                   mem.o       nwbutton.h   nwbutton.h
cd1865.h                     mini6410_adc.c nozomi.h    nwflash.c
cyclades.c                  mini6410_adc.mod.c nsc_gpio.c pc8736x_gpio.c
digi1.h                      mini6410_adc.o  nvram.c    pcmcia
digiFep1.h                  mini6410_buttons.c mini6410_buttons.o ppdev.c
digiPCI.h                   mini6410_buttons.o  mini6410_hello_module.c ps3flash.c
ds1302.c                     mini6410_hello_module.c mini6410_hello_module.mod.c ramoops.c
ds1620.c                     mini6410_hello_module.o  mini6410_hello_module.mod.o random.c
dsp56k.c                     mini6410_hello_module.o  mini6410_hello_module.o random.o
dtlk.c                       mini6410_hello_module.o  mini6410_leds.c tb02
efirtc.c                     mini6410_hello_module.o  mini6410_leds.ko tlcl
epca.c                       mini6410_hello_module.o
epcaconfig.h                 mini6410_hello_module.o
```

2022S-104e  
(CMPE242)

## Example: Kernel Space

Device Driver Code Requirements: Code Spec.

Note1:  
 Connect the Code to the CPU  
 Datasheet  
 ↓  
 Debug

```

66 static int __init dev_init(void)
67 {
68     int ret;
69
70     {
71         unsigned tmp;
72         tmp = readl(S3C64XX_GPECON);
73         tmp = (tmp & ~(0xffffU<<16))|(0x1111U<<16);
74         writel(tmp, S3C64XX_GPECON);
75
76         tmp = readl(S3C64XX_GPEDAT);
77         tmp |= (0xF << 4);
78         writel(tmp, S3C64XX_GPEDAT);
79     }
80
81     ret = misc_register(&misc);
82
83     printk (DEVICE_NAME"\nHarry: PGE initialized\n");
84 }
```

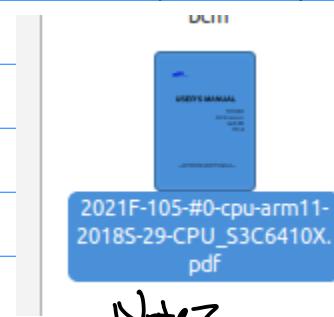
Note2. Read long 32bit

Naming: ID — Peripheral Control  
 (Manufacturer Part) GPP



Memory map.

Ref: CPU Datasheet.



Note2.

TP320.

a) GPE Con

6410X\_UM

## 10.5.5 PORT E CONTROL REGISTERS

There are five control registers including GPECON, GPEDAT, GPEPUD, GPECONS, and GPEPUDS in the Port E Control Registers.

Register	Address	R/W	Description	Reset Value
GPECON	0x7F008080	R/W	Port E Configuration Register	0x00
GPEDAT	0x7F008084	R/W	Port E Data Register	Undefined
GPEPUD	0x7F008088	R/W	Port E Pull-up/down Register	0x00000155
GPECONS	0x7F00808C	R/W	Port E Sleep mode Configuration Register	0x0
GPEPUDS	0x7F008090	R/W	Port E Sleep mode Pull-up/down Register	0x0

C. GPEDAT.

d. Two Addition types:

↓  
 GPEPUD  
 ↓  
 GPECONS  
 GPEPUDS

Power Control

GPDCON	Bit	Description		Initial State
GPE0	[3:0]	0000 = Input 0010 = PCM SCLK[1] 0100 = AC97 BITCLK 0110 = Reserved	0001 = Output 0011 = I2S CLK[1] 0101 = Reserved 0111 = Reserved	0000
GPE1	[7:4]	0000 = Input 0010 = PCM EXTCLK[1] 0100 = AC97 RESETn 0110 = Reserved	0001 = Output 0011 = I2S CDCLK[1] 0101 = Reserved 0111 = Reserved	0000

Note 3. From the D.D. Code, GPE1 is utilized for the I/O function

$$\text{GPDCON}[7:4] = 0001$$

5  
GPIO  
pins

GPDCON	Bit	Description		Initial State
GPE0	[3:0]	0000 = Input 0010 = PCM SCLK[1] 0100 = AC97 BITCLK 0110 = Reserved	0001 = Output 0011 = I2S CLK[1] 0101 = Reserved 0111 = Reserved	0000
GPE1	[7:4]	0000 = Input 0010 = PCM EXTCLK[1] 0100 = AC97 RESETn 0110 = Reserved	0001 = Output 0011 = I2S CDCLK[1] 0101 = Reserved 0111 = Reserved	0000
GPE2	[11:8]	0000 = Input 0010 = PCM FSYNC[1] 0100 = AC97 SYNC 0110 = Reserved	0001 = Output 0011 = I2S LRCLK[1] 0101 = Reserved 0111 = Reserved	0000
GPE3	[15:12]	0000 = Input 0010 = PCM SIN[1] 0100 = AC97 SDI 0110 = Reserved	0001 = Output 0011 = I2S DI[1] 0101 = Reserved 0111 = Reserved	0000
GPE4	[19:16]	0000 = Input 0010 = PCM SOUT[1] 0100 = AC97 SDO 0110 = Reserved	0001 = Output 0011 = I2S DO[1] 0101 = Reserved 0111 = Reserved	0000

How To

Question: Make GPE1 as an output pin,  
But keep the rest unchanged?

Sept. 18 (Monday)

Note: 1<sup>o</sup> Homework Posted on the  
CANVAS.

2<sup>o</sup> Homework, Due Sept. 27  
(Wed), PWM Testing.

① Enable PWM Device  
Driver via Driver mapping  
utility By NVIDIA

② Test PWM Output By  
Changing f<sub>PWM</sub> from 2 kHz  
to 50 Hz; By changing  
Duty Cycle from 5% to 90%.

Then, Observe its Output

Note: Output with 2222 npn Transistor  
to drive a LED. (see the  
details in the Class PPT on  
github). (U.S.)

Note: Prepare the Source Distribution  
Download, to build Kernel  
Image from the distribution.  
(1 ~ 1½ week).

Note: Ref. on Smartphone Apps.  
Android APPs Development.

## Note: Device Driver Sample Code

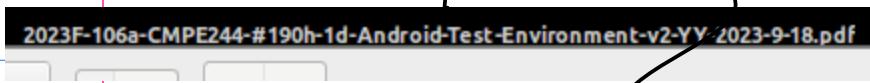
- 2023F-104-gpio-command-line-2023...
- 2023F-105a-2022s-104d-userSpace...
- 2023F-105b-mini6410\_leds.mod.c
- 2023F-106a-CMPE244-#190h-1d-A...

README.md

Update README.md

APPS .

Note: Install Android Studio  
ON your Laptop .



## Install Android Studio on Ubuntu 18.04 (9/15-8/3/2023)

1. Check Java version

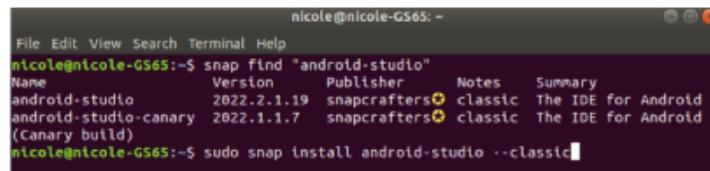
```
nicole@nicole-GS65:~$ java --version
openjdk 11.0.19 2023-04-18
OpenJDK Runtime Environment (build 11.0.19+7-post-Ubuntu-0ubuntu118.04.1)
OpenJDK 64-Bit Server VM (build 11.0.19+7-post-Ubuntu-0ubuntu118.04.1, mixed mode, sharing)
nicole@nicole-GS65:~$
```

3. Once installed, double click the icon to start the studio

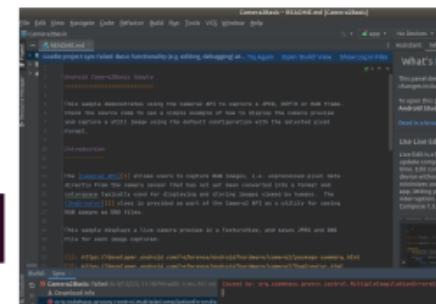


2. Install Android Studio using snap

```
$ snap find "android-studio"
$ sudo snap install android-studio --classic
```



```
(base) harry@harrys-gpu-laptop:~$ sudo snap install android-studio --classic
[sudo] password for harry:
android-studio 2022.3.1.18 from Snapcrafters* installed
```



Note: Team Project (1) Formation of  
The Team ; (2) Selection of Smart phone  
for the APP. (3) Stepper motor  
Drive Board and Stepper motor.

Example: GPIO & PWM .

2023F-104

GPIO Command Line

<https://jetsonhacks.com/2019/06/07/jetson-nano-gpio/>

```
# Map GPIO Pin
# gpio79 is pin 12 on the Jetson Nano
$ echo 79 > /sys/class/gpio/export
# Set Direction
$ echo out > /sys/class/gpio/gpio79/direction
# Bit Bangin'!
$ echo 1 > /sys/class/gpio/gpio79/value
$ echo 0 > /sys/class/gpio/gpio79/value
# Unmap GPIO Pin
$ echo 79 > /sys/class/gpio/unexport
# Query Status
$ cat /sys/kernel/debug/gpio
```

PWM

2021F-114b - ~

Note: Establish Remote Access to your target, e.g. Laptop to Access your target Board.

→ Next Monday, Show+Tell in class

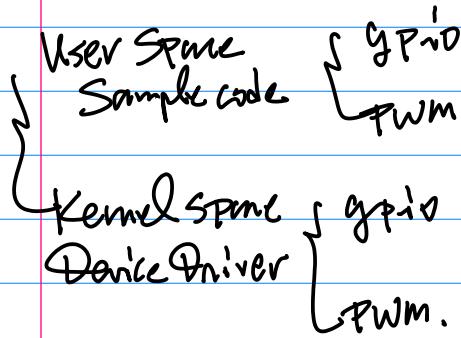
Sept 25 (Monday).

Note: 1<sup>o</sup> Updated github Sample code.

(1) 2023F-107.

Booting Jetson Nano without HDMI Connection.

(2) 2023F-105a to 2023F-105f.



Target Board Connection

Requirements.

a. The Demo/Show+Tell in Class is required, Also

Midterm Exam, and Final Exam are Based on Analyzing & Executing your Implementation Code on the target platform;

b. Bring gpio Homework with the target Board to the Classroom

Wednesday for Quick Inspection,

Show+Tell; (Sept. 27, Wednesday).

Note: HDMI Monitor is optional, To Be Able to Boot your System is the requirement.

Consider the github Sample code.

Ref: -105a, User Space program.

for GPIO.   
 {  
 open()  
 ioctl()  
 close()  
 }

-105b & c

