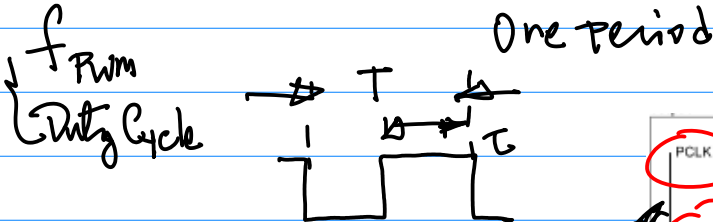


March 16 (Wed)

Topics: 1° PWM Architecture/Hardware
Aspect — Waveforms,
Timing Diagrams, SPZs
2° LSM303 Sensor I2C

Example: PWM Discussion.



Duty Cycle = $\frac{T_{on}}{T} \dots (1)$.
Square Wave: D.C. = 50%.

Architectural Aspects:

2021F-105-#0-cpu-arm11-2018S-29...

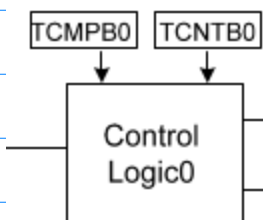
6410X_UM

32

PWM TIMER

This chapter describes the functions and usage of PV

d. Special Purpose Registers



CONF (Configuration Register)

CNT (Control — "Count")

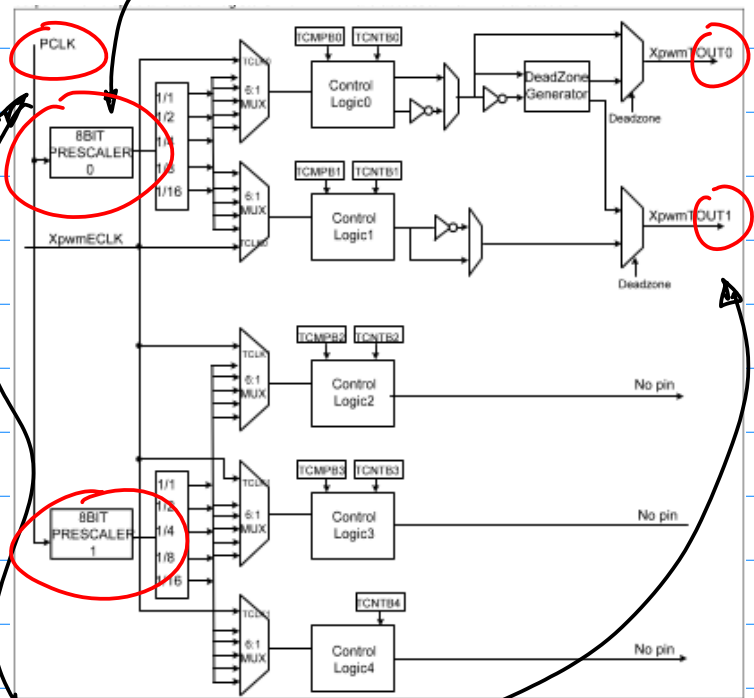
CMP (Comparison)

define f_{PWM} & Duty Cycle.

C. Prescaler for f_{PWM} Config

8 bit

PP1107



a. Input: PCLK peripheral clock.

$\frac{1}{2}, \frac{1}{4}, \frac{1}{8}, \dots$ of the System Clock

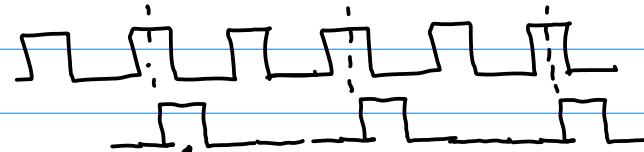
b. Output (2 outputs)

2022S-107e-pwm-waveform-v3-2018-3-4.jpg

2022S-107f-pwm-specialPurposeRegister-v3-2018-3-4.jpg

2022S-107g-pwm-calculation-v3-2018-3-4.pdf

Note: Background on Counters.



Count By 2

Expand this to A counter for Both integer Number & Fractional Number (in general) $\Rightarrow f_{PWM}$ (for integer Only) then, use Another Counter to get Duty cycle.

