

August 21 (Monday)

## Organizational Meeting.

1. The "GreenShot" 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 Department, San Jose State University
Office Location:	Engineering Building 267A
Telephone:	(408) 924-4060 (650) 400-1126
Email:	<a href="mailto:hua.li@sjsu.edu">hua.li@sjsu.edu</a>
Class Days/Time:	Mondays and Wednesdays, 4:30 pm – 5:45 pm, Aug
Office Hours:	<u>Mondays and Wednesdays, 3:00 pm – 4:00 pm</u>
Classroom:	Engineering Building Room 295
Prerequisites:	CMPE 180A and CMPE 180D, classified standing, or Computer Engineering or Software Engineering majors only.

2. Emphasis on POSIX O.S. Linux Open Source 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

Option 1. NVIDIA Jetson Nano. (GPU 128)  
4 GB Version GPU JetPack

Option 2. BroadCom Pie3B+, Pie4.

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

Selection Decision in 1 week

Option 4. NXP LPC1114 or  
LPC1779, RTOS. NXP  
Dev. Forum.

Has limited Processing power.  
May Not meet the need for our Project

#### 4. Textbook & References

Set I: Datasheet(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. Pie 3B+, or Pie 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-cxd2t?P=1z0jm4m&Keyword=LPC1769&FS=True&gclid=Cj0KCQjwqKuKBhCgARIsACf4XuHyN8WfqTQ24WGtoMdKd6n-kl7c-YNz-r1hTcPt0ErdZN62jrMQmgaAtXZEALw\\_wcB](https://www.mouser.com/NXP-Semiconductors/Embedded-Solutions/Engineering-Tools/Embedded-Processor-Development-Kits/Development-Boards-Kits-ARM/_/N-cxd2t?P=1z0jm4m&Keyword=LPC1769&FS=True&gclid=Cj0KCQjwqKuKBhCgARIsACf4XuHyN8WfqTQ24WGtoMdKd6n-kl7c-YNz-r1hTcPt0ErdZN62jrMQmgaAtXZEALw_wcB) or Option 5: Samsung ARM11 developer platform.
2. Linux Host Machine (Ubuntu 18.04).

2021F-114-handout-gpi... Add files via upload

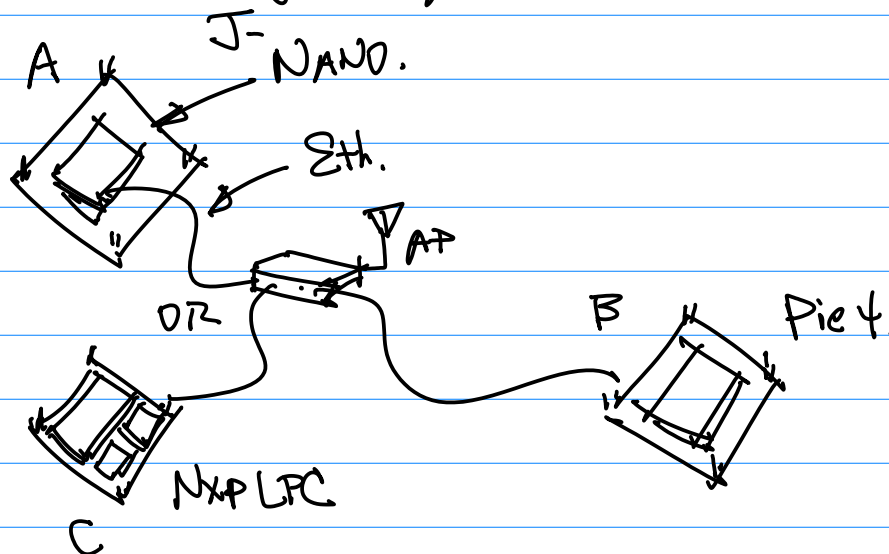
2021F-114b-pwm-nano... Add files via upload

yr. Semester ID

Naming Convention:

A & B  
A & C

Note: Regarding The Selection of A Target Platform:



## 5. Grading Policy

Project Assignment (Two Projects) <sup>Phased</sup>  
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: Rm 268

Ref: Datasheets.