```

1 #include <mach/gpio-bank-k.h>
2
3 #define DEVICE_NAME "leds0"
4
5 static long sbc2440_leds_ioctl(struct file *filp, unsigned
6                                long arg)
7 {
8     switch(cmd) {
9         case 0:
10            unsigned tmp;
11
12            make
13            memory
14            for the Kernel
15            Driver
16            Configuration.
17
18            make
19            memory
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1138           Configuration.
1139
1140           make
1141           memory
1142           for the Kernel
1143           Driver
1144           Configuration.
1145
1146           make
1147           memory
1148           for the Kernel
1149           Driver
1150           Configuration.
1151
1152           make
1153           memory
1154           for the Kernel
1155           Driver
1156           Configuration.
1157
1158           make
1159           memory
1160           for the Kernel
1161           Driver
1162           Configuration.
1163
1164           make
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1166           for the Kernel
1167           Driver
1168           Configuration.
1169
1170           make
1171           memory
1172           for the Kernel
1173           Driver
1174           Configuration.
1175
1176           make
1177           memory
1178           for the Kernel
1179           Driver
1180           Configuration.
1181
1182           make
1183           memory
1184           for the Kernel
1185           Driver
1186           Configuration.
1187
1188           make
1189           memory
1190           for the Kernel
1191           Driver
1192           Configuration.
1193
1194           make
1195           memory
1196           for the Kernel
1197           Driver
1198           Configuration.
1199
1200           make
1201           memory
1202           for the Kernel
1203           Driver
1204           Configuration.
1205
1206           make
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1208           for the Kernel
1209           Driver
1210           Configuration.
1211
1212           make
1213           memory
1214           for the Kernel
1215           Driver
1216           Configuration.
1217
1218           make
1219           memory
1220           for the Kernel
1221           Driver
1222           Configuration.
1223
1224           make
1225           memory
1226           for the Kernel
1227           Driver
1228           Configuration.
1229
1230           make
1231           memory
1232           for the Kernel
1233           Driver
1234           Configuration.
1235
1236           make
1237           memory
1238           for the Kernel
1239           Driver
1240           Configuration.
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1245           Driver
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1257           Driver
1258           Configuration.
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1263           Driver
1264           Configuration.
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1266           make
1267           memory
1268           for the Kernel
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1274           for the Kernel
1275           Driver
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1281           Driver
1282           Configuration.
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1287           Driver
1288           Configuration.
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1290           make
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1292           for the Kernel
1293           Driver
1294           Configuration.
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1296           make
1297           memory
1298           for the Kernel
1299           Driver
1300           Configuration.
1301
1302           make
1303           memory
1304           for the Kernel
1305           Driver
1306           Configuration.
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1311           Driver
1312           Configuration.
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1315           memory
1316           for the Kernel
1317           Driver
1318           Configuration.
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1322           for the Kernel
1323           Driver
1324           Configuration.
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1326           make
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1328           for the Kernel
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1330           Configuration.
1331
1332           make
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1334           for the Kernel
1335           Driver
1336           Configuration.
1337
1338           make
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1340           for the Kernel
1341           Driver
1342           Configuration.
1343
1344           make
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1346           for the Kernel
1347           Driver
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1350           make
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1352           for the Kernel
1353           Driver
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1364           for the Kernel
1365           Driver
1366           Configuration.
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1370           for the Kernel
1371           Driver
1372           Configuration.
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1383           Driver
1384           Configuration.
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1395           Driver
1396           Configuration.
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1398           make
1399           memory
1400           for the Kernel
1401           Driver
1402           Configuration.
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1404           make
1405           memory
1406           for the Kernel
1407           Driver
1408           Configuration.
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1410           make
1411           memory
1412           for the Kernel
1413           Driver
1414           Configuration.
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1416           make
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1418           for the Kernel
1419           Driver
1420           Configuration.
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1422           make
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1424           for the Kernel
1425           Driver
1426           Configuration.
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1428           make
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1430           for the Kernel
1431           Driver
1432           Configuration.
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1434           make
1435           memory
1436           for the Kernel
1437           Driver
1438           Configuration.
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1440           make
1441           memory
1442           for the Kernel
1443           Driver
1444           Configuration.
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1446           make
1447           memory
1448           for the Kernel
1449           Driver
1450           Configuration.
1451
1452           make
1453           memory
1454           for the Kernel
1455           Driver
1456           Configuration.
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1458           make
1459           memory
1460           for the Kernel
1461           Driver
1462           Configuration.
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1464           make
1465           memory
1466           for the Kernel
1467           Driver
1468           Configuration.
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1470           make
1471           memory
1472           for the Kernel
1473           Driver
1474           Configuration.
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1476           make
1477           memory
1478           for the Kernel
1479           Driver
1480           Configuration.
1481
1482           make
1483           memory
1484           for the Kernel
1485           Driver
1486           Configuration.
1487
1488           make
1489           memory
1490           for the Kernel
1491           Driver
1492           Configuration.
1493
1494           make
1495           memory
1496           for the Kernel
1497           Driver
1498           Configuration.
1499
1500           make
1501           memory
1502           for the Kernel
1503           Driver
1504           Configuration.
1505
1506           make
1507           memory
1508           for the Kernel
1509           Driver
1510           Configuration.
1511
1512           make
1513           memory
1514           for the Kernel
1515           Driver
1516           Configuration.
1517
1518           make
1519           memory
1520           for the Kernel
1521           Driver
1522           Configuration.
1523
1524           make
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1526           for the Kernel
1527           Driver
1528           Configuration.
1529
1530           make
1531           memory
1532           for the Kernel
1533           Driver
1534           Configuration.
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1536           make
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1538           for the Kernel
1539           Driver
1540           Configuration.
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1548           make
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1550           for the Kernel
1551           Driver
1552           Configuration.
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1554           make
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1556           for the Kernel
1557           Driver
1558           Configuration.
1559
1560           make
1561           memory
1562           for the Kernel
1563           Driver
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1566           make
1567           memory
1568           for the Kernel
1569           Driver
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1572           make
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1593           Driver
1594           Configuration.
1595
1596           make
1597           memory
1598           for the Kernel
1599           Driver
1600           Configuration.
1601
1602           make
1603           memory
1604           for the Kernel
1605           Driver
1606           Configuration.
1607
1608           make
1609           memory
1610           for the Kernel
1611           Driver
161
```

## Kconf

Kernel configuration for make menuconfig.

```

80
81 source "drivers/hid/Kconfig"
82
83 source "drivers/usb/Kconfig"
84
85 source "drivers/uwb/Kconfig"
86
87 source "drivers/mmc/Kconfig"
88
89 source "drivers/memstick/Kconfig"
90
91 source "drivers/leds/Kconfig" Red circle around this line
92
93 source "drivers/nfc/Kconfig"
94
95 source "drivers/accessibility/Kconfig"
96

```

Kernel folder/driver folder

```

if (argc != 3 || sscanf(argv[1], "%d", &led_no)
    on < 0 || on > 1 || led_no < 0
    fprintf(stderr, "Usage: leds led_no 0|1"
    exit(1);
}

fd = open("/dev/leds0", 0); Red circle around /dev/leds0
if (fd < 0) {
    fd = open("/dev/leds", 0);
}
if (fd < 0) {
    perror("open device leds");
}

```

Note: 1°

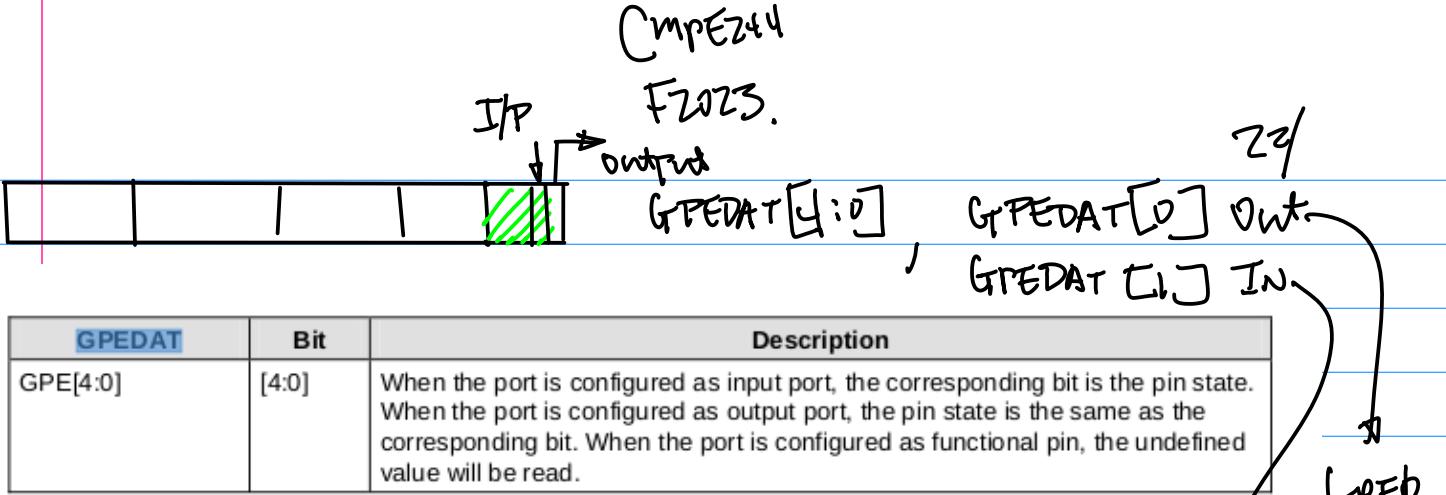
Note 2° SPR. Naming convention/addr. e.g.  
pointed from CPU Data sheet.

```

35 static long sbc2440_leds_ioctl(struct file *filp, unsigned int cmd, unsigned long arg)
36 {
37     switch(cmd) {
38         unsigned tmp;
39     case 0:
40     case 1:
41         if (arg > 4) {
42             return -EINVAL;
43         }
44         tmp = readl(S3C64XX_GPKDAT);
45         tmp &= ~(1 <(4 + arg));
46         tmp |= ((!cmd) <(4 + arg));
47        	writel(tmp, S3C64XX_GPKDAT);
48         //printk (DEVICE_NAME": %d %d\n", arg, cmd);
49         return 0;
50     default:
51         return -EINVAL;
52     }
53 }

```

↳ Bitwise Operations.



Note: Each bit (pin) can be set as an input or output by GPECON.

PP 320.

GPDCON	Bit	Description	Initial State
GPE0	[3:0]	0000 = Input 0010 = PCM SCLK[1] 0100 = AC97 BITCLK 0110 = Reserved	0000
GPE1	[7:4]	0000 = Input 0010 = PCM EXTCLK[1] 0100 = AC97 RESETn 0110 = Reserved	0000
GPE2	[11:8]	0000 = Input 0010 = PCM FSYNC[1] 0100 = AC97 SYNC 0110 = Reserved	0000
GPE3	[15:12]	0000 = Input 0010 = PCM SIN[1] 0100 = AC97 SDI 0110 = Reserved	0000
GPE4	[19:16]	0000 = Input 0010 = PCM SOUT[1] 0100 = AC97 SDO 0110 = Reserved	0000

Find the Binary Pattern to set these 2 pins.

$$GPECON[3:4] = 0001 \quad (O/P)$$

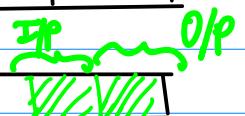
$$GPECON[7:4] = 0000 \quad (I/P)$$

for init & config.

Define Bitwise Operation mask

Design the Binary Pattern.

GPECON



mask to Be Designed

static void \_\_exit dev\_exit(void)

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Bitwise "OR" Note: 1° Init module  
2°