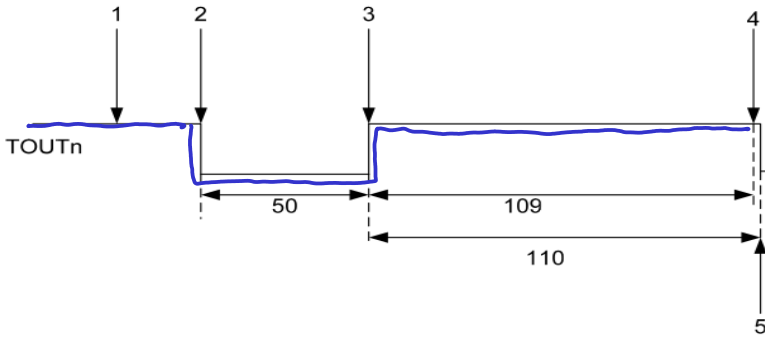
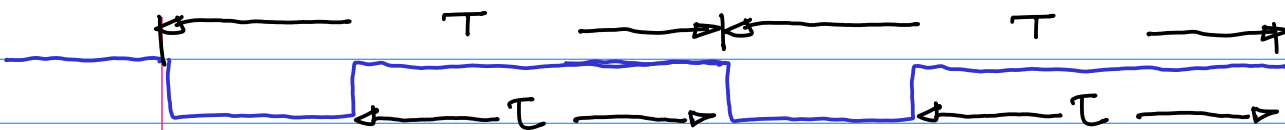


Figure 32-2. Simple Example of PWM Cycle Block Diagram



$$T = \frac{1}{f_{PWM}} \dots (2), \quad f_{PWM} = \frac{PCLK}{(\text{Prescaler} + 1) \text{Div}} \dots (3)$$

Frequency = $PCLK / (\{\text{prescaler value} + 1\} / \{\text{divider value}\})$

$$\text{Suppose } PCLK = \frac{1}{4}(\text{System Clock}) = \frac{1}{4}(800 \times 10^6) \\ = 200 \times 10^6$$

Defined By Special Purpose Register.

Design Guidelines for PWM:

① CNT (TCNTB0) Define f_{PWM}
COUNT/Timer Buffer for PWM

③ CONF Configuration Register. Defines f_{PWM}

② CMP (TCMPB0) Defines Duty Cycle
Comparison

Example: Suppose $PCLK = 500 \times 10^6$ (MHz), Find the Counts for TCNTB0
Suppose to Drive A Stepper Motor $f_{PWM} = 2 \text{ kHz} = 2 \times 10^3$
 $\frac{PCLK}{N} = f_{PWM} \dots (4)$

$\frac{PCLK}{N} = f_{PWM}$, Substitute the design requirements into it.

$$\frac{500 \times 10^6}{N} = 2 \times 10^3$$

$$\therefore N = \frac{500 \times 10^6}{2 \times 10^3} = 250 \times 10^3$$

Verify if TCNTB₀ can hold up to that Number

pp1117

32.4 SPECIAL FUNCTION REGISTERS

32.4.1 REGISTER MAP

Register	Offset	R/W	Description
TCFG0	0x7F006000	R/W	Timer Configuration Register two 8-bit Prescaler and Dec
TCFG1	0x7F006004	R/W	Timer Configuration Register and DMA Mode Select Bit
TCON	0x7F006008	R/W	Timer Control Register
TCNTB0	0x7F00600C	R/W	Timer 0 Count Buffer Register
TCMPB0	0x7F006010	R/W	Timer 0 Compare Buffer Register
TCNT00	0x7F006014	R	Timer 0 Count Observation
TCNTB1	0x7F006018	R/W	Timer 1 Count Buffer Register

2³²

32.4.1.4 TCNTB0 (Timer0 Counter Register)

Register	Offset	R/W	Description
TCNTB0	0x7F00600C	R/W	Timer 0 Count Buffer Register

Conclusion: 5-Steps operation of PWM. Can be described as (1) Count By N with Eqn (4), pp3. And deposit