C	A	D	B.
bcm	lpc	nvda	sam
Broadcom Pi Linux O.S.	NXP LPC1769 RTOS IP Stack Micro Web Server	Jetson NANO. JetPack O.S. Linux (Ubuntu) + Additional Packages.	Samsung ARM II

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

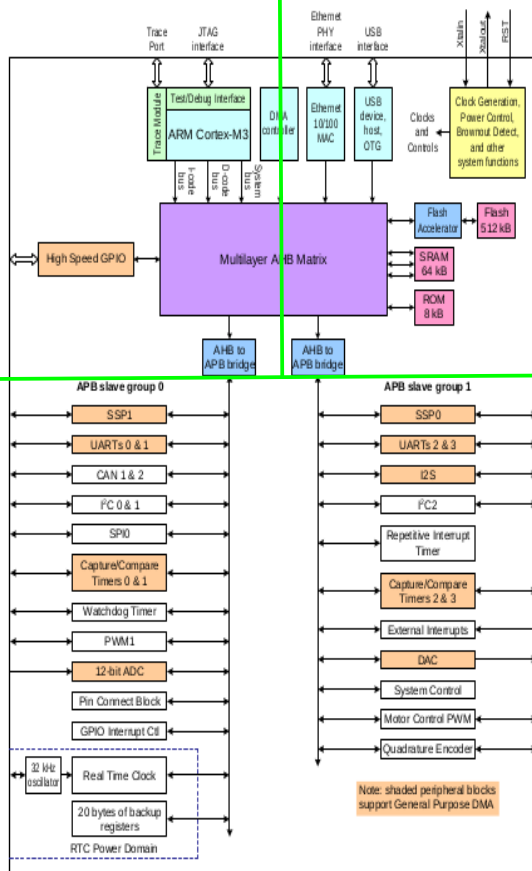


Fig 1. LPC1768 simplified block diagram

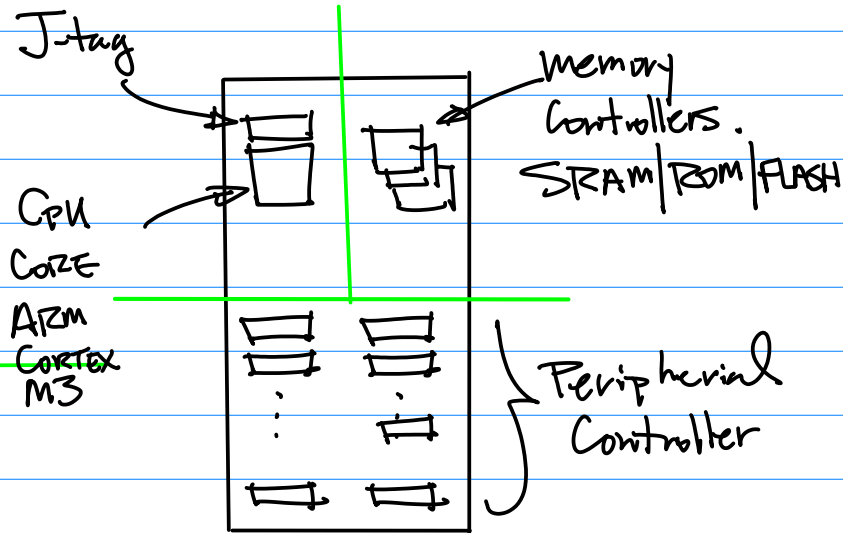
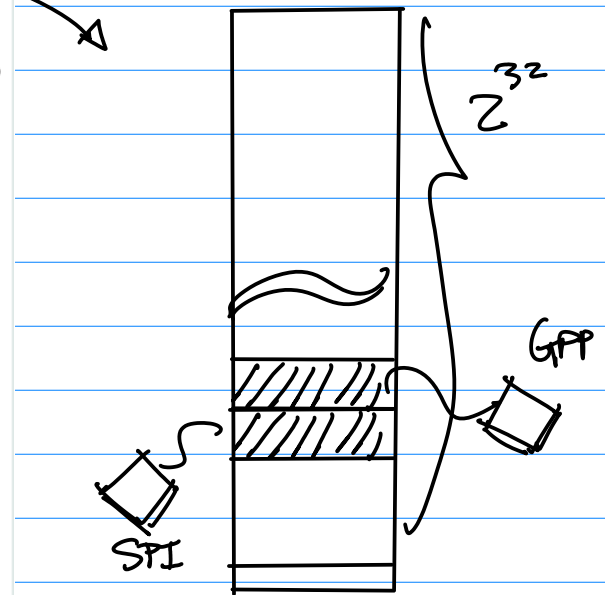
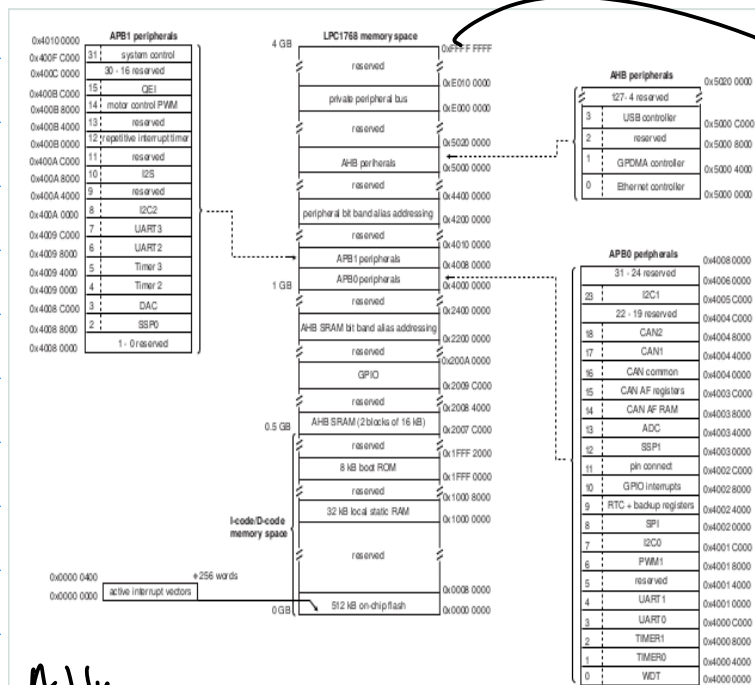