```
66 static int __init dev_init(void)
67 {
68     int ret;
69
70     {
71         unsigned tmp;
72         tmp = readl(S3C64XX_GPECON);
73         tmp = (tmp & ~(0xffffU<<16)) | (0x1111U<<16);
74        	writel(tmp, S3C64XX_GPECON);
75
76         tmp = readl(S3C64XX_GPEDAT);
77         tmp |= (0xF << 4);
78        	writel(tmp, S3C64XX_GPEDAT);
79     }
80
81     ret = misc_register(&misc);
82
83     printk (DEVICE_NAME"\Harry: PGE initialized\n");
84
85     return ret;
86 }
```

From 2023F-105c-mini6410\_leds.c

#define DEVICE\_NAME "leds0"

static long sbc2440\_leds\_ioctl(struct file \*filp, unsigned int cmd, unsigned long arg)

static int \_\_init dev\_init(void)

static void \_\_exit dev\_exit(void)

GPIO SPI for Configuration

Hardware  
Software  
User Code  
Driver Code  
CPU  
Datasheet

Sept. 27 (Wed).

Note 1: Homework 1 #2.

Note 2: Inspection of the Prototype System

GPIO Testing.

Example: Architecture

Device Driver

OS Kernel Image

Note: PWM + I2C  
for the future discussion

Let's consider Configure + Build OS. Kernel Image.

Step 1. Download OS Distribution

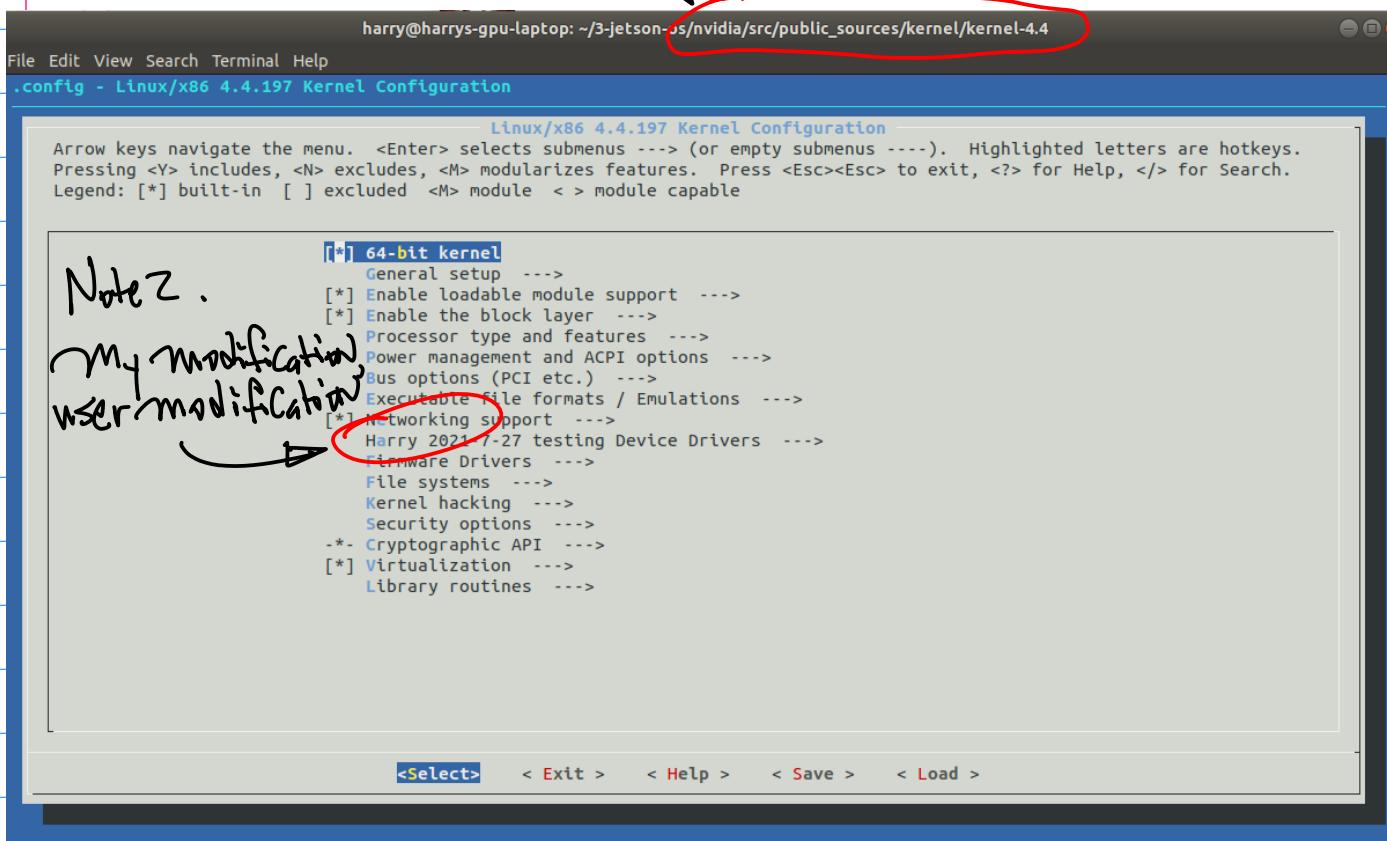
↓  
Step 2. Menutools to Build OS.

By the manufacturer's Default  
setting



Step 3. Create User-Defined  
Kernel image.

Note1: menuconfig UI



Now, Similar Setup for Sam's Arm11, Check Kconf for UI Customization  
at the Root folder.)

```

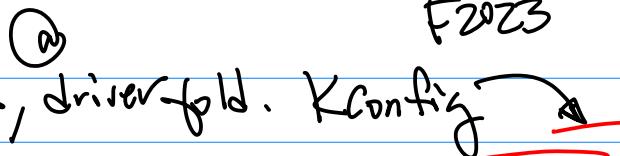
harry@harry-laptop: /opt/FriendlyARM/mini6410/linux/linux-2.6.38
1 #
2 # For a description of the syntax of this configuration file,
3 # see Documentation/kbuild/kconfig-language.txt.
4 #
5 mainmenu "Linux/$ARCH $KERNELVERSION Kernel Configuration"
6
7 config SRCARCH
8     string
9     option env="SRCARCH"
10
11 source "arch/$SRCARCH/Kconfig"

```

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Next Level, driver-fold. Kconfig 

```
x - harry@harry-laptop: /opt/FriendlyARM/mini6410/linux/linux-2.6.38/drivers
1 menu "Device Drivers"
2
3 source "drivers/base/Kconfig"
4
5 source "drivers/connector/Kconfig"
6
7 source "drivers/mtd/Kconfig"
8
9 source "drivers/of/Kconfig"
10
11 source "drivers/parport/Kconfig"
12
13 source "drivers/pnp/Kconfig"
14
15 source "drivers/block/Kconfig"
16
17 # misc before ide - BLK_DEV_SGIIOC4 depends on SGI_IOC4
18
19 source "drivers/misc/Kconfig"
20
21 source "drivers/ide/Kconfig"
22
```

Next Level to "Char" folder, KConfig.

```
x - harry@harry-laptop: /opt/FriendlyARM/mini6410/linux/linux-2.6.38/drivers/char
1 #
2 # Character device configuration
3 #
4
5 menu "Character devices"
6
7 config VT
8     bool "Virtual terminal" if EXPERT
9         depends on !S390
10        select INPUT
11        default y
12        ---help---
13            If you say Y here, you will get support for terminal devices with
14            display and keyboard devices. These are called "virtual" because you
15            can run several virtual terminals (also called virtual consoles) on
16            one physical terminal. This is rather useful, for example one
17            virtual terminal can collect system messages and warnings, another
18            one can be used for a text-mode user session, and a third could run
19            an X session, all in parallel. Switching between virtual terminals
20            is done with certain key combinations, usually Alt-<function key>.
21
22            The setterm command ("man setterm") can be used to change the
23            properties (such as colors or beeping) of a virtual terminal. The
```

```

100 #
109 # Harry: Feb 17, 2016
110 #
111 config MINI6410_I2CSEN_MODULE
112     tristate "Harry 2021-2-3: I2C sensor module"
113     depends on CPU_S3C6410
114     help
115         I2C sensor module Feb 17, 2016.
116 #
117 #
118 #
119 # Harry: Here is my modification
120 #
---[END_OF_KERNEL_MODULE]

```

Ref: 2023 F-109, Readme.

Oct. 2nd (Monday) . Oct. 8 (Sun)

Note1. Homework, Due 1 week

Continuation from the Homework  
of O.S. Kernel Source Distribution  
Installation.

Modify Kconfig, to

1° Add user defined device  
Driver Option as a char  
device.

The option appears as.

FirstName\_LastName\_CMPE244\_driverX, see Ref Below.

```

harry@harry-laptop: /opt/FriendlyARM/mini6410/linux/linux-2.6.38
.config - Linux/arm 2.6.38 Kernel Configuration

Character devices

Arrow keys navigate the menu. <Enter> selects submenus --->. Highlighted letters are hotkeys. Pressing <Y> includes, <N> excludes, <M> modularizes features. Press <Esc><Esc> to exit, <?> for Help, </> for Search. Legend: [*] built-in [ ] excluded [M] module < > module capable

-# Virtual terminal
[ ] Support for binding and unbinding console drivers
[ ] /dev/kmem virtual device support
<M> LED Support for Mini6410 GPIO LEDs
<M> Harry 2021-2-3: I2C sensor module
<M> Harry: 2016-Feb-22, CMPE 242 Mini6410 module sample
<M> Harry: Mini6410 Test module

```

2° Provide Screen Capture  
of your UI.

3° provide Kconfig file  
which realizes this  
function.

4° Hardware Side.  
Motor Drive Board.

Note: place comments to highlight the modification

```

105      This option enables support for LEDs connected to GPIO lines
106      on Mini6410 boards.
107
108 #-----#
109 # Harry: Feb 17, 2016
110 #
111 config MINI6410_I2CSEN_MODULE
112     tristate "Harry 2021-2-3: I2C sensor module"
113     depends on CPU_S3C6410
114     help
115         I2C sensor module Feb 17 2016

```

Option to consider.

Be Careful, Power budget  
for A4988 is  
16mA.



A4988 Stepper  
Motor Driver...

\$5.89

Amazon.com  
Free shipping

Note 2: Quiz is scheduled A  
week from today Oct. 9th  
(Monday).

1° Bring the target Board &  
Prototype Board to the Class

2° Be sure to have a way  
to capture the UI.

3° Scope of the Quiz:

CPU Datasheet, CPU Architecture  
Memory-map, SPRs (Special  
Purpose Registers) for GPP.

→ ARM11, Background Info  
from LPC;

4° Execute GPIO Code

5° take a photo of your  
entire System Setup.

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6° Screen Capture from your target Board to show the execution of the code with Personal ID is in the Screen Capture.

Time to Complete: 20 min  
for the Quiz, 15 min. to  
Prepare the Submission

Example: Continuation on KConfig.

7° Python Code.

8° Submission.

→ photos in png/jpg.

Code

A piece of paper with  
handwritten Answer.



Take a photo to Capture  
your answer sheet, then  
Convert it to pdf.

Then, place all the files  
(2 photos, 1 pdf, 1 code)

into one package, Zip it.

Naming the file:

FirstName - LastName - SID - 244.zip.  
(4 digits)

Submission to the CANVAS.

CMPE242

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Objectives: To Be Able to Customize OS, Kernel, e.g. by modifying KConfig to have the following feature.

The screenshot shows a terminal window titled ".config - Linux/arm 2.6.38 Kernel Configuration". The menu path is ". Character devices". A callout arrow points from the handwritten note "To Be Able to Customize OS, Kernel, e.g. by modifying KConfig to have the following feature." to this menu. The menu lists various kernel modules under the "Virtual terminal" section, including support for Mini6410 development boards, Harry sensor modules, and serial drivers. At the bottom, there are buttons for "<Select>", "< Exit >", and "< Help >".

Note 1. The Architecture of the KConfig.