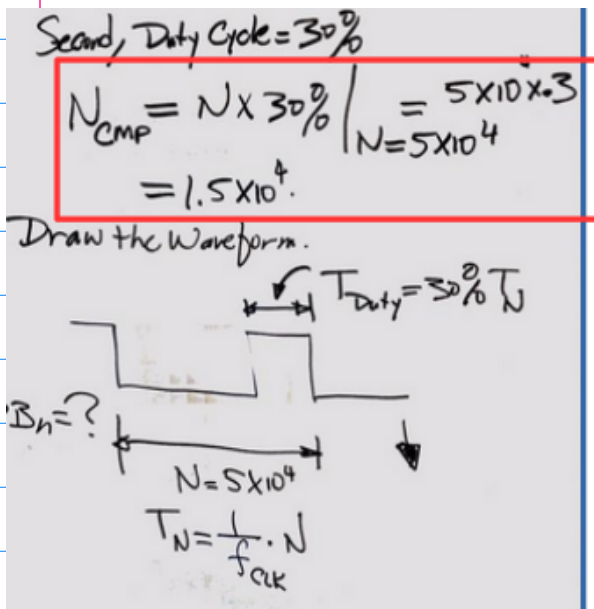
N into TCNTB₀; (2)

Deposit Count M into TCMPB₀, where $M = (D.C.) \times N$... (5)

(3) The Down Counting will decrement TCNTB₀'s count by 1 at a time, And a

Comparison is made to TCMPB₀, if matched, then trigger the Output to "1", Down Counting continues till the Count in TCNTB₀ = 0 One period is reached. Then Repeat this process.

Feb. 21. 21.
Example: Suppose CLK = 50 MHz.
Design Implementation Technique to produce $f_{PWM} = 1000$ Hz, to Drive Stepper motor Controller, in addition, Duty Cycle is 30%.
Find: (1) TCNTB_n = ? ; (2) Find TCMPB_n
Sol: First, find the Counts N Based on the given condition.
 $\frac{50 \times 10^6}{N} = f_{PWM}$... (1)
 $N = \frac{50 \times 10^6}{1 \times 10^3} = 5 \times 10^4 \rightarrow \text{Hex}$ $f_{PWM} = 1000$
TCNT_n ←



Software Side O.S. distribution.

- Toolchain,
- menu config.

f. SPIs in Driver Code.

GPIO user program.

```
fd = open("path/Driver");
ioctl(
```

Kernel Space Program Sample

GPECON, etc → CPU
Datasheet

g. GPIO Testing, I/P Testing
O/P Testing.

Ref:

2022S-101-notes-cmpe242-3-14.pdf

PP.9

CKT → Pin Selection

gpio 79 (pin 2)

gpio 78 (pin 40)

2.

Question(s) on PID Controller Design.

Hardware → Motor Drive
Software → GPP/PWM

Motor Drive Pin Connection Requirements
Sch. , Connectivity Table.

March 21 (Monday)

Midterm on 23rd (Wed).

1 hr. Exam, + 15 min.

Review on Midterm.

3 Questions.

1. A question on Basic Concepts.

1. CPU Architecture

32 Bit Architecture

a. Memory map, Banks,

b. GPP/IO Peripheral Controller.

c. SPIs. Naming, functions.

GPX CON, GPX DAT

Tech. Spec → Binary Pattern

d. ARM11 Reference, Code

User Space, Kernel Space

e. Target Platform, NAND,

"Demo" Live Execution of your program.

i. Board is Ready. Take a photo of your Board During the exam.

ii. Stepper motor/motor Drive And the Prototype Board work together, Take a photo, Screen Capture of program execution.

motor Operation, micro steps, Angular Displacement.

Target Platform. Hardware Configuration to access device driver, such as GPIO, PWM or I2C.

3. Theoretical Aspects of the PID Controller Design.

a. PID Block Diagram.

P_N , PI_N , PD , ... etc.
Derivative Controller) Short
future.

I (Integration Controller) history

b. Computation. Forward Difference, Backward Difference, Central Difference. Kernels, Computation.

Integration Controller. history
Back N steps

c. Sensor Interface Hardware I2C I/F.

LSM303 I2C Based Sensor.