Fig. 1

Note 1: The GPU Block Diagram for LPC1769 is a Sample for the Rest of the target platforms, e.g. Pre3/4; Sam's ARM 11; NVIDIA Jetson NANO

Note 2:



0x0000-0000 PWR - up Addr.

Addr.  
 $2^{32} = 2^{10} \cdot 2^{10} \cdot 2^{10} \cdot 2^2$   
 1024 : : 4  
 1K : : 1  
 1Meg. : : 1  
 1G. : : 1  
 4 G Addresses.

Fig. 2

Datasheets.

2021F-105-#0-cpu-arm11-  
 2018S-29-CPU\_53C6410X.  
 pdf

Locate the page with the top level  
 Description of the CPU Architecture

Example: "B", Sam's CPU  
 ARM11

J-tag

CPU  
 Core  
 ARM11

GPP  
 SPI

Graphics  
 Video Codec

Memory  
 Controllers.  
 SRAM/ROM/FLASH  
 a. Graphics Engine  
 b. Video Codec  
 MPEG/H.264

Peripheral  
 Controller

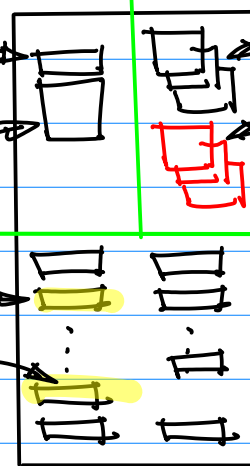


Fig. 3.

Differentiation

Vector Graphics / pixels Graphics

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Example: Connection to (Embedded)  
Software Architecture