```
harry@harry-laptop:~/opt/FriendlyARM/mini6410/linux/linux-2.6.38$ cd drivers/char/
harry@harry-laptop:~/opt/FriendlyARM/mini6410/linux/linux-2.6.38/drivers/char$ ls
Kconfig
harry@harry-laptop:~/opt/FriendlyARM/mini6410/linux/linux-2.6.38/drivers/char$ vi Kconfig
harry@harry-laptop:~/opt/FriendlyARM/mini6410/linux/linux-2.6.38/drivers/char$ cd ..
harry@harry-laptop:~/opt/FriendlyARM/mini6410/linux/linux-2.6.38$ cd ..
harry@harry-laptop:~/opt/FriendlyARM/mini6410/linux/linux-2.6.38$ ls Kconfig
harry@harry-laptop:~/opt/FriendlyARM/mini6410/linux/linux-2.6.38$ cd drivers/
harry@harry-laptop:~/opt/FriendlyARM/mini6410/linux/linux-2.6.38$ ls Kconfig
harry@harry-laptop:~/opt/FriendlyARM/mini6410/linux/linux-2.6.38$ cd char
harry@harry-laptop:~/opt/FriendlyARM/mini6410/linux/linux-2.6.38$ ls Kconfig
harry@harry-laptop:~/opt/FriendlyARM/mini6410/linux/linux-2.6.38$ cd char
harry@harry-laptop:~/opt/FriendlyARM/mini6410/linux/linux-2.6.38$ ls
```

Annotations:

- a) at the Root
- b. drivers
- c. Char. ==

Note: To Create an entry, use "Config"

```

107
108 #
109 # Harry: Feb 17, 2016
110 #
111 config MINI6410_I2CSEN_MODULE
112 tristate "Harry 2021-2-3: I2C sensor module"
113 depends on CPU_S3C6410
114 help
115     I2C sensor module Feb 17, 2016.
116 #
117
118 #

```

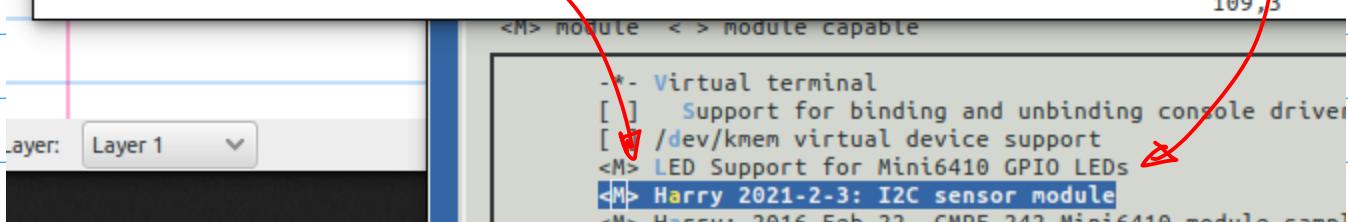
Note: To define the target CPU, use "depends on" followed by Manufacturer ID & Device ID.

```

107
108 #
109 # Harry: Feb 17, 2016
110 #
111 config MINI6410_I2CSEN_MODULE
112 tristate "Harry 2021-2-3: I2C sensor module"
113 depends on CPU_S3C6410
114 help
115     I2C sensor module Feb 17, 2016.
116 #
117
118 #
119 # Harry: Here is my modification
120 #

```

Note:



Note 2: To pre-select, use default "y"

```

70
91 config DEVKMEM
92     bool "/dev/kmem virtual device support"
93     default y
94     help
95         Say Y here if you want to support the /dev/kmem device. The
96         /dev/kmem device is rarely used, but can be used for certain
97         kind of kernel debugging operations.
98         When in doubt, say "N".

```

Note: To provide Description for the option, use "help"

Once the KConfig is updated with matching Name of the Device Driver, then \$make all

\$insmod *driverName*  
\$printk( )  
\$rmmod *driverName*

Oct. 4 (Wed.).

Consider Debugging the Device  
Driver(s) from Manufacturer's  
Distribution.

Example: Embedded Software in this

Example: UserSmartphone → Jetson Nano → User APP. → Device  
WebServer Program Driver

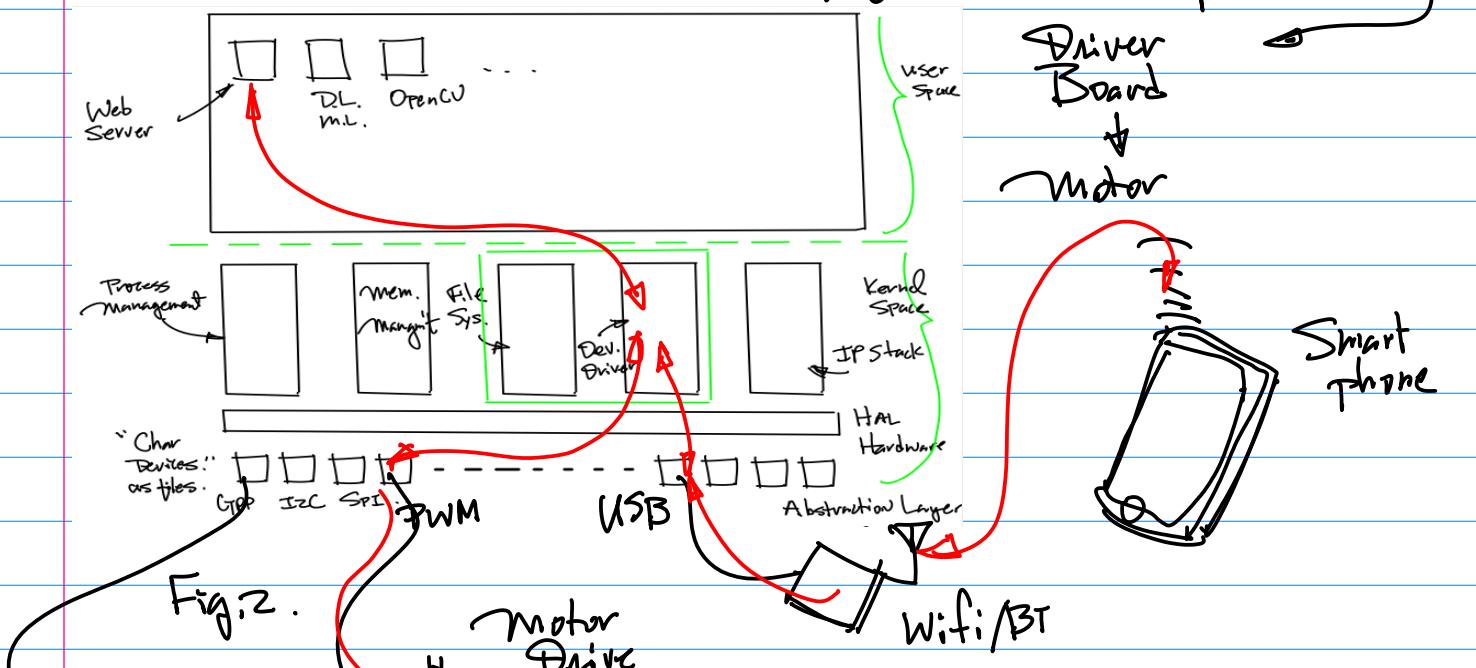


Fig. 2.

## Background On the Motor & motor Driver Board.

1° Stepper motor pins. (4)

$A^+, A^-, B^+, B^-$ .

## 2° Driver Board Pins

## ✓ Infant Group

Output Group. (4 pins)

ENABLE>Select.

Speed Input Pin: PWM f<sub>PWM</sub>

## Direction Control .GPP

Others. { Configuration Pins. x

Al, Cu, Bi, S, Others, ...

~~-0.7m/s, ...~~

$2^x$  No. of  
Config. Patterns

Table 1. Connectivity Table  
Driver Board to the Stepper Motor.

Driver Board	NEMA 17
A+	A+
A-	A-
B+	B+
B-	B-

Now, for the Configuration of the driver board.

Background On the Stepper motor Drive Board.

Note: 1 Full Step of the Stepper Motor.

$$\frac{2\pi}{200} \Rightarrow \frac{360}{200}$$

1.8 degree/step

1 half Step. 0.9 Degree/  
Half Step

$\frac{1}{4}$  Step 0.45 Degree

$\frac{1}{8}$  Step 0.225 Degree.

:

A typical Driver Board consists of 4 pins for Configuration Conn1, Conn2, Conn3, Conn4

Example:  $f_{pwm}$  is set to its target frequency,  $f_{pwm} = 2 \times 10^3$

And Duty Cycle 5% to 95% Allows the Control of the Speed.

Sample code to Realize this Control function.

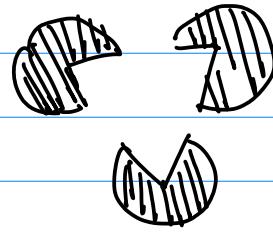
a. Set f<sub>pwm</sub>

b. Set & Change Duty Cycle.

Ref: Ref code to Be posted on line. To Be Referenced for your design & debugging

Note 1.

```
harry@harry-laptop:~/opt/FriendlyARM/mini6410/linux/examples/pwm$ makefile pwm_test pwm_test.c pwm_testNew.c temp.c
```



CMPE244

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34/

```

99     open_buzzer();
100
101    printf( "\nBUZZER TEST ( PWM Control )\n" );
102    printf( "Press +/- to increase/reduce the frequency of the BUZZER\n" );
103    printf( "Press 'ESC' key to Exit this program\n\n" );
104
105
106    while( 1 )

```

Note: Set  $f_{PWM}$ , But Need to set duty cycle as well.

```

109
110    set_buzzer_freq(freq);
111    printf( "\tFreq = %d\n", freq );
112
113    key = getch();
114
115    switch(key) {

```

Note: Access to the Device Driver By "fd" (file Descriptor).