Example: An Application of LSM303

2022S-108b-AngularSensing-i2c-LSM303- final HL 2017-3-13.pdf

Roll angle of the vehicle, "skipping" may occur

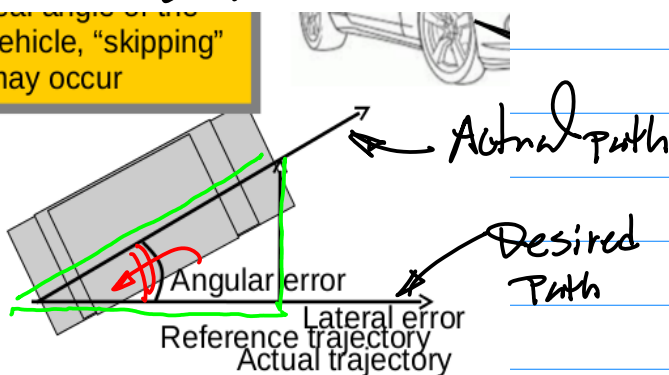


Fig 1.

α : from LSM303
 \vec{p}_A : is measurable

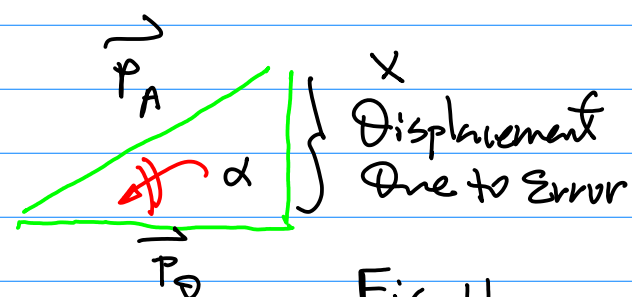


Fig. 1b

Cmpt242 March 21, 22

Find $\|\vec{P}_A\|$ is defined by
PWM Driven Stepper motor
action.

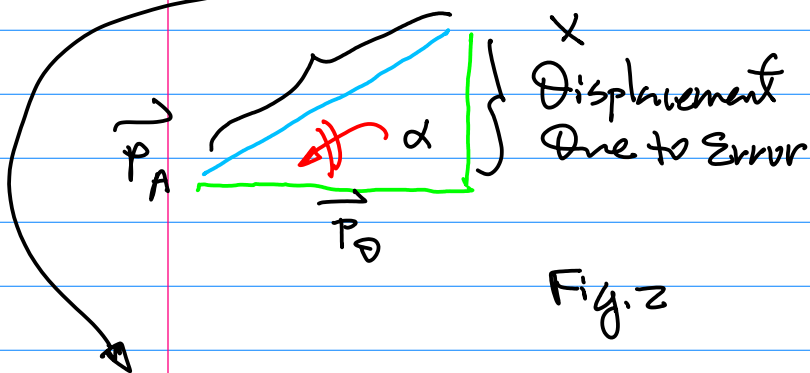


Fig. 2

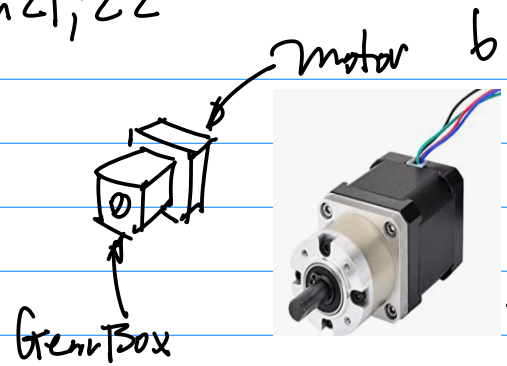


Fig. 3.

STEPPERONLINE Nema 17 Geared Stepper
Motor Gear Ratio 5:1 3D Printer Extruder
Motor DIY CNC Robotics
Visit the STEPPERONLINE Store
★★★★★ 25 ratings
Amazon's Choice In 3D Printer Motors by STEPPERONLINE
\$40⁰⁵

Reduction Ratio, R_R

For the purpose of increasing the
Torque.