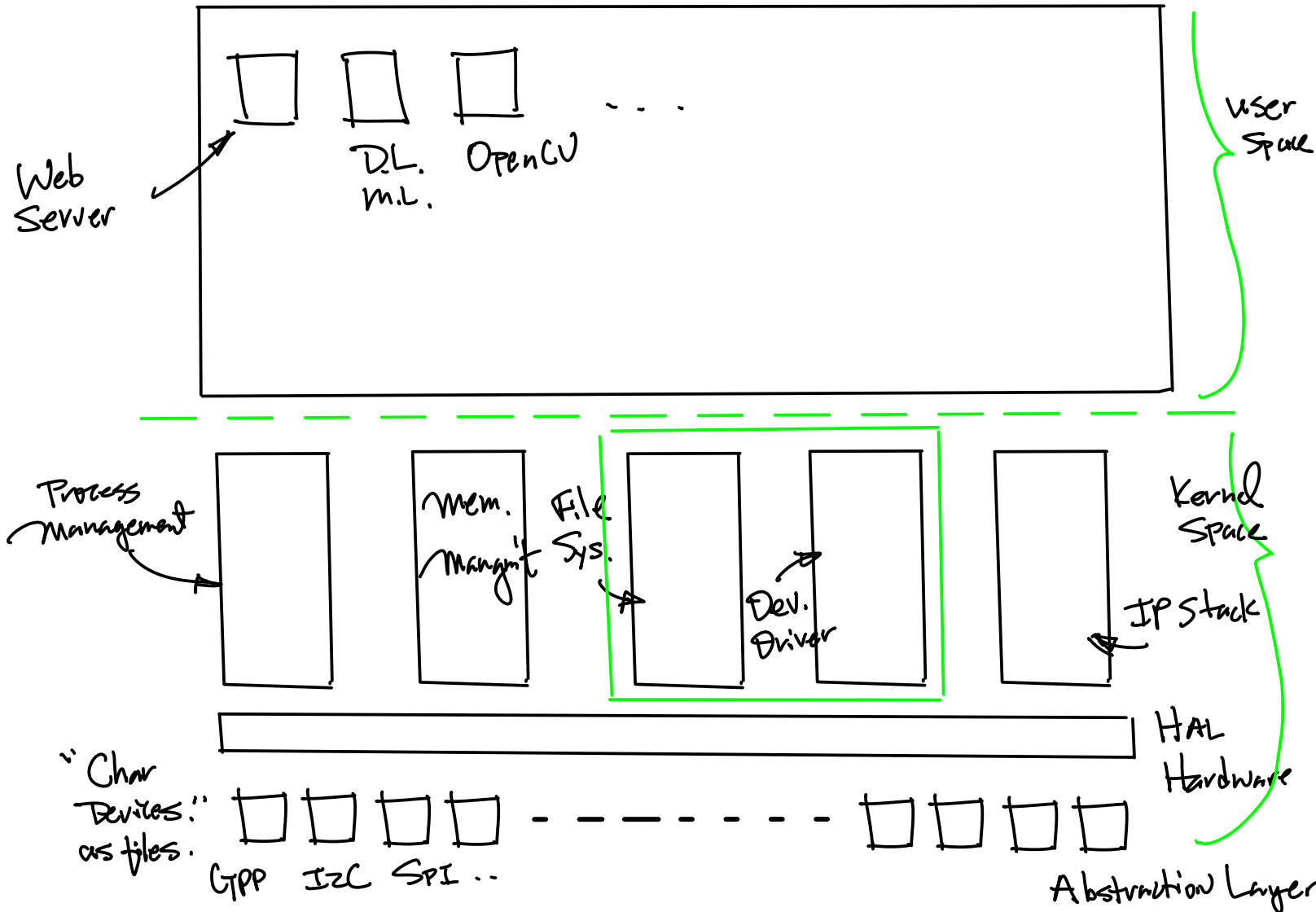


Fig.1.

Note: Data Size for 1080P  
Image 0.2 720P

August 28 (Monday)

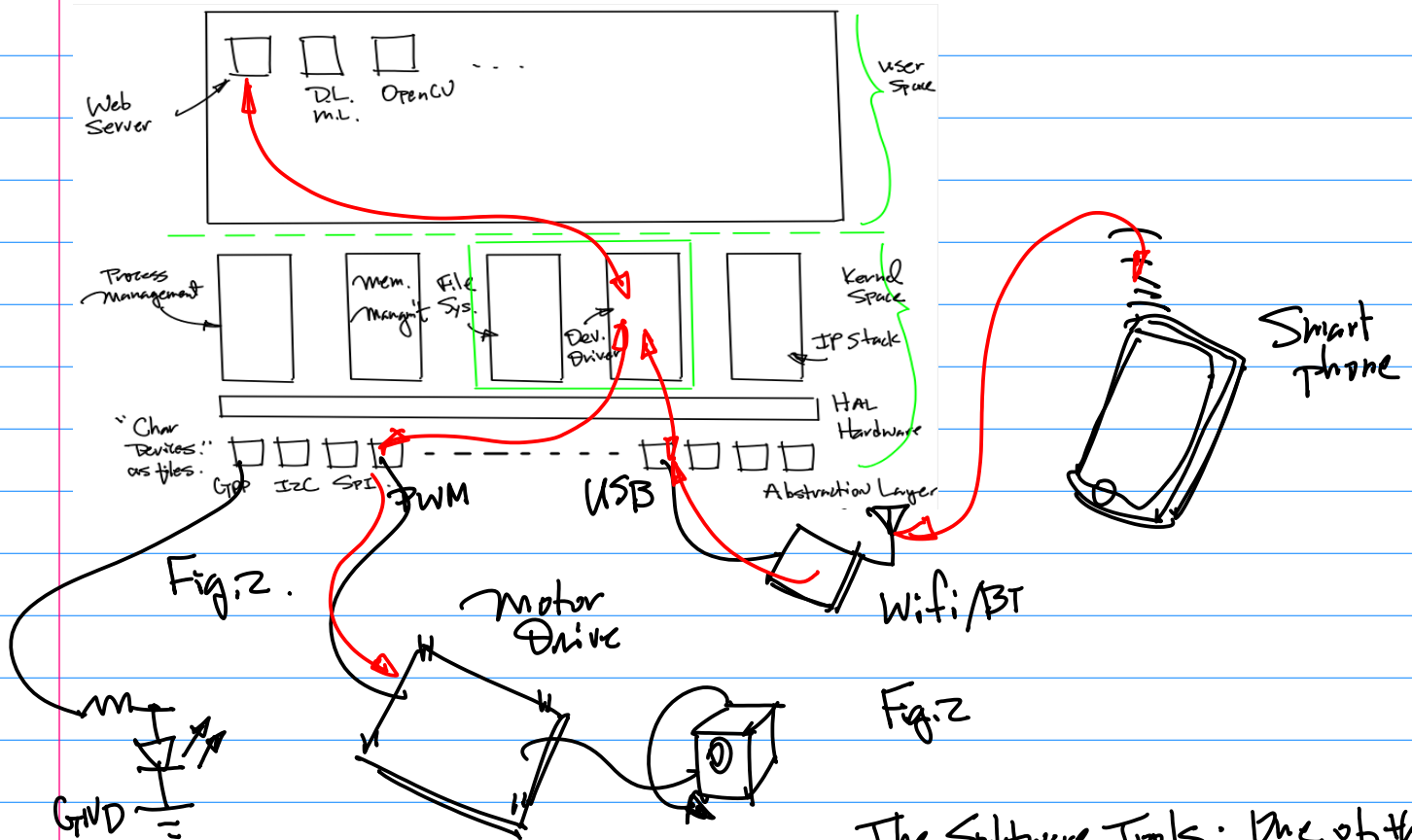
Note: 1<sup>st</sup> Brief Description on  
the Scope of Semester-Long  
Project.