```

4/
48 static int fd = -1;
49 static void close_buzzer(void);
50 static void open_buzzer(void)
51 {
52     fd = open("/dev/pwm", 0);
53     if (fd < 0) {
54         perror("open pwm_buzzer");
55         exit(1);
56     }
57 }

```

## Oct 8th (Monday)

Example: Debugging PWM Driver (ATMEL Example).

References with C code have been posted, And IDs are provided to the class.

C } user Space Code.  
  } Kernel Space Code.

Objective: To modify the Device Driver Code to include Duty function.

To upgrade the user Code to Allow Both  $f_{PWM}$  and

$f_{PWM}$

$f_{PWM}$ .

modification of this module?  
Add duty cycle if possible.

Duty Cycle to Be Defined and Selected by user.

Step 1. Modify / Upgrade User Space Code, to Add duty function.

Step 2. Modify / Upgrade Kernel Space Code, e.g., device Driver.

Control / Config.  $f_{PWM}$ .

Control / Config. Duty Cycle

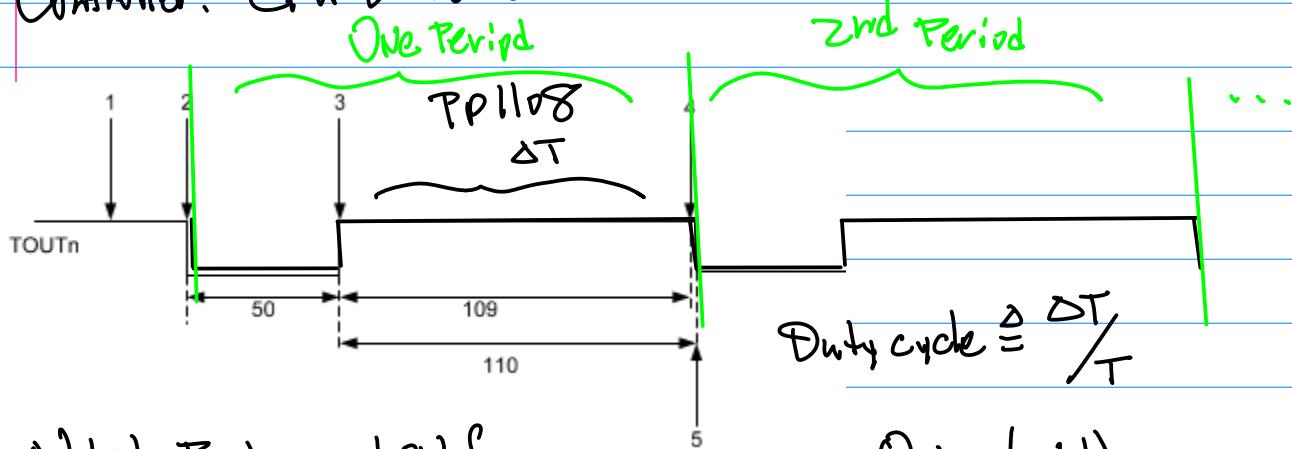
Step 3. Inspection of Control / Configuration Registers, e.g., SFRs to Allow Duty to Be a part of the Driver function.

CPU Data sheet.

Step 4. Option, But if the Name of the Device Driver is Changed One to

the upgrade, then we need  
to change/update the script  
in "KConfig"

## Discussion on PWM Peripheral Controller. CPU Datasheet



Note 1. Background on f<sub>PWM</sub>

System Clock  $\rightarrow$  PCLK  $\rightarrow$  PWM  
 $f_{sys}$  peripheral clock  $f_{PCLK}$   $f_{PWM}$

SPR(s) to Control/Config.

PCLK.

$\frac{1}{2}, \frac{1}{4}, \frac{1}{8}, \dots$

16 bits.

$$f_{PWM} = \frac{f_{PCLK}}{\text{DVSZ} * (\text{Prescaler})} \dots (1)$$

Not necessarily tied to a commercial product.

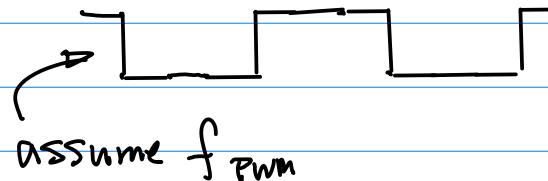
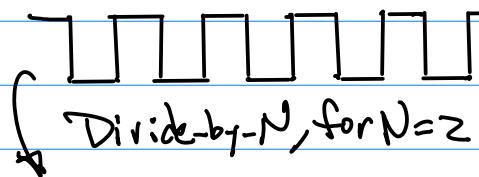
Oct. 11 (Wed)

Continuation on PWM  
Driver Debugging &  
update

$f_{PWM}$   
Duty

Note 1. Waveform for  
Divide-by-N  
Counter

Input CLK  
PCLK



If  $N$  is 8 bits, then

$$N \in [0, 255]$$

Question: How many different frequencies for  $f_{\text{PWM}}$  can we have with this  $N$ ?

Alternative to Increase the No. of  $f_{\text{PWM}}$  by introducing a Product

$$N = N_1 * N_2$$

Where  $N_1$  is 8 bit,  $N_2$  is 8 bit

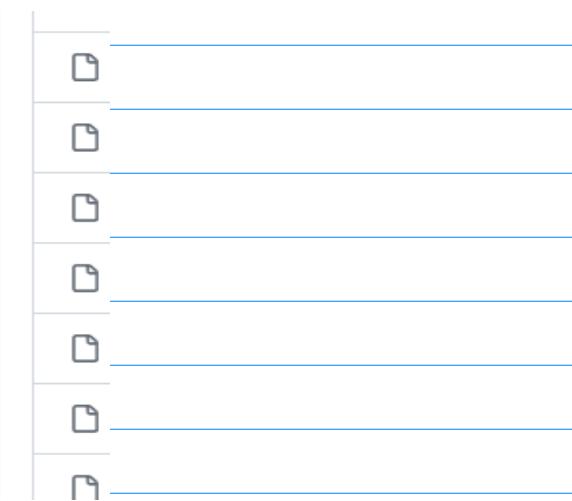
To Achieve the increase the No. of  $f_{\text{PWM}}$ .

Consider A Duty Cycle Implementation

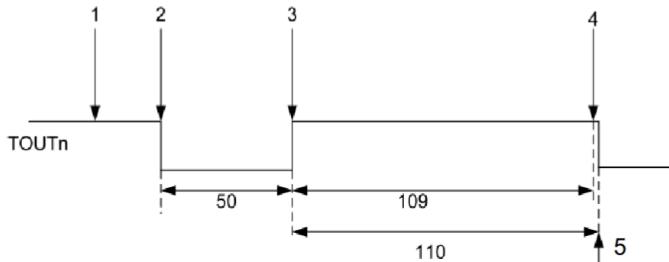
We need { A Counter { Count Up  
Count Down.  
} Interrupt }

Ref. from github for CmPEZ42

- 2022S-107a-PID-v5-2019-4-25.pdf
- 2022S-107b-pwm-pid.pdf
- 2022S-107c-pwm-config-v4-hl-2022-3-3.pdf
- 2022S-107d-pwm-nano-coding-hl-2021-12-19.pdf
- 2022S-107e-pwm-waveform-v3-2018-3-4.jpg
- 2022S-107f-pwm-specialPurposeRegister-v3-20...
- 2022S-107g-pwm-calculation-v3-2018-3-4.pdf
- 2022S-107h-spec-motor-drive-WS55-1800 (copy...)
- 2022S-108-L5M2023IUC.pdf



## PWM Operation



Example:

1. Initialize the TCNTBn with 159(50+109) and the TCMPBn with 109.
2. Start Timer by setting the start bit and manual update bit off.
- The TCNTBn value of 159 is loaded into the down-counter, the output is driven low.
3. When down-counter counts down to the value in the TCMPBn register 109, the output is changed from low to high.
4. When the down-counter reaches 0, the interrupt request is generated.
5. The down-counter is automatically reloaded with TCNTBn, which restarts the cycle.

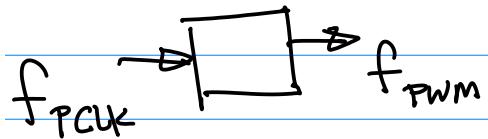
Example: Given  $f_{sys} = 800 \text{ MHz}$ .

$$\text{assume } f_{PCLK} = 800/8 = 100 \text{ MHz}$$

assume

$$f_{PWM} = 2 \text{ kHz}$$

find



Try:

$$TCNTB\phi = \frac{f_{PCLK}}{f_{PWM}}$$

from the given condition

## TCFG0, TCNTBn and TCMPBn

### 32.4.1.1 TCFG0 (Timer Configuration Register), pp 1118

Register	Offset	R/W	Description
TCFG0	0x7F006000	R/W	Timer Configuration Register 0 that configures the two 8-bit Prescaler and DeadZone Length

Timer input clock Frequency = PCLK / ( {prescaler value + 1} ) / {divider value}  
{prescaler value} = 1~255  
{divider value} = 1, 2, 4, 8, 16, TCLK

### 32.4.1.2 TCFG1 (Timer Configuration Register)

Register	Offset	R/W	Description
TCFG1	0x7F006004	R/W	Timer Configuration Register 1 that controls 5 MUX and DMA Mode Select Bit

### 32.4.1.3 TCON (Timer Control Register)

Register	Offset	R/W	Description
TCON	0x7F006008	R/W	Timer Control Register

### 32.4.1.5 TCMPB0 (Timer0 Compare Register)

Register	Offset	R/W	Description
TCMPB0	0x7F006010	R/W	Timer 0 Compare Buffer Register

Harry Li, Ph.D.

## 32.4 SPECIAL FUNCTION REGISTERS

## 32.4.1 REGISTER MAP

Note1.

PP1117

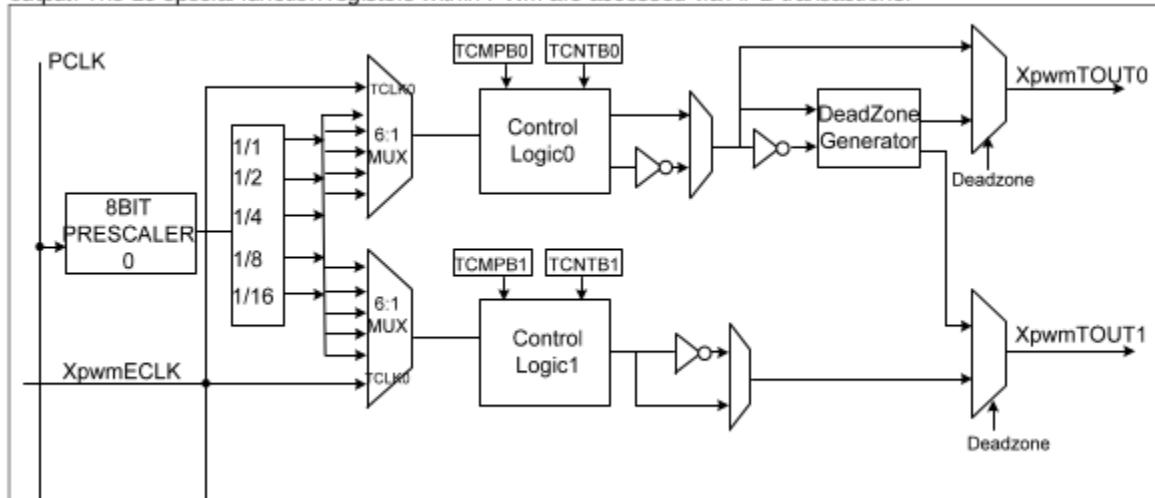
TCNTB0

CNTB : Count Buffer

Register	Offset	R/W	Description	Reset Value
TCFG0	0x7F006000	R/W	Timer Configuration Register 0 that configures the two 8-bit Prescaler and DeadZone Length	0x0000_0101
TCFG1	0x7F006004	R/W	Timer Configuration Register 1 that controls 5 MUX and DMA Mode Select Bit	0x0000_0000
TCON	0x7F006008	R/W	Timer Control Register	0x0000_0000
<u>1</u> TCNTB0	<u>0x7F00600C</u>	<u>R/W</u>	<u>Timer 0 Count Buffer Register</u>	<u>0x0000_0000</u>
<u>2</u> TCMPB0	<u>0x7F006010</u>	<u>R/W</u>	<u>Timer 0 Compare Buffer Register</u>	<u>0x0000_0000</u>
TCNTO0	0x7F006014	R	Timer 0 Count Observation Register	0x0000_0000
TCNTB1	0x7F006018	R/W	Timer 1 Count Buffer Register	0x0000_0000
TCMPB1	0x7F00601c	R/W	Timer 1 Compare Buffer Register	0x0000_0000
TCNTO1	0x7F006020	R	Timer 1 Count Observation Register	0x0000_0000
TCNTB2	0x7F006024	R/W	Timer 2 Count Buffer Register	0x0000_0000
TCNTO2	0x7F00602c	R	Timer 2 Count Observation Register	0x0000_0000
TCNTB3	0x7F006030	R/W	Timer 3 Count Buffer Register	0x0000_0000
TCNTO3	0x7F006038	R	Timer 3 Count Observation Register	0x0000_0000
TCNTB4	0x7F00603c	R/W	Timer 4 Count Buffer Register	0x0000_0000
TCNTO4	0x7F006040	R	Timer 4 Count Observation Register	0x0000_0000
TINT_CSTAT	0x7F006044	R/W	Timer Interrupt Control and Status Register	0x0000_0000

Reference for  $f_{Pwm}$  formula.

output. The 16 special function registers within PWM are accessed via APB transactions.



Oct 16 (mon).

Note1. Homework Assignment

On CANVAS:

## PWM Device Driver + Board Implementation.

### CMPE 244 Homework PWM Driver Debugging and Stepper Motor Actuation Demo

#### Part I:

1. Download the PWM user program and driver program from the class github, see the figure below for the document ID:

2023F-105d-user-p...	Add files via upload	3 weeks ago
2023F-105e-user-p...	Add files via upload	3 weeks ago
2023F-105f-#20-20...	Add files via upload	3 weeks ago

The github for the pwm user space program:

[https://github.com/hualili/CMPE244/blob/main/2023F-105d-user-pwm\\_test.c](https://github.com/hualili/CMPE244/blob/main/2023F-105d-user-pwm_test.c)

Example: Continuation of the PWM modification.

SPR.

Define the Counts value to Achieve Required Duty Cycle.

$T_{CNTBn}$  is compared against  $T_{CMPBn} = 109$ .

Then, if equal, trig the waveform change from the default "0" to high "1"

Design Requirements for the example:

Suppose 33% Duty Cycle.

Initialize  $T_{CMPBn} = ?$

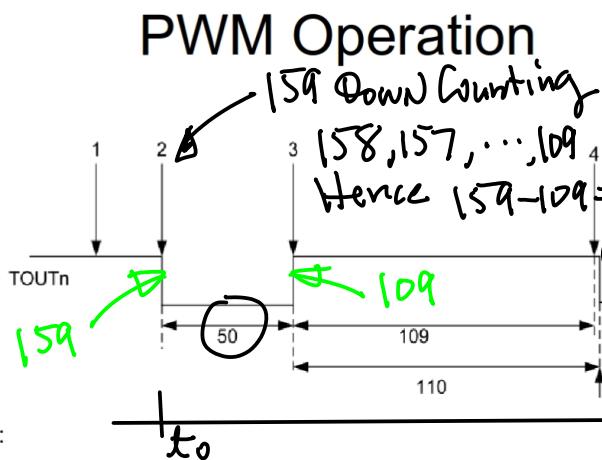
$$\therefore T_{CNPBn} = 50 \times 10^3$$

We can now,

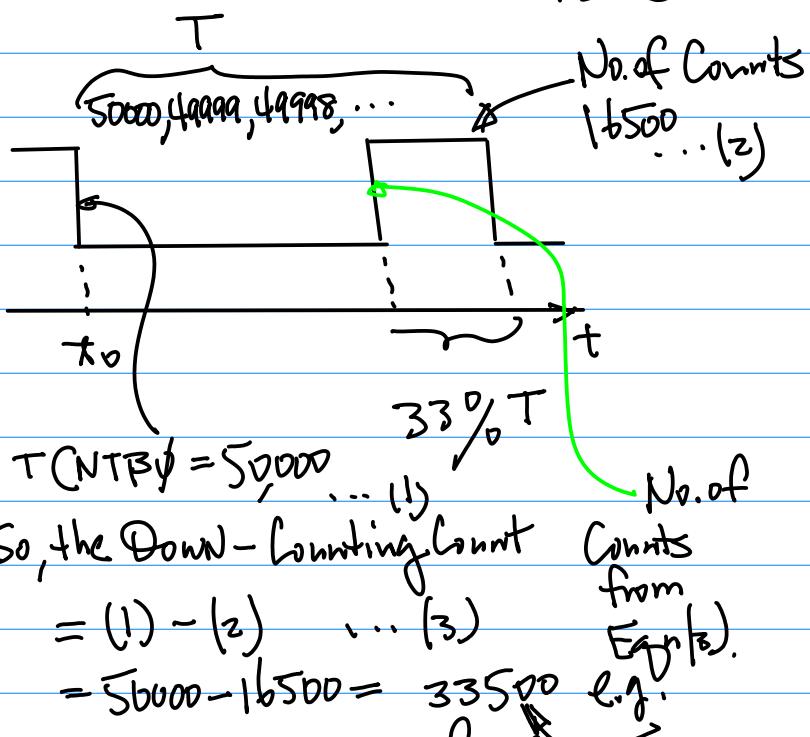
$$0.33 \times 50 \times 10^3$$

$$= 16500$$

Now, to visualize it, we have

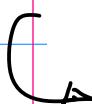


1. Initialize the  $TCNTBn$  with 159(50+109) and the  $TCMPBn$  with 109.
2. Start Timer by setting the start bit and manual update bit off.
3. When down-counter counts down to the value in the  $TCMPBn$  register 109, the output is changed from low to high.
4. When the down-counter reaches 0, the interrupt request is generated.
5. The down-counter is automatically reloaded with  $TCNTBn$ , which restarts the cycle.



Therefore, to get the initial value  
for  $T_{(MPB)} = 33500$ ,

Now, Read C code of Device Driver.



On the Class  
github.

2023F-105F-#20-2021S-9-  
mini6410\_pwmHarry (1).c