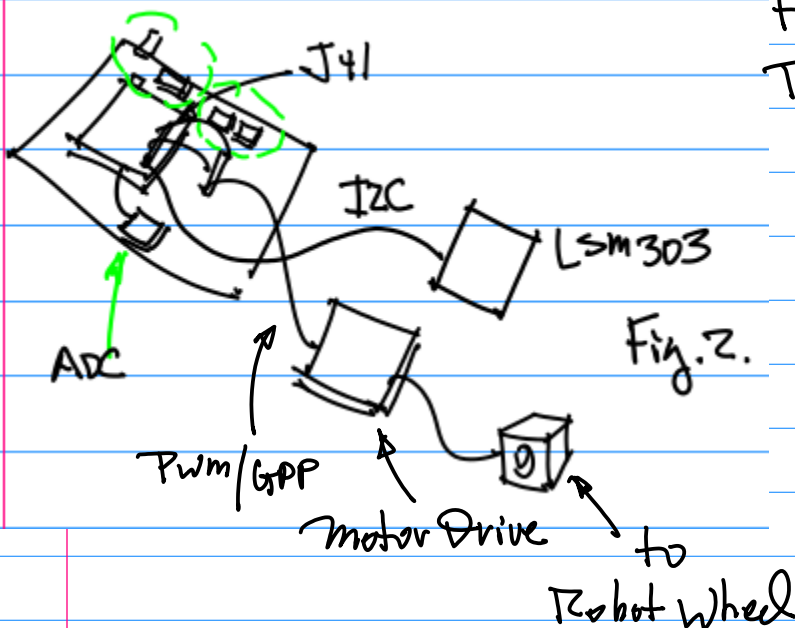
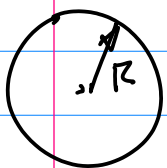


Fig. 2.



Fig. 4a, 4b With Reduction Ratio.
Gear Box.



the wheel of the
Robot has the
dimension $R = 100\text{mm}$

Now, Let's take a look at
the hardware of the motor
Combo.



To find / Establish one-to-one mapping Between the actual Path and PWM Operation.

April 4 (Monday)

Topics: 1^o I2C Interface for LSM303 Sensor Integration.

Ref:

2022S-108b-AngularSensing-i2c-LSM303- final HL 2017-3-13.pdf

I2C Hardware Features

{ Protocol Definition

Coding Implementation

Hardware Features:

1. Pins { SDA: Bi-Directional Data Pin. (Signals in Both Direction)
SCL: Serial Clock.

Speed: $\sim 4 \text{ mbps}$, $\leq 10 \text{ mbps}$

2. I2C Bus

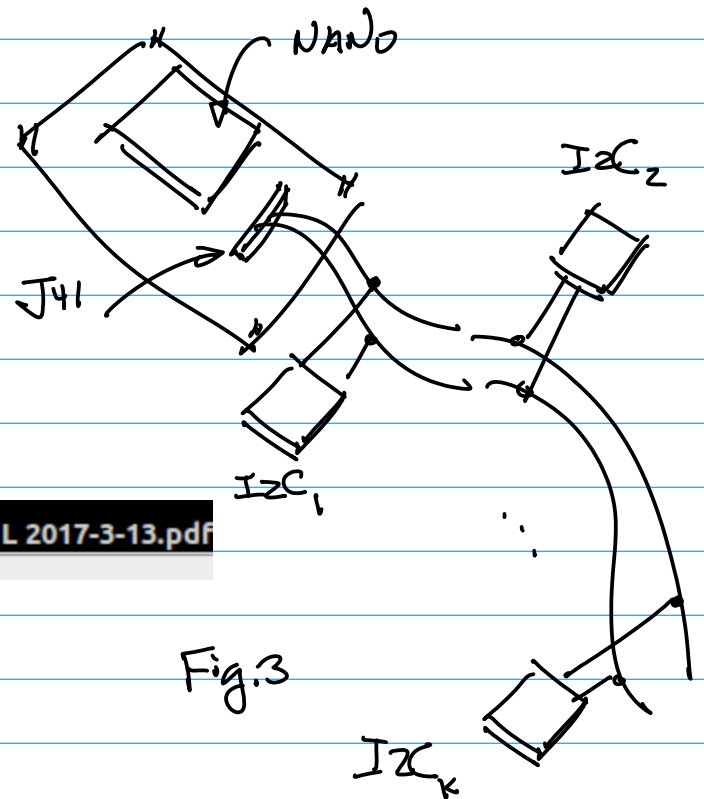


Fig.3

Sub-Address: 7 bits, $2^7 = 128 \rightarrow K = 128$ Devices, But in Real Engineering Design, "FAN-IN", "FAN-OUT" (e.g. Adequate Electric Current) have to be taken into consideration.