Embedded Software; Kernel v.s.  
Device Driver → APPS for iPhone/  
Android phone

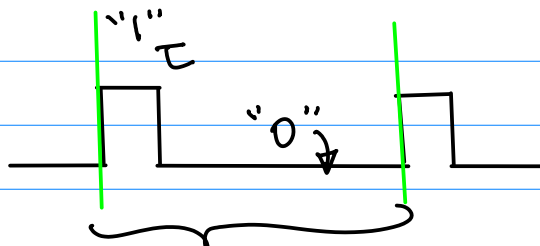
2<sup>nd</sup> CANVAS is up.  
Honesty pledge

3<sup>rd</sup> Target platform → Minor upgrade  
to Enable RTC By Adding On-Board  
Battery

Example: Continuation of the Introduction/Embedded Software Architecture.



Note: PWM — Pulse Width Modulation.



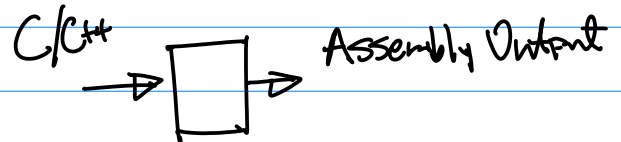
T One Period

$$\text{Duty Cycle} = \frac{\tau}{T} \dots (1)$$

$$f_{\text{PWM}} \dots (2)$$

Fig. 2

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 Addr in the Block.

151  
0x2009-C000

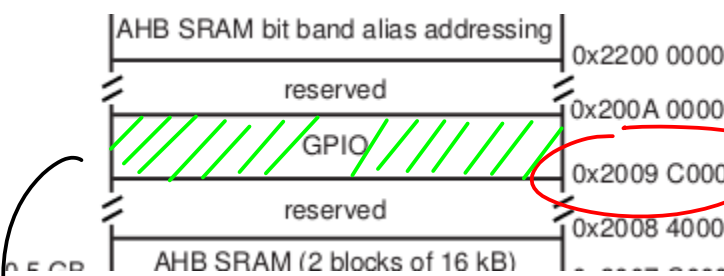
Identify A peripheral controller, GPP

Then, make a GPP as

- ① Output Port
- ② Turn on "LED"
- ③ Turn off the "LED"

See Fig. 3.

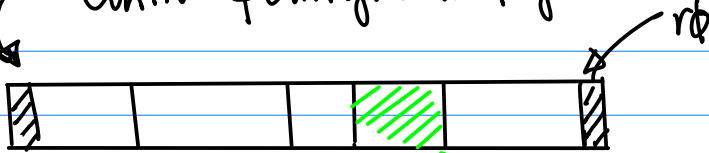
Fig. 3.



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

Go to 32Bit Control/Configuration  
Register. To Define Init & Conf.  
for GPP output.

Control & Configuration Register



For Selection of Port &  
Pin(s).

4 G Possible Configurations Theoretically  
( $2^{32} = 2^7 \cdot 2^{10} \cdot 2^{10} \cdot 2^{10}$ )

Coding (Software Aspect)

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

Next. Naming Convention.

Guideline:

RTSC → UC Berkeley David  
Patterson  
Stanford, John. Hennessy.

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

0x2009-C000  
GPPx CON

1K 1K 1K  
1M

1 G.





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Porting    Porting  
gcc/g++ → ARM → CORTEX  
Porting ↓  
Board

Sept 6 (Wed).

Note: 1<sup>st</sup> Target Board  
Inspection:

Purpose: J41 Connector

RTC Battery  
Ref: ON the github.