```

multi-thread.py 2022S-103c-#nn_sample_2022.py 2023F-105F-#20-2021S-9-mini6410_pwmHarry (1).c
1  /*
2   * Program: mini6410_pwmHarry.c;
3   * Modified by: HL; Date: Feb 10, 2016 *
4   * Purpose: To add PWM duty cycle change function *
5   *           by altering CMP compare register. *
6   */
7
8 #include <linux/module.h>
9 #include <linux/kernel.h>
10 #include <linux/fs.h>
11 #include <linux/init.h>
12 #include <linux/delay.h>
13 #include <linux/poll.h>
14 #include <asm/irq.h>
15 #include <asm/io.h>
16 #include <linux/interrupt.h>
17 #include <asm/uaccess.h>
18 #include <mach/hardware.h>
19 #include <plat/regs-timer.h>
20 #include <mach/regs-irq.h>
21 #include <asm/mach/time.h>
22 #include <linux/clk.h>
23 #include <linux/cdev.h>
24 #include <linux/device.h>
25 #include <linux/miscdevice.h>
26
27 #include <mach/map.h>
28 #include <mach/regs-clock.h>
29 #include <mach/regs-gpio.h>
```

Note 1. Driver Name in the User Space,

```

35 #define DEVICE_NAME "pwm"
36
37 #define PWM_IOCTL_SET_FREQ 1
38 #define PWM_IOCTL_STOP 0
39
40 static struct semaphore lock;
41
42

```

`OPEN("drivers/pwm" ...)`

Initially Enabled.

Note 2. Add the function  
to change duty cycle.  
`PWM_IOCTL_SET_DUTY`  
for Example.

```

41 static struct semaphore lock;
42
43 /* freq: pclk/50/16/65536 ~ pclk/50/16
   * if pclk = 50MHz, freq is 1Hz to 62500Hz
   * human ear : 20Hz~ 20000Hz
   */
44
45 //static void PWM_Set_Freq( unsigned long freq)
46 static void PWM_Set_Freq( unsigned long freq, duty ) //Hz
47 {
48     unsigned long tcon;
49     unsigned long tcnt;
50     unsigned long tduy; //Harry
51     unsigned long tcfg1;
52     unsigned long tcfg0;
53
54     struct clk *clk_p;
55     unsigned long pclk;
56
57     unsigned tmp;
58
59     tmp = readl(S3C64XX_GPFCON);
60     tmp &= ~(0x3U << 28);
61     tmp |= (0x2U << 28);
62    	writel(tmp, S3C64XX_GPFCON);
63
64     tcon = __raw_readl(S3C_TCON);
65     tcfg1 = __raw_readl(S3C_TCFG1);
66     tcfg0 = __raw_readl(S3C_TCFG0);
67
68
69

```

Note 3. Preserve the module Name  
for minimum Modification  
or, update to  
`PWM_Set_Freq_Duty( )`.  
New Parameter for the  
Duty Cycle is added.

#### 32.4.1.3 TCON (Timer Control Register)

Register	Offset	R/W	Descr
TCON	0x7F006008	R/W	Timer Control Register
TCON	Bit	R/W	

TP 1119  
Read Datasheet, for Example "oneshot"  
V.S. "Auto-Reload" etc.

Oct. 18 (Wed)

Note: Roadmap of the Class



Introduction.

CPU/SPR/Driver

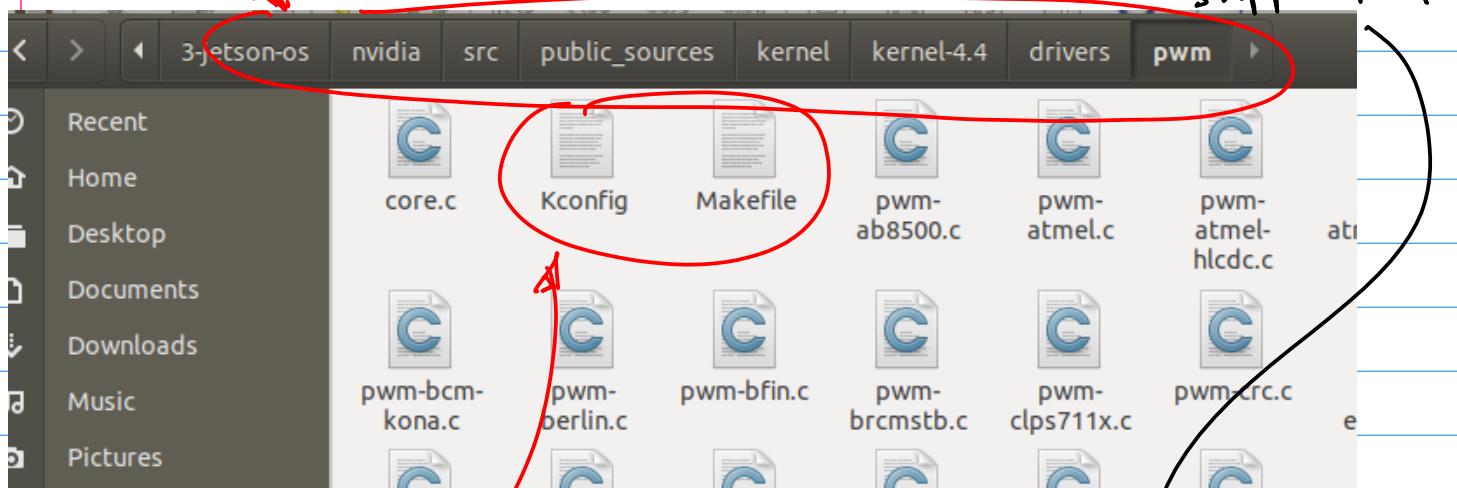
Device Driver  
Debug Development  
PWM,

In About a week Time frame,  
in-Class Brief presentation (Update, e.g.  
one paragraph Description for the  
Semester Long Project.)

Oct. 25 (Wed)

2 Person Team OR  
individual.

Q & A : Note 1. Device Driver folder, PWM Device Driver, Target Platform Device Driver: Note 2. Kernel 4.4 is chosen for my need with Ubuntu 18.04 on Jetson NAND. To Support AI.



Note 3. Two files.

KConfig → UI for menuconfig

Script per the  
Developer choice  
To Build Kernel  
image and Device  
Drivers.

makefile.

Per NVIDIA Requirements.