Bus Communication { Master Device
Slave Device(s)

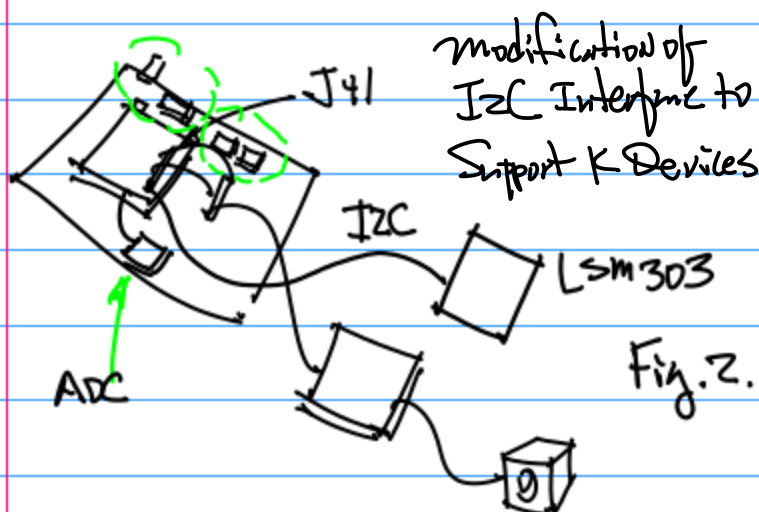


Fig.2.

Ref:

2022S-108-LSM303DLHC.PDF

I2C Interface

- (1) The transaction started through a START (ST) signal, defined as a high-to-low on the data line while the SCL line is held high.
- (2) After ST, the next byte contains the slave address (the first 7 bit), bit 8 for if the master is receiving or transmitting data.
- (3) When an address sent, each device compares the first seven bits after ST. If they match, the device is addressed.

CMPE242 Apr 24, 22

8

Note: t_0, t_1, t_2, t_3

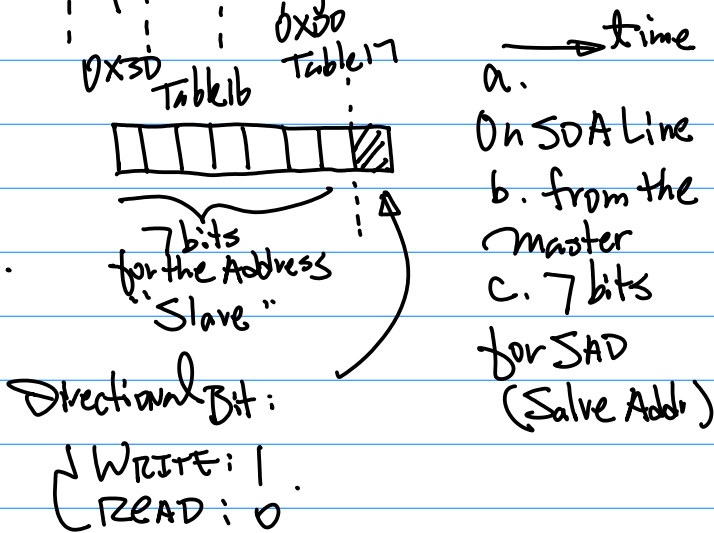
Table 11. Transfer when master is writing one byte to slave, pp 20, datasheet

Master	ST	SAD + W	SUB	DATA	SP
Slave		SAK	SAK	SAK	

Note: Space-Time Diagram.

→ Space
Target (NAND) "Slave"
I2C Master LSM303

Fig. 4.



Note: 1° ST Start

2° SAD Slave Address

3° SAK Slave Ack.

