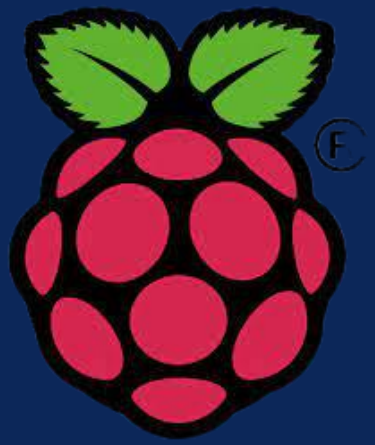


RaspberryPi

ADC(I2C), Thread

PMOD 김효진

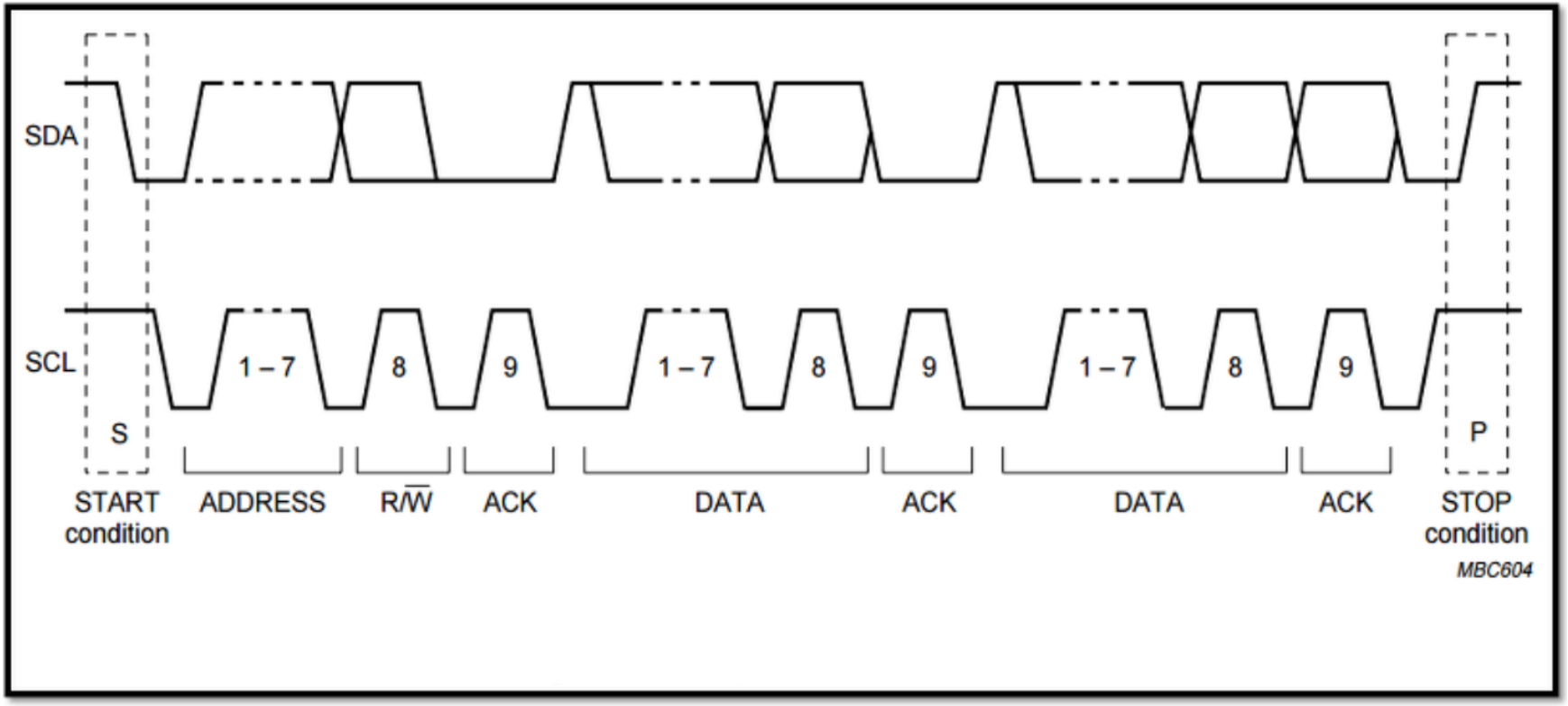
목차

I2C(Inter-Intergrated Circuit)
TWI(Two Wire Interface)