2021F-114 ~

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

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## 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	6	GND	
gpio216	AUDIO_MCLK	7	8	UART_2_TX /dev/ttyTHS1	
	GND	9	10	UART_2_RX /dev/ttyTHS1	
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_1_CS0	gpio19
	GND	25	26	SPI_1_CS1	gpio20

Sysfs GPIO	Name	Pin	Pin	Name	Sysfs GPIO
	GND	25	26	SPI_1_CS1	gpio20
	I2C_1_SDA I2C Bus 0	27	28	I2C_1_SCL I2C Bus 0	
gpio149	CAM_AF_EN	29	30	GND	
gpio200	GPIO_P20	31	32	LCD_BL_PWM	gpio168
gpio38	GPIO_PE6	33	34	GND	
gpio76	I2S_4_LRCK	35	36	UART_2_CTS	gpio51
gpio12	SPI_2_MOSI	37	38	I2S_4_SDIN	gpio77
	GND	39	40	I2S_4_SDOUT	gpio78

Harry Li, Ph.D.

Note 1<sup>st</sup> Power Pins

GND: 6/9/25/39  
V<sub>out</sub>: 3.3VDC/5VDC  
Pin 1 / Pin 2, 4.  
V<sub>in</sub>: J25 (5A or higher @ 5VDC)