Question: SAD for LSM303

Table 14. SAD+Read/Write patterns

Command	SAD[7:1]	R/W	SAD+R/W
Read	0011001	1	00110011 (33h)
Write	0011001	0	00110010 (32h)

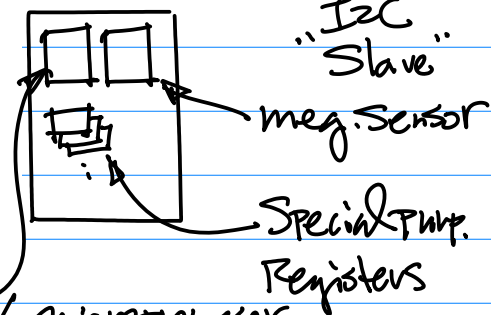
0011001X
3
(1) 0011 Read: 3
(2) 0010 Write: 2

0X33 Read
0X32 Write

Note: Read Op is very often the 1st one from the master. to get Manufacturer's ID & Device ID etc.

And at t_3 : SUB Sub-Slave-Addr. to Address the unit inside the Slave Device.

Fig. 6

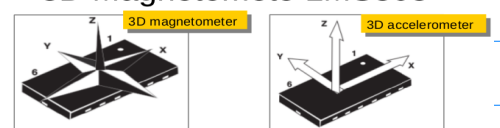


FSM: Finite State Machine

SPRs: Config & Control, Data Sensing

Example: Find Sub Addr.

3D Accelerometer and 3D Magnetometer LSM303



Ref: Slide 7. a. Sub-Addr. for Magnetic Sensor

2. identify control register(s) for the right sensor block with the sub-address to set data rate
(1) CRA_REG_M register (0x00) to set data rate

Control/Config Register's Address: 0x00
"SUB"
For Magnetic Sensor.

Table 16. SAD

Command	SAD[6:0]	R/W	SAD+R/W
Read	0011110	1	00111101 (3Dh)
Write	0011110	0	00111100 (3Ch)

Table 17. Register address map (continued)

Name	Slave address	Type	Register address		Default
			Hex	Binary	
TIME_LATENCY_A	Table 14	rw	3C	011 1100	00000000
TIME_WINDOW_A	Table 14	rw	3D	011 1101	00000000
Reserved (do not modify)	Table 14		3E-3F	--	--
CRA_REG_M	Table 16	rw	00	00000000	0001000
CRB_REG_M	Table 16	rw	01	00000001	0010000
MR_REG_M	Table 16	rw	02	00000010	00000011
OUT_X_H_M	Table 16	r	03	00000011	output

Example: Tech Spec.

1° Read Angular Information / x-, y-, z- Acceleration
2° Sample Rate (of Read): 30 Hz

Find 1° Special Purpose Register Responsible to perform Configuration.

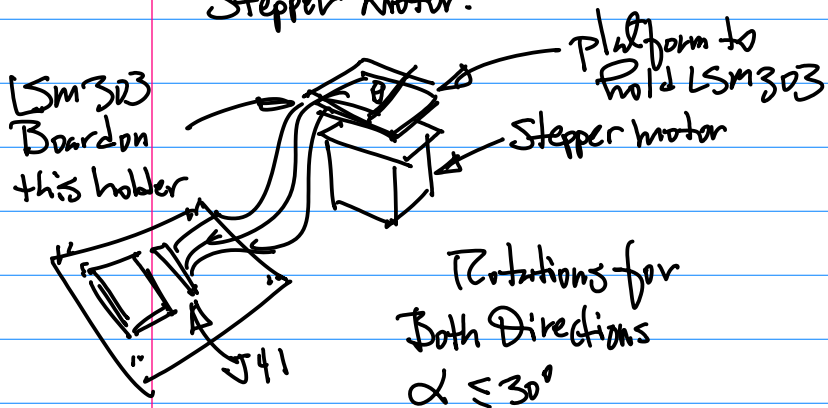
2° Find Binary Pattern to initialize the SPR.

April 7, Wed

Topics: 1° LSM-303 Interface Design.
Project Due April 18 before Class.

Project Requirements:

1. Written Assignments + Tutorials
Are to Be posted online,
on CANVAS.
2. Integrate L5M303 Sensor to
Stepper motor.



3. To Run Stepper motor program to Actuate motor Rotation, then Read LSM303 Data to find for each Actual the displacement Value.
4. Test 3 Configuration of the motor, e.g.
 - a. Full Step. 1.8 Degree Angle per Step.
 - b. Half Step. 0.9 Degree
 - c. $\frac{1}{4}$ Step. 0.45 Degree

5. Form A table to List the Data Read from Lsm 303

pwm pulses	LSM303 Input

Note: Try to Run multiple pulses of the PWM, for Example, 5 to 10 Pulses. When Collecting Data

6. Create Readme file, one page to Describe your implementation.
 - a. Schematics
 - b. Screen Capture of your code execution
 - c. Generate 10 Sec. ~ 15 Secs Video Clips to Show the working system.
 - d. 2 photos.
 - One for the entire System.
(Laptop, Target Platform, Stepper motor, Sensor)
 - One for the Sensor (smr33) Interface Design
7. Includes All your Source code for testing/Verification.

8. Put all of the Above into A Zip file, Submit the file to CANVAS

Note: please Bring your Implementation Board to the Class for Demo.
Next Monday.

Example: Process/Steps to Interface to LSm303.

Step 1. Addr. of the Sensor. See Table 16
For mag. sensor.

Note: Table 17, Special Purpose Registers

- For Config/Control
- For Data

CMPE242 April 7, 22

11

7.2 Magnetic field sensing register

7.2.1 CRA_REG_M (00h)

8 bit Register

a.

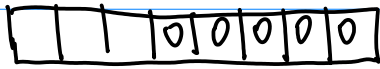


Table 73

CRA_REG[7:5]

Table 73. CRA_REG register

GN2	GN1	GN0	0 ⁽¹⁾	0 ⁽¹⁾	0 ⁽¹⁾	0 ⁽¹⁾	0 ⁽¹⁾
-----	-----	-----	------------------	------------------	------------------	------------------	------------------

1. This bit must be set to '0' for correct working of the device.

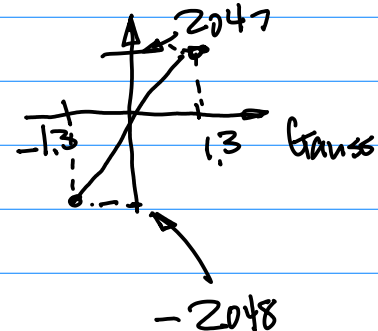
Table 75. Gain setting

GN2	GN1	GN0	Sensor input field range [Gauss]	Gain X, Y, and Z [LSB/Gauss]	Gain Z [LSB/Gauss]	Output range
0	0	1	±1.3	1100	980	0xF800-0x07FF (-2048-2047)
0	1	0	±1.9	855	760	
0	1	1	±2.5	670	600	
1	0	0	±4.0	450	400	
1	0	1	±4.7	400	355	
1	1	0	±5.6	330	295	
1	1	1	±8.1	230	205	

b. For Mag Sensor Smaller Range / more Sensitive

c. Out Range

$$Z'' = 1024 \times 2 = 2048$$



Larger Range / Less Sensitive

GN2=0, GN1=0, GN0=1

Note: Start with either default setting of the Gain, or Set the gain to GN2 GN1 GN0 = 100

Then, Control Register for Operation mode Selection

Only 2 Bits

4. identify the control register responsible for mode of operation, from datasheet, pp 37, table 76, 78 MR_REG_M (02h) ← Sub-Addr. for this Register

0 ⁽¹⁾	0 ⁽¹⁾	0 ⁽¹⁾	0 ⁽¹⁾	0 ⁽¹⁾	0 ⁽¹⁾	MD1	MD0
------------------	------------------	------------------	------------------	------------------	------------------	-----	-----

Use Continuous mode

MD1	MD0	Mode
0	0	Continuous-conversion mode
0	1	Single-conversion mode

CMP242 April 7, 22

12

To Config/Access to Special Purpose Registers), follow this "Write"

Pattern: SPR's Address: 0x01 for GRAN Setting, CRB-REG-M
0x02 for mode MR-REG-M,



Binary Pattern

For Reading After the Configuration, we will need find SADR (Sub Addr. for Read), Example is given in PPT, from Data sheet, Table 15, pp.20.

Coding Implementation: C/C++ Option
Python Option.