```

1 menuconfig PWM
2   bool "Pulse-Width Modulation (PWM) Support"
3   help
4     Generic Pulse-Width Modulation (PWM) support.
5
6     In Pulse-Width Modulation, a variation of the width of pulses
7     in a rectangular pulse signal is used as a means to alter the
8     average power of the signal. Applications include efficient
9     power delivery and voltage regulation. In computer systems,
10    PWMs are commonly used to control fans or the brightness of
11    display backlights.
12
13    This framework provides a generic interface to PWM devices
14    within the Linux kernel. On the driver side it provides an API
15    to register and unregister a PWM chip, an abstraction of a PWM
16    controller, that supports one or more PWM devices. Client
17    drivers can request PWM devices and use the generic framework
18    to interface with them directly.

```

Some support Target CPU.

```

44 config PWM_ATMEL
45     tristate "Atmel PWM support"
46     depends on ARCH_AT91 || AVR32
47     help
48         Generic PWM framework driver for Atmel SoC.
49
50         To compile this driver as a module, choose M here: the module
51         will be called pwm-atmel.
52

```

Note: Broadcom

```

77 config PWM_BCM_KONA
78     tristate "Kona PWM support"
79     depends on ARCH_BCM_MOBILE
80     help
81         Generic PWM framework driver for Broadcom Kona PWM block.
82
83         To compile this driver as a module, choose M here: the module
84         will be called pwm-bcm-kona.
85
86 config PWM_BCM2835
87     tristate "BCM2835 PWM support"
88     depends on ARCH_BCM2835
89     help
90         PWM framework driver for BCM2835 controller (Raspberry Pi)

```

Graphics Acceleration  
Unit.

Note: CPU from NXP

```

201
202 config PWM_LPC18XX_SCT
203     tristate "LPC18xx/43xx PWM/SCT support"
204     depends on ARCH_LPC18XX
205     help
206         Generic PWM framework driver for NXP LPC18
207         supports 16 channels.
208         A maximum of 15 channels can be requested
209         must have the same period.
210
211         To compile this driver as a module, choose
212         will be called pwm-lpc18xx-sct.
213
214 config PWM_LPC32XX
215     tristate "LPC32XX PWM support"
216     depends on ARCH_LPC32XX
217     help
218         Generic PWM framework driver for LPC32XX.

```

Activities Text Editor ▾

Open ▾     en  

Wed 17:07 Kconfig    

-/3-jetson-os/nvidia/src/public\_sources/kernel/kernel-4.4/drivers/pwm

```

354 netp Generic PWM framework driver for STiH4xx SoCs.
355
356 To compile this driver as a module, choose M here: the module
357 will be called pwm-sti.
358
359
360 config PWM SUN4I
361 tristate "Allwinner PWM support"
362 depends on ARCH_SUNXI || COMPILER_TEST
363 depends on HAS_IOMEM && COMMON_CLK
364 help
365 Generic PWM framework driver for Allwinner SoCs.
366
367 To compile this driver as a module, choose M here: the module
368 will be called pwm-sun4i.
369
370 config PWM TEGRA
371 tristate "NVIDIA Tegra PWM support"
372 depends on ARCH_TEGRA
373 help
374 Generic PWM framework driver for the PWM controller found on NVIDIA
375 Tegra SoCs.
376
377 To compile this driver as a module, choose M here: the module
378 will be called pwm-tegra.
379
380 config PWM TEGRA_DFL
381 tristate "NVIDIA Tegra DFL PWM support"
382 depends on ARCH_TEGRA
383 help
384 PWM driver support for the Tegra DFL module found on NVIDIA
385 Tegra SoCs.
386
387 To compile this driver as a module, choose M here: the module
388 will be called pwm-tegra-dfl.
389
390 config PWM TEGRA_PMC_BLINK
391 tristate "NVIDIA Tegra PMC blink PWM support"
392 depends on ARCH_TEGRA
393 help
394 PWM driver support for the Tegra PMC blink module found on NVIDIA
395 Tegra SoCs.
396
397 To compile this driver as a module, choose M here: the module

```

Note. TEGRA CPUs for Jetson NAND  
one of

Plain Text ▾ Tab Width: 8 ▾ Ln 330, Col 19 ▾ INS

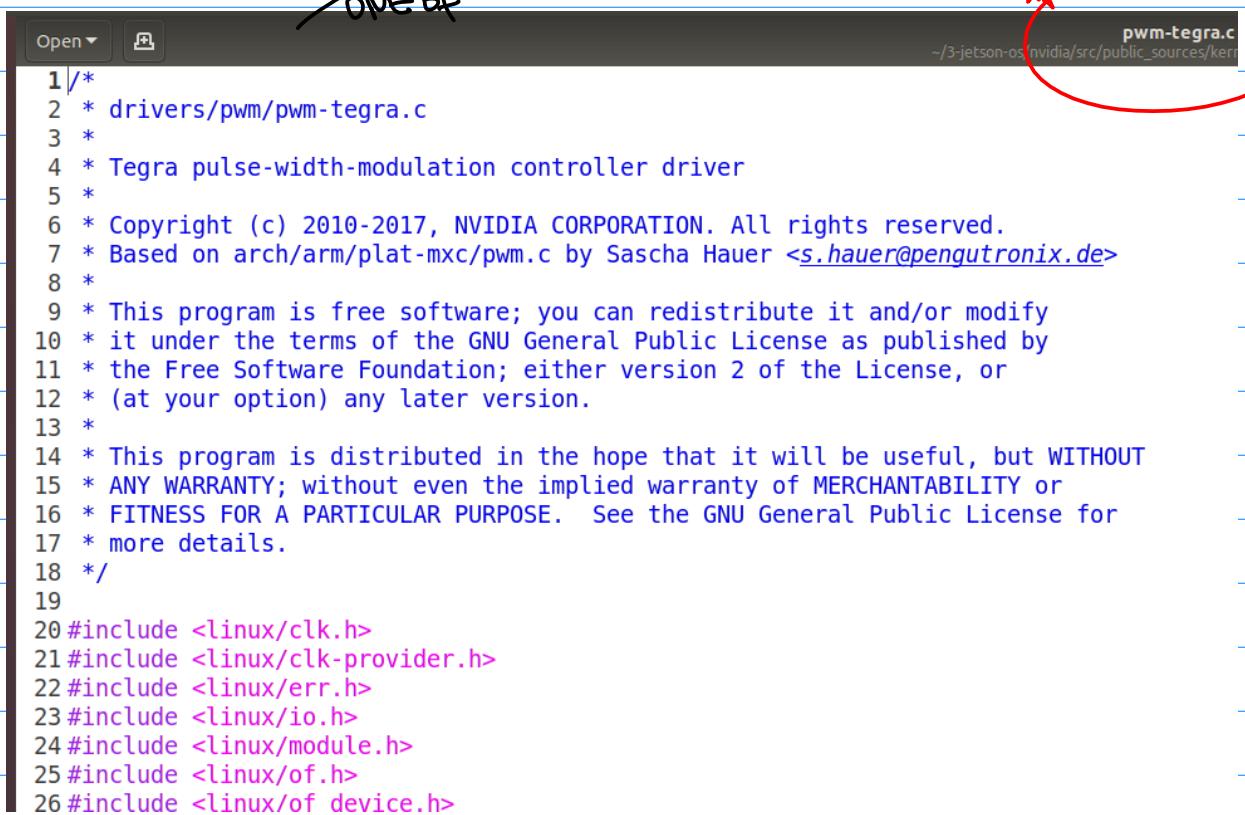
CMPE244

F2023

Note: makefile as the result output from KConf. Drivers Built 44|  
per Developer Selection.

```
File Edit View Search Terminal Help  
Subdir-ccflags-y += -Werror  
  
obj-$(CONFIG_PWM) += core.o  
obj-$(CONFIG_PWM_SYSFS) += sysfs.o  
obj-$(CONFIG_PWM_AB8500) += pwm-ab8500.o  
obj-$(CONFIG_PWM_ATMEL) += pwm-atmel.o  
obj-$(CONFIG_PWM_ATMEL_HLCD_C_PWM) += pwm-atmel-hlcdc.o  
obj-$(CONFIG_PWM_ATMEL_TCB) += pwm-atmel-tcb.o  
obj-$(CONFIG_PWM_BCM_KONA) += pwm-bcm-kona.o  
obj-$(CONFIG_PWM_BCM2835) += pwm-bcm2835.o  
obj-$(CONFIG_PWM_BERLIN) += pwm-berlin.o  
obj-$(CONFIG_PWM_BFIN) += pwm-bfin.o  
obj-$(CONFIG_PWM_BRCMSTB) += pwm-brcmstb.o  
obj-$(CONFIG_PWM_CLPS711X) += pwm-clps711x.o  
obj-$(CONFIG_PWM_CRC) += pwm-crc.o  
obj-$(CONFIG_PWM_EP93XX) += pwm-ep93xx.o  
obj-$(CONFIG_PWM_FSL_FTM) += pwm-fsl-ftm.o  
obj-$(CONFIG_PWM_IMG) += pwm-img.o  
obj-$(CONFIG_PWM_IMX) += pwm-imx.o  
obj-$(CONFIG_PWM_JZ4740) += pwm-jz4740.o  
obj-$(CONFIG_PWM_LP3943) += pwm-lp3943.o  
obj-$(CONFIG_PWM_LPC18XX_SCT) += pwm-lpc18xx-sct.o  
obj-$(CONFIG_PWM_LPC32XX) += pwm-lpc32xx.o  
obj-$(CONFIG_PWM_LPSS) += pwm-lpss.o  
obj-$(CONFIG_PWM_LPSS_PCI) += pwm-lpss-pci.o  
obj-$(CONFIG_PWM_LPSS_PLATFORM) += pwm-lpss-platform.o  
obj-$(CONFIG_PWM_MTK_DISP) += pwm-mtk-disp.o  
obj-$(CONFIG_PWM_MXS) += pwm-mxs.o  
obj-$(CONFIG_PWM_PCA9685) += pwm-pca9685.o  
obj-$(CONFIG_PWM_PUV3) += pwm-puv3.o  
obj-$(CONFIG_PWM_PXA) += pwm-pxa.o  
obj-$(CONFIG_PWM_RCAR) += pwm-rcar.o  
obj-$(CONFIG_PWM_RENESAS_TPU) += pwm-renesas(tpu).o  
obj-$(CONFIG_PWM_ROCKCHIP) += pwm-rockchip.o  
obj-$(CONFIG_PWM_SAMSUNG)
```

Note: Inspection of PWM Driver  
ONE OF