Note 2<sup>nd</sup> GPIO

J41 Pins

J41-12

J41-40

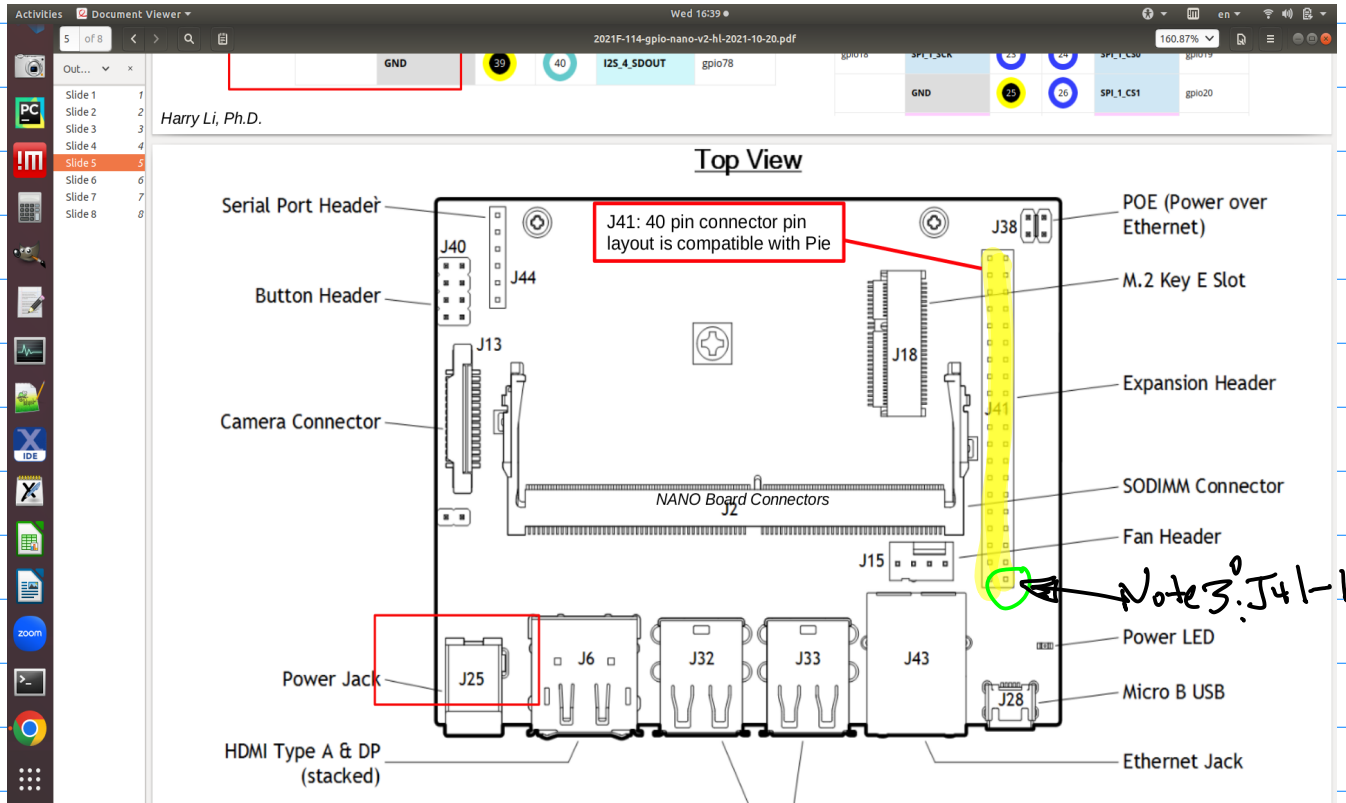
CPU Functionality

gpio79

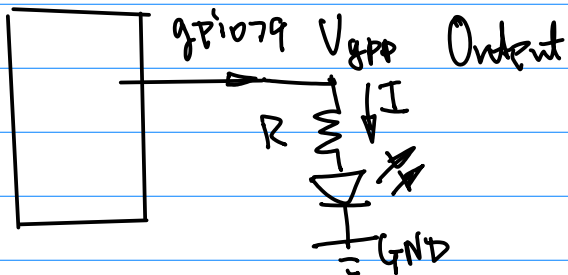
gpio78

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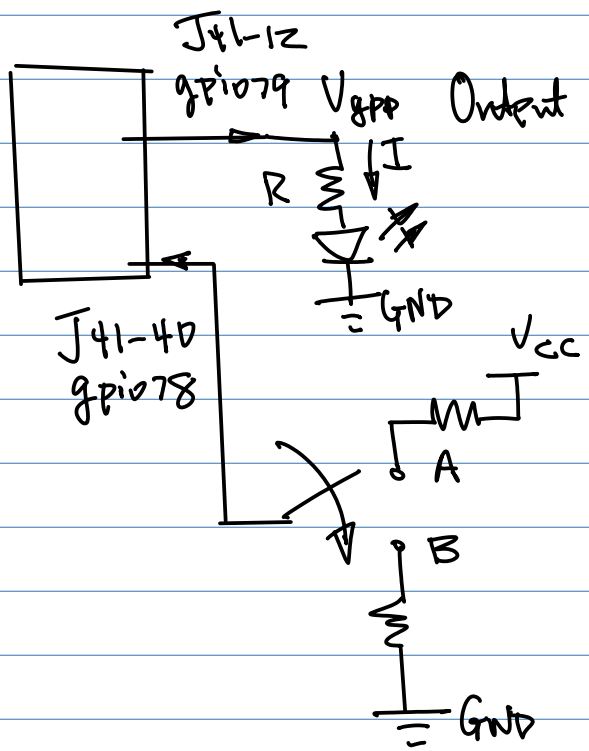
Note 4<sup>o</sup>: GPIO Input/Output Testing CKT  
Build the following Testing CKT.



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

$$V_{gpp.H} = IR + V_{LED} \dots (1)$$

W/o Resistor with Proper Selected LED.

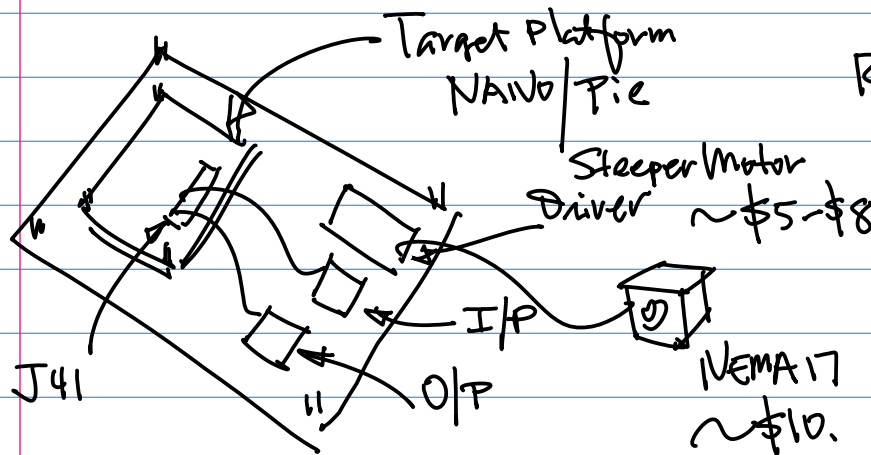


GPIO J41 Pins	CPU Functionality	Note
J41-12	gpio79	Output
J41-40	gpio78	Input

Code { User Space Code  
Kernel Space Code

Take a Reference Design from ARM || 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.

Scoop: Hardware Layer  
(Sensors/Actuators)  
↓  
"Security"  
Device Driver/Kernel Space  
↓  
Process Management

Web Server

Smart phone APPs.