- 필립스에서 개발한 2개의 신호선으로 다수의 I2C통신을 지원하는 직렬통신방식
- Multi Master, Multi Slave(N:N)
- Half duplex synchronous
- 100k, 400k, 3.4Mk(SPI와 UART의 중간)
- Open-Drain, Wired AND, Full-Up Register
- 3.3V~5V
- SDA(Serial Data Line), SCLK(Serial Clock Line)

I2C(Inter-Intergrated Circuit)
TWI(Two Wire Interface)

- Transmitter, Reciver, Master, Slave
- Ack(Acknowledge)



I2C(Inter-Intergrated Circuit)
TWI(Two Wire Interface)

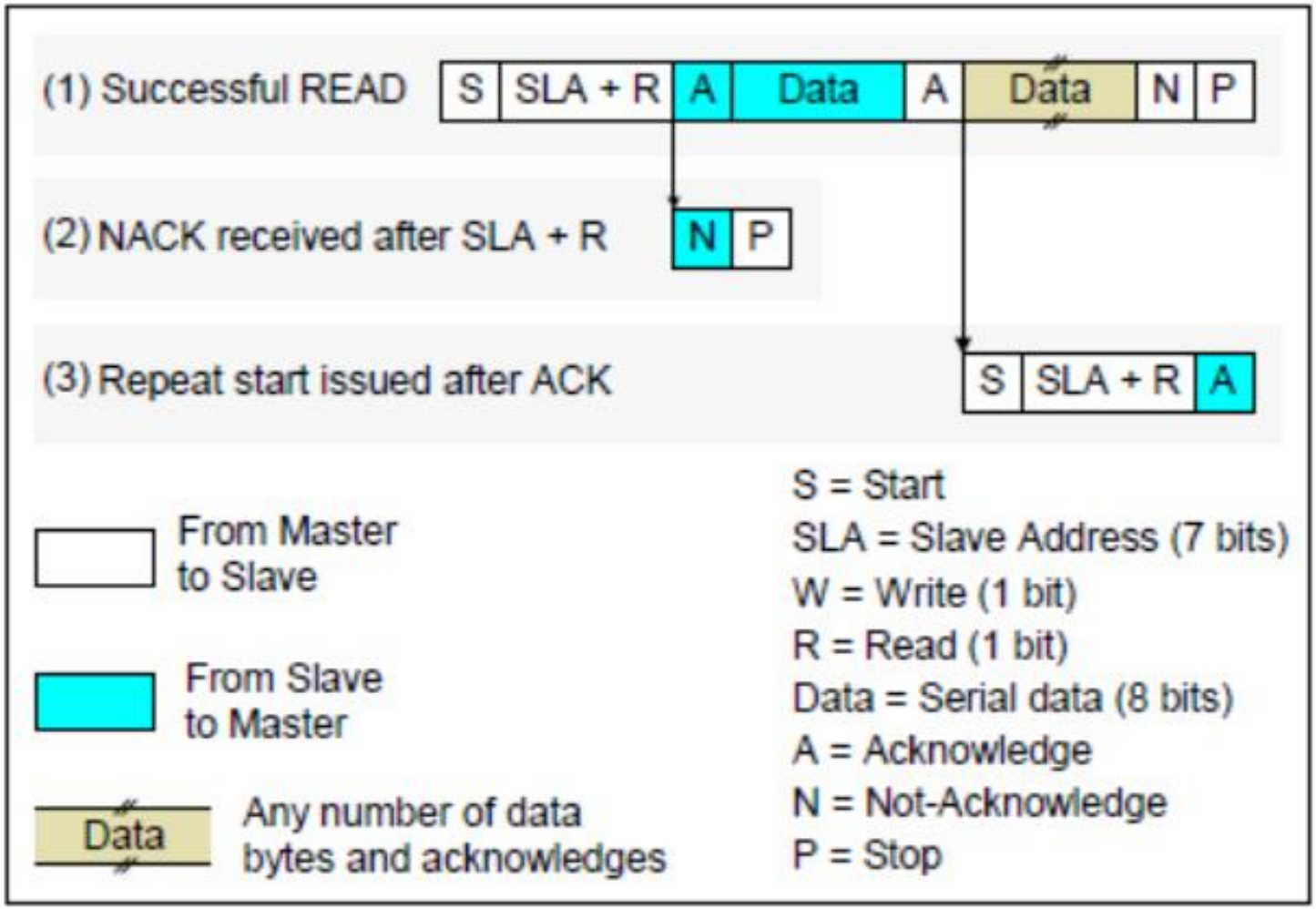


Figure 4. Typical READ Scenarios

I2C(Inter-Intergrated Circuit)
TWI(Two Wire Interface)

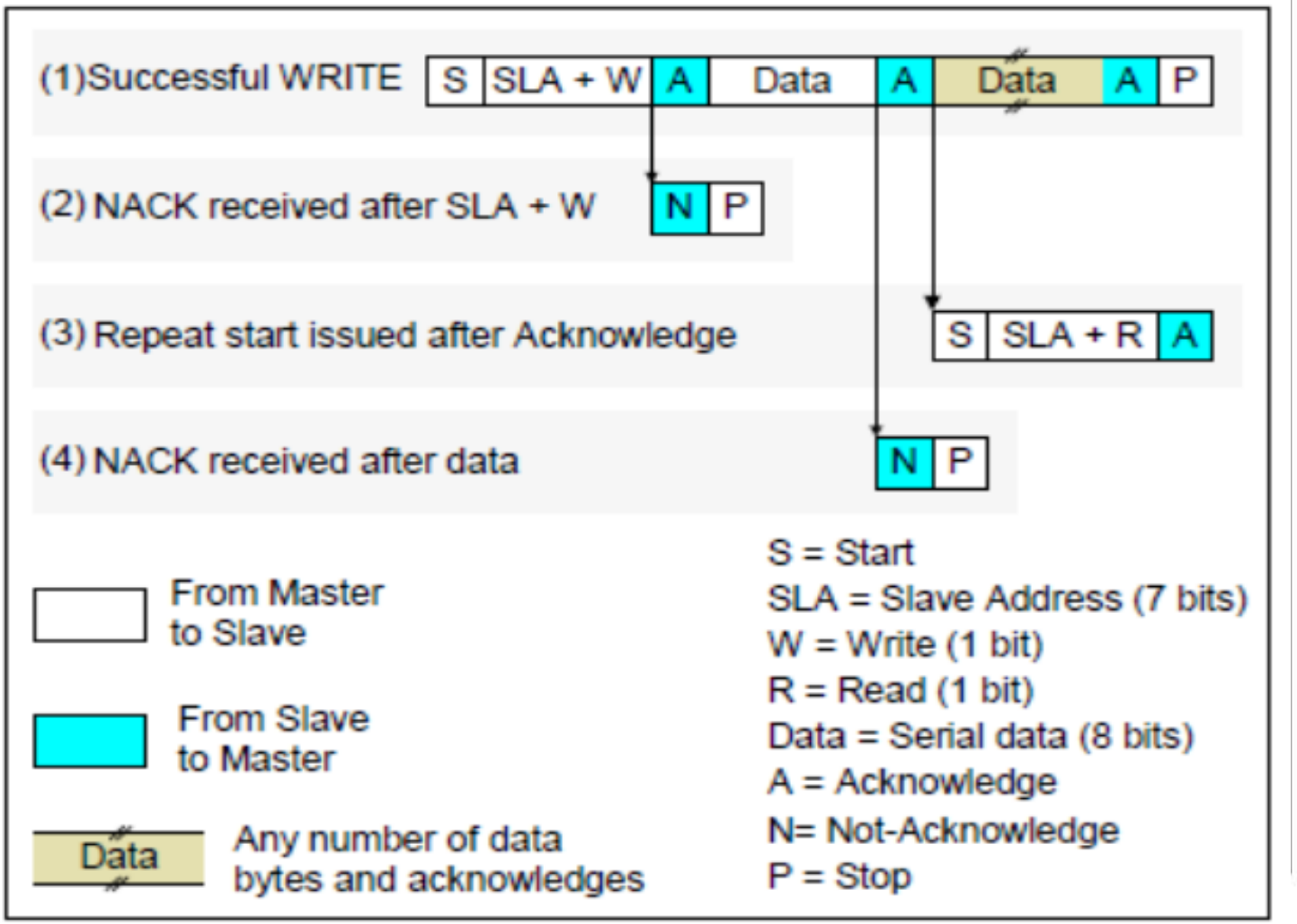
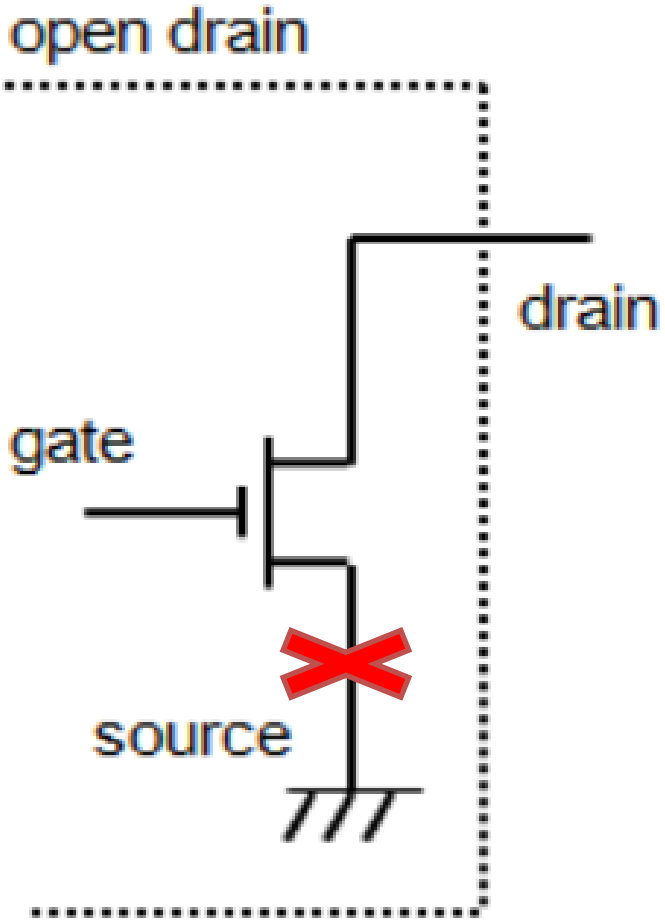


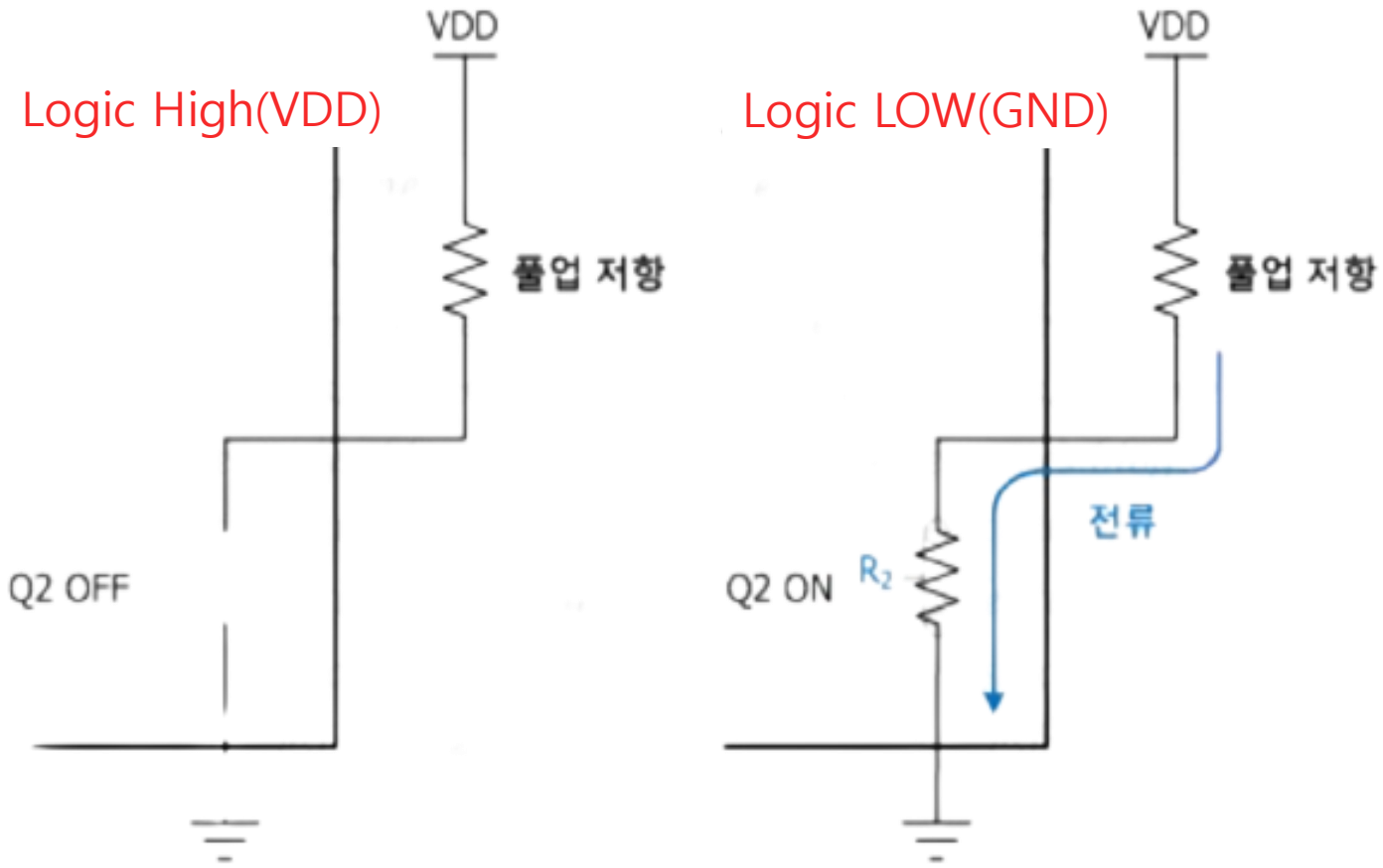
Figure 3. Typical WRITE Transfer Scenarios

Open-Drain Output(NMOS)
Full-Up Register
Wired AND

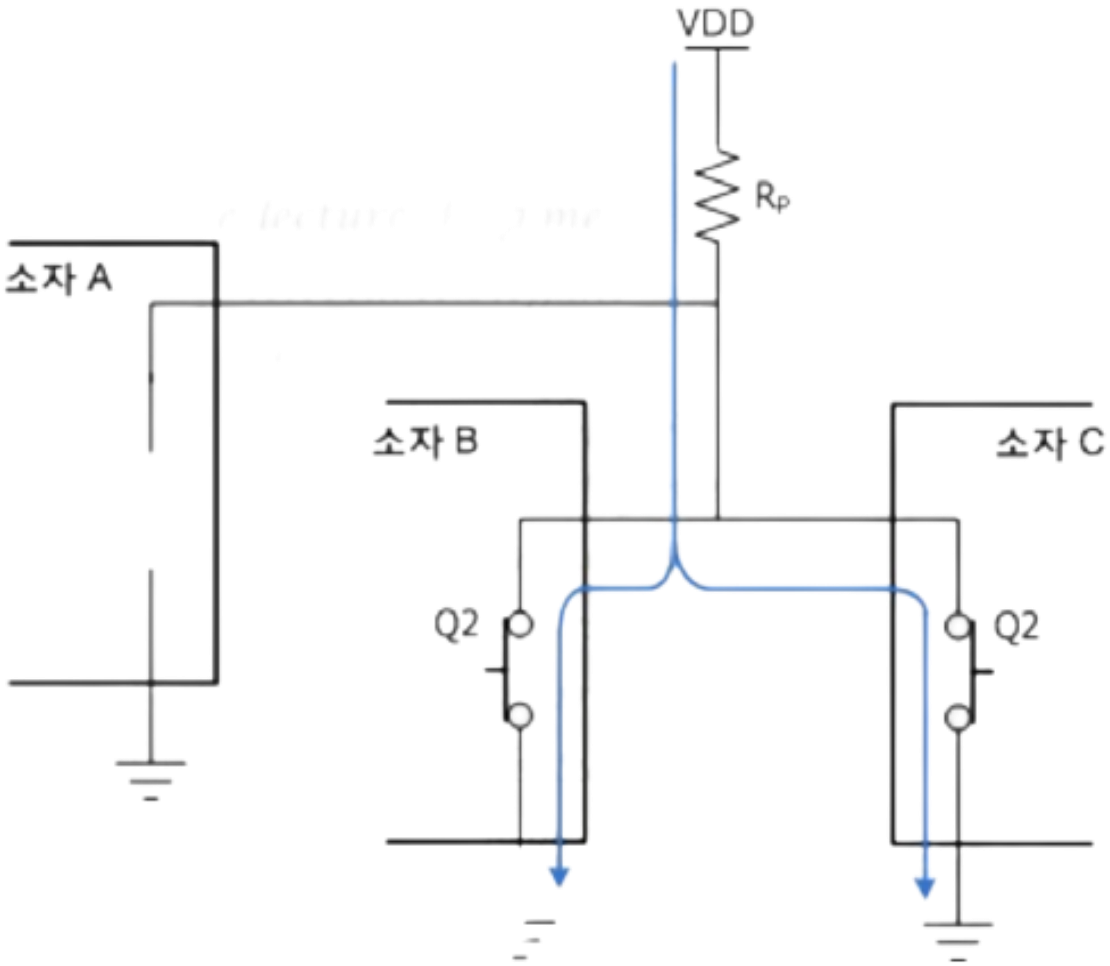


Open-Drain Output(NMOS)
Full-Up Register
Wired AND

Level Shift, Wired AND

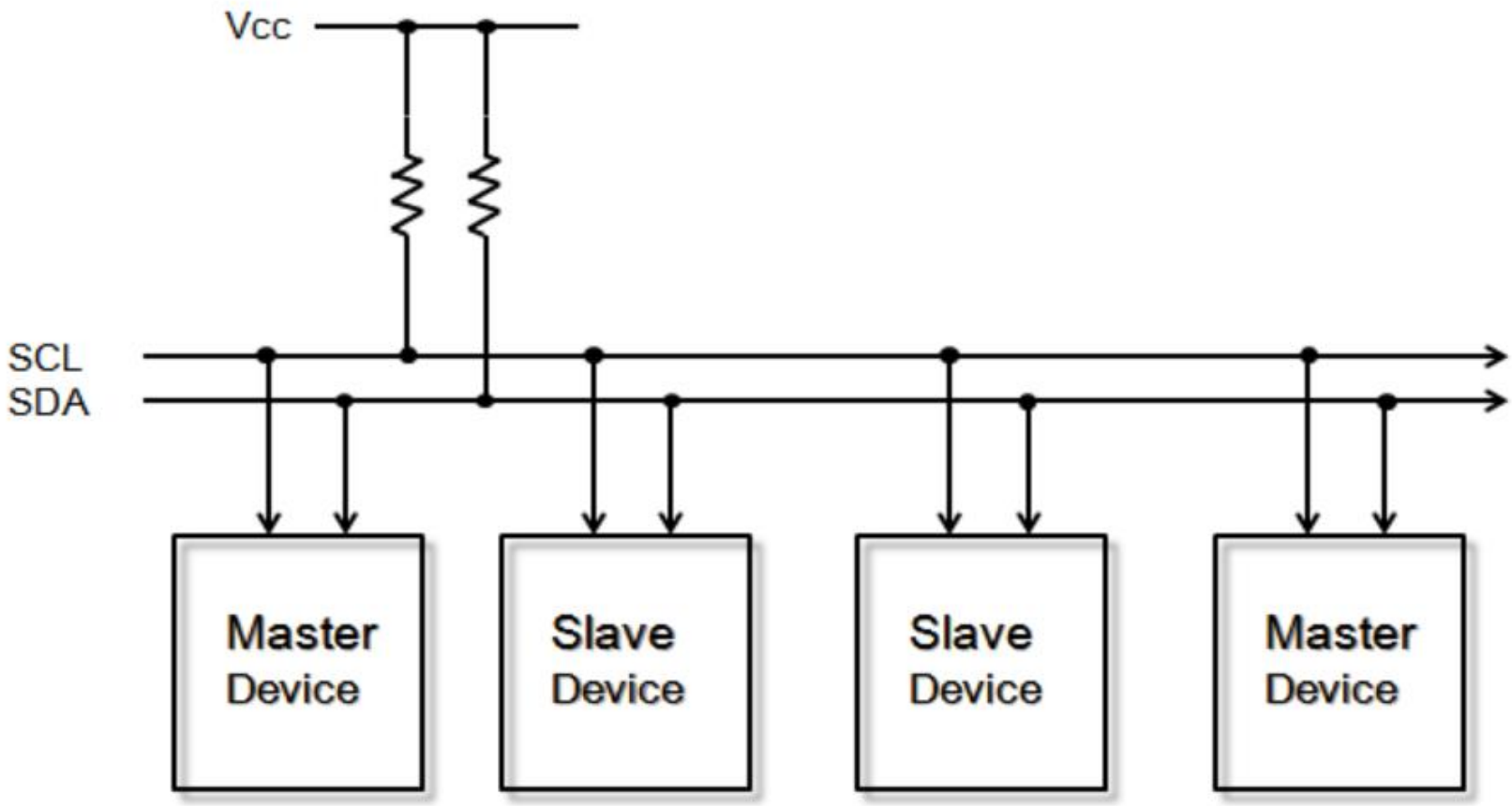


Open-Drain Output(NMOS)
Full-Up Register
Wired AND



소자 A	소자 B	소자 C	논리
ON	ON	ON	0
ON	ON	OFF	0
ON	OFF	OFF	0
OFF	OFF	OFF	1

Open-Drain Output(NMOS)
Full-Up Register
Wired AND



Push – Pull
Open – Collector Output

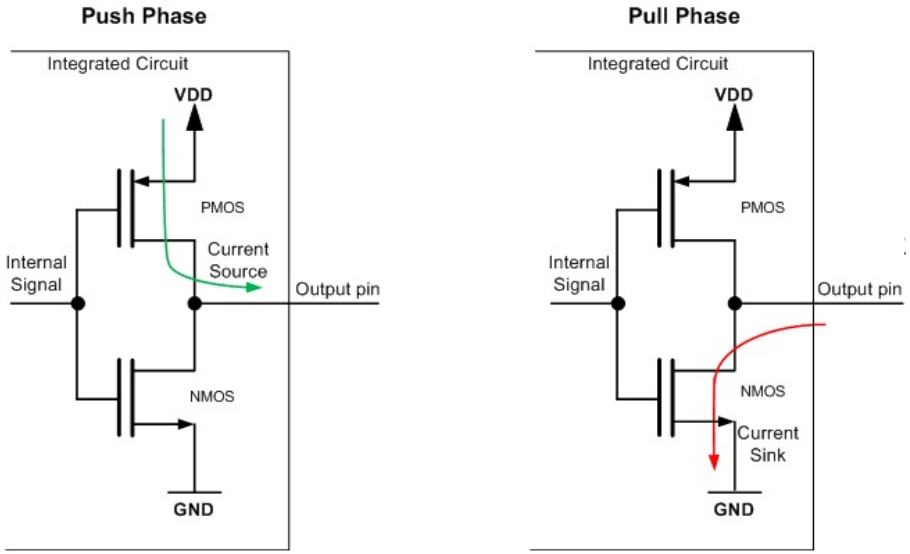
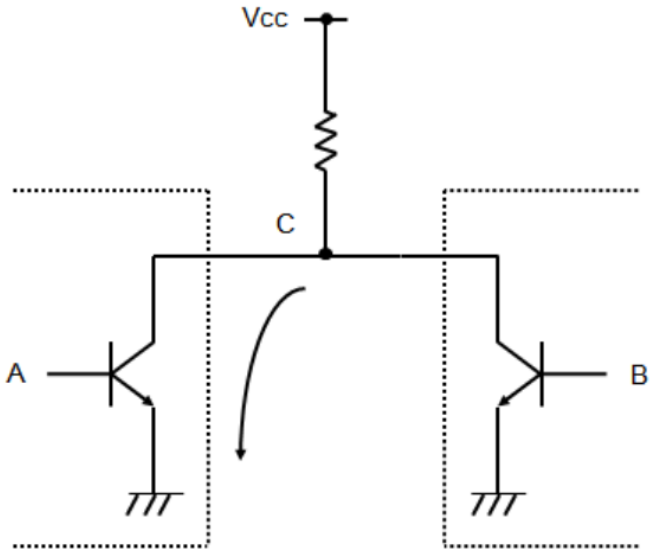


Fig. 1 Simplified schematic of a push-pull output



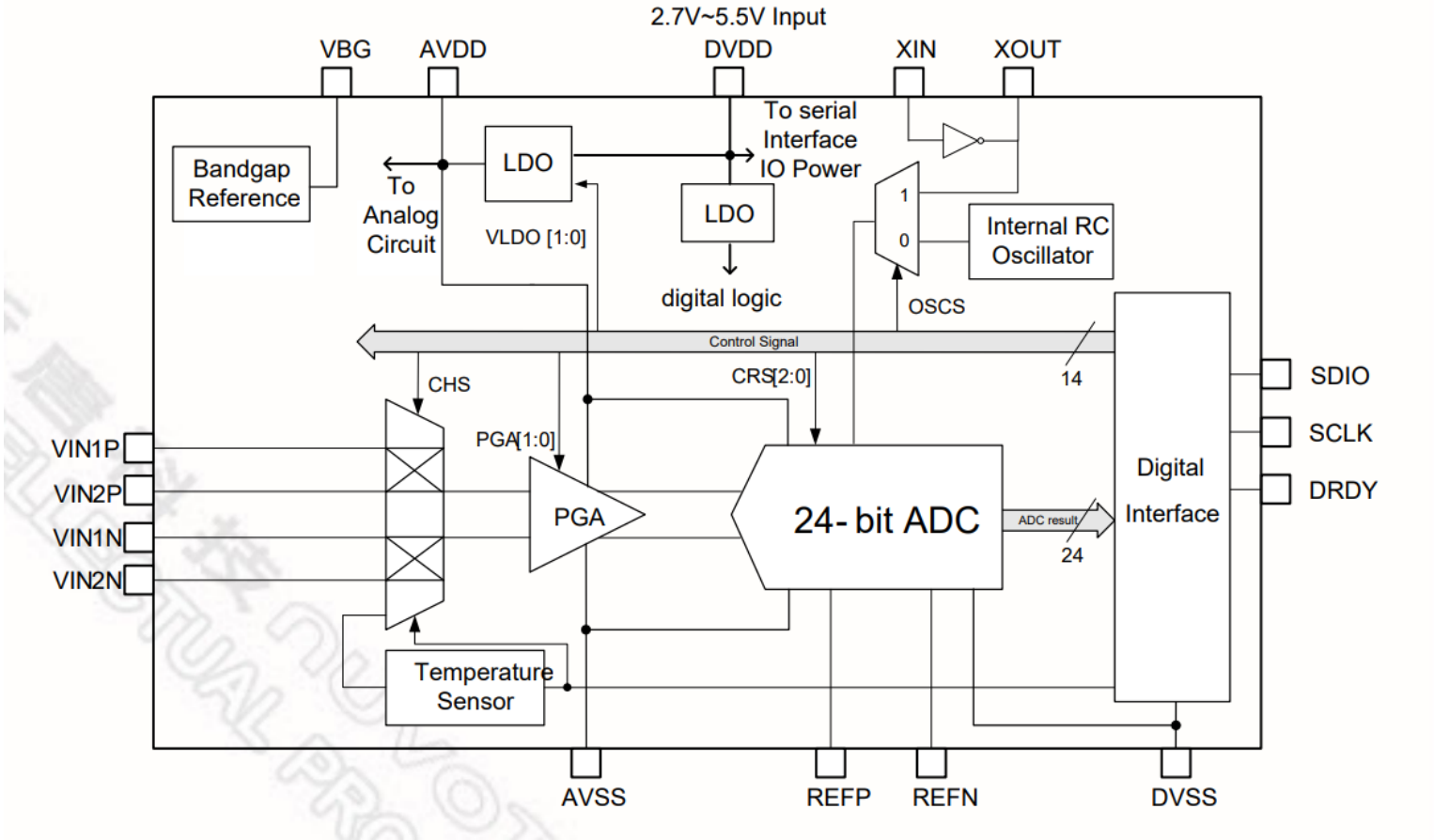
A	B	C	C'
0	0	1	0
0	1	0	1
1	0	0	1
1	1	0	1

Nuvoton NAU7802 FEATURES

- Supply Power : 2.7V ~ 5.5V
- 저전력 24-Bit ADC
- I2C Interface
- Sigma-Delta ADC
- 외부 기준 차동 입력 :0.1V ~ 5V

- System Clock : 외부 수정 발진자(4.9152Mhz) or 내부 수정 발진자(4.9152Mhz)
- 작동 온도 : -40℃ ~ 85℃
- PGA(Programmable Gain Amplifier) : 1 ~ 128
- Slave로만 동작, 표준모드(0~100Khz), 고속모드(0~400Khz)

Nuvoton NAU7802
System Block Diagram