```

1 /*
2  * drivers/pwm/pwm-tegra.c
3  *
4  * Tegra pulse-width-modulation controller driver
5  *
6  * Copyright (c) 2010-2017, NVIDIA CORPORATION. All rights reserved.
7  * Based on arch/arm/plat-mxc/pwm.c by Sascha Hauer <s.hauer@pengutronix.de>
8  *
9  * This program is free software; you can redistribute it and/or modify
10 * it under the terms of the GNU General Public License as published by
11 * the Free Software Foundation; either version 2 of the License, or
12 * (at your option) any later version.
13 *
14 * This program is distributed in the hope that it will be useful, but WITHOUT
15 * ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or
16 * FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License for
17 * more details.
18 */
19
20 #include <linux/clk.h>
21 #include <linux/clk-provider.h>
22 #include <linux/err.h>
23 #include <linux/io.h>
24 #include <linux/module.h>
25 #include <linux/of.h>
26 #include <linux/of_device.h>
```

Example: Continued from

PWM Driver Code.

```

66 tcon = __raw_readl(S3C_TCON);
67 tcfg1 = __raw_readl(S3C_TCFG1);
68 tcfg0 = __raw_readl(S3C_TCFG0);
69 ... - - -
```

#### 32.4.1.3 TCON (Timer Control Register)

Register	Offset	R/W	Description
TCON	0x7F006008	R/W	Timer Control Register

TCON	Bit	R/W	Description
Reserved	[31:23]	R	Reserved Bits
Timer 4 Auto Reload on/off	[22]	R/W	0: One-Shot 1: Interval Mode(Auto-F
Timer 4 Manual Update	[21]	R/W	0: No Operation 1: Update TCNTB4
Timer 4 Start/Stoo	[20]	R/W	0: Stop 1: Start Timer 4

Oct. 23rd (Monday).

4b/

# Note 1. Project Assignment on CANVAS

CMPE258

Semester Long Team Project On Embedded Software Systems

HL

1. Design and implement a team project based on each 2-person team (or individual person). The project requirements are listed in details below. Note this project counts **total 10 points** and is due at the end of the semester and it requires a team presentation in the last week of the semester.

2. The technical requirements of the projects:

(2.1) Design and implement your team project which has to utilize embedded Linux OS on your chosen

Votez. This Coming Wednesday

Presentation of your  
project proposal, e.g.,

The Abstract.

3. One page project executive summary:

(3.1) Create one page executive summary of your project, with the following information

a. Title of the Project

b. List of each team members: First Name, Last Name, SID, Email Address, and Affiliation (such as Computer Engineering, Software Engineering, MS AI);

c. Team coordinator: Identify the team coordinator;

d. Abstract (up to one page):

Describe

(i) the objectives of the project ;

(ii) the technical challenges;

(iii) the proposed methodology to be employed;

(iv) the software tools and hardware platform;

(v) results and deliverable;

(vi) Experience gained and/or lessons learned.

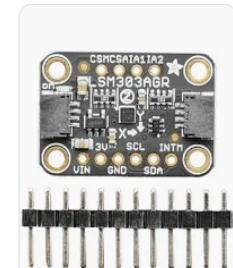
e. table with list of the work contributed by each team member

In-Class Presentation on  
Wednesday.

Homework : Nov. 1st (Wed) In-Class Demo.

1<sup>o</sup> Buy LSm303 sensor. 2<sup>o</sup> Enable  
(I2C Interface)

PWM Driver on Your target platform  
Then use Python, DR C/C++

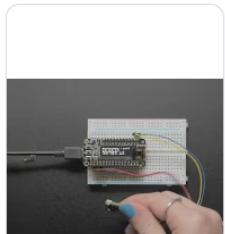


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Adafruit...

\$12.50

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To write an user program to read sensor information, and display the Sensor information on the console.

Slope: OS, Kernel Build.

Device Drivers,  
Kconfig.

Note 2: Quiz (Nov. b).

### 3' In-Class Demo Requirements:

Bring your prototype Board together with the Sensor interface to the Class for Demo.

Ref 1. from the github, First 25 slides.

[CMPE244 / 2021F-116a3-i2c-v2-hl-2021-11-18.pdf](#)

Ref 2. Command Line Commands for I2C Device Detection, and Python Sample Code.

[2023S-102-i2c-command-line-2023S-104-i2c-v2-jetson-nano-2023-02-8.pdf](#) (SPRs)

Note: Midterm Exam is to be scheduled Once the I2C Sensor interface work is covered and homework is done. Most likely in the 2nd ~ 3rd week of November.

Oct. 25 (Wed).

Note 1. Quiz Next Monday.

Please Bring Your Laptop/Prototype System to the Class.

Note 3. Midterm Exam.

Nov. 13 (Monday).

- ① Architecture CPU  
Datasheet; Device Drivers (GPIO, PWM, I2C)
- ② Cooling  $\rightarrow$  Register Level
- ③ Hard calculation for Code Debugging.

Oct. 30 Monday

Note 1. The road map for the 2nd half of the class.

- (1) Enable/design/deploy webserver solution by using GI (Gate Way Interfaces), e.g., WSGI and CGI, the first one is the backend code (engine) written in Python, the 2nd one is CGI for C/C++ based backend solution.
- (2) Design/develop/deploy ChatGPT API Version 3.5 to build technical/user support system.
- (3) APP development for the Android platform.

(4) Embedded software system will provide scalability and vertical integration. On hardware side, we will add I2C sensor interface, LSM 303.

Note 2. Midterm exam is scheduled on Nov. 13 (Monday),

(1) One hour exam, one page formula is permitted. But close book and close notes.

(2) 15 minutes for prep for CANVAS submission.

Note: all the submission has to via CANVAS to be official, no late submission will be accepted. If the system is crashed or not responding to the subssion, please do screen capture to keep the record with time stamps and your ID.

(3) Scope of the midtem: from the introduction to I2C SPR's init and configuration.

(4) format of the exam:

a. Combination of hand calculation and execution of your code.

b. you will need to bring your target platform to the exam.

c. The submitted homework, code can be reused.

d. Development platform, OS kernel compilation and build, which is a part of the subjects to be includeded.

kernel space debugging;

Kconf,

make menconfiguration;

e. Please bring your smart phone, you will need to take photos of your prototype board and the photo(s) of the actual implementation, be sure to place SID card next to your board.

f. Scree captures may be needed, to capture the execution of your code with your ID.

(5) Prepare for the submission:

a. photos to be converted to pdf;

b. take photos of your hand calculation

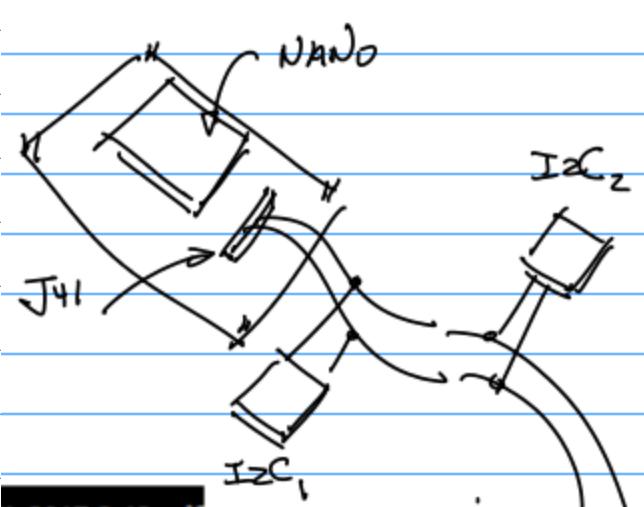
then convert the photos to pdf  
c. combine all the pdf in a proper orcler into one pdf document.

Note: please use 1024x768 resolution as a reference when taking photos.

Example: On I2C protocole and I2C sensor interface.

Ref. 1.

2022S-101-note-part2-cmpe242-2022-05-9.pdf



L 2017-3-13.pdf

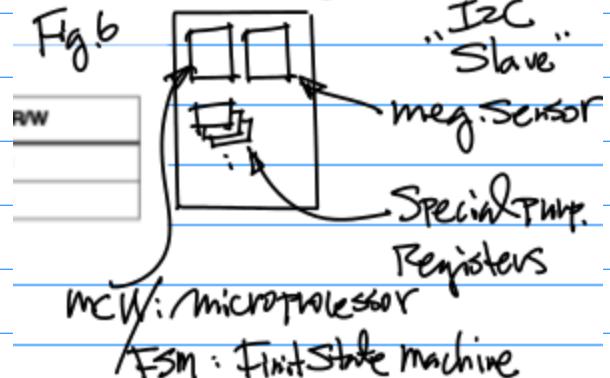
Fig.3

pp. 8

Slave Device.

LSM303

Fig.6



SPRs: Control & Control Data

- Note: 1. Master and Slave of I<sup>2</sup>C devices;  
 2. Total number of slaves possible, theoretically, up to 7 bits, e.g.,  $2^7 = 128$ .  
 3. There is a MCU inside the slave for communication with this the master and execution of commands/instructions from the master, and perform init&config and other required task. 4. In case of LSM 303, there are 3 sensors in one package.



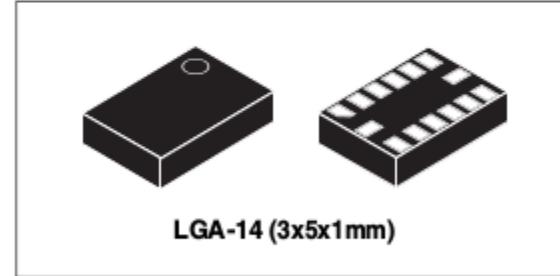
## LSM303DLHC

Ultra compact high performance e-compass  
 3D accelerometer and 3D magnetometer module

Preliminary data

### Features

- 3 magnetic field channels and 3 acceleration channels
- From  $\pm 1.3$  to  $\pm 8.1$  gauss magnetic field full-scale
- $\pm 2g/\pm 4g/\pm 8g/\pm 16g$  selectable full-scale
- 16 bit data output
- I<sup>2</sup>C serial interface
- Analog supply voltage 2.16 V to 3.6 V
- Power-down mode/ low-power mode
- 2 independent programmable interrupt



### Description

The LSM303DLHC is a system-in-package featuring a 3D digital linear acceleration sensor