Check GPT 3.5 API + Python Interface

Example: Sample Code for GPP 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 Git

```
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)

Note 1. Homework, Due in 1 1/2 Weeks.

To Be posted on Line today;

- Bring up the target, Screen Capture with Personal Identifier.
- GPIO Testing (Python + Hardware Circuit).

Note 2: B.o.M. (Bill of Material)  
for the class/Project

a. Motor (1) 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.

NVDA JetPack (O.S.)

Note:

With gpio Testing  
Ckt.

(Work-In-  
Progress)

Target  
Board

Prototype  
Board.

NVDA Jetson Nano Bread Board/

OR Wirewrapping  
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

```
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
```

Note 1: "Char" Device. open the Device just like a file.

Kernel (O.S. Image)  
path to the Device.  
The Device Driver can be either integrated as the whole kernel image OR module (Installed/Removed)

Note 2: for passing control parameter(s) to the Device for Control Action.

Note 3. Close it, when Done !



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Build  
Kernel image using  
"menuconfig"

Android.

→ NVDA, Broadcom, Smart phones  
Embedded

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

Linux/arm 2.6.38 Kernel Configuration
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

General setup --->
[*] Enable loadable module support --->
-* Enable the block layer --->
  System Type --->
  Bus support --->
  Kernel Features --->
  Boot options --->
  CPU Power Management --->
  Floating point emulation --->
  Userspace binary formats --->
  Power management options --->
[*] Networking support --->
  Device Drivers --->
  File systems --->
  Kernel hacking --->
  Security options --->
-* Cryptographic API --->
  Library routines --->
  Load an Alternate Configuration File
  Save an Alternate Configuration File

<Select> < Exit > < Help >
```

```
.config - Linux/arm 2.6.38 Kernel Configuration

Device Drivers
Arrow keys navigate the menu. <Enter> selects submenus --->. H
<Y> includes, <N> excludes, <M> modularizes features. Press <Es
Search. Legend: [*] built-in [ ] excluded <M> module < > mod

^(-)
  SCSI device support --->
  < > Serial ATA and Parallel ATA drivers --->
  [ ] Multiple devices driver support (RAID and
  < > Generic Target Core Mod (TCM) and ConfigFS
  [*] Network device support --->
  [ ] ISDN support --->
  < > Telephony support --->
  Input device support --->
  Character devices --->
  <*> I2C support --->
  [ ] SPI support --->
  PPS support --->
  -* GPIO Support --->
  < > Dallas's 1-wire support --->
  < > Power supply class support --->
  <*> Hardware Monitoring support --->
```

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

```

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

-* Virtual terminal
[ ] Support for binding and unbinding console
[ ] 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
<M> Harry: Mini6410 Test module
<M> Harry: Mini6410 PWM2 module
< > Buttons driver for FriendlyARM Mini6410 deve
< > Buzzer driver for FriendlyARM Mini6410 devel
< > ADC driver for FriendlyARM Mini6410 develop
[ ] Non-standard serial port support
< > GSM MUX line discipline support (EXPERIMENTA
Serial drivers --->
-* Unix98 PTY support
[ ] Support multiple instances of devpts
[*] Legacy (BSD) PTY support
(16) Maximum number of legacy PTY in use
[ ] ARM JTAG DCC console
< > TPM1 top-level message handler --->

```

(N|b|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
20-20215-9-mini6410_pwmHarry.c  ip2  misc.c  rtc.c
2q  ipmi  misc.o  scc.l
agp  isicom.c  mmtimer.c  scx20
amiserial.c  installion.c  modules.built.in  ser_
apm-emulation.c  Kconfig  modules.order  ser_
applicom.c  lp.c  moxa.c  ser_
applicom.h  Makefile  moxa.h  ser_
bfin_jtag_comm.c  Makefile-backup  mspec.c  seri
bfin-otp.c  mbcs.c  nwave  snsc
briq_panel.c  mbcs.h  mxser.c  snsc
bsr.c  mem.c  mxser.h  snsc
built-in.o  mem.o  nozomi.c  sonyi
cd1865.h  mini6410_adc.c  nse_gpio.c  spec
cyclades.c  mini6410_adc.mod.c  nvram.c  spec
digi1.h  mini6410_adc.o  nwbutton.c  stal
digiFep1.h  mini6410_buttons.c  nwbutton.h  sxboi
digiPCI.h  mini6410_buttons.o  nwflash.c  sx.c
ds1302.c  mini6410_hello_module.c  pc8736x_gpio.c  sx.h
ds1620.c  mini6410_hello_module.ko  pcmcia  sxwi
dsp56k.c  mini6410_hello_module.mod.c  ppdev.c  sync
dtlk.c  mini6410_hello_module.mod.o  ps3flash.c  sync
efirtc.c  mini6410_hello_module.o  ramoops.c  sync
epca.c  mini6410_leds.c  random.c  tb02
epcaconfig.h  mini6410_leds.ko  random.o  tlcl

```

2025-10-4  
(CMPE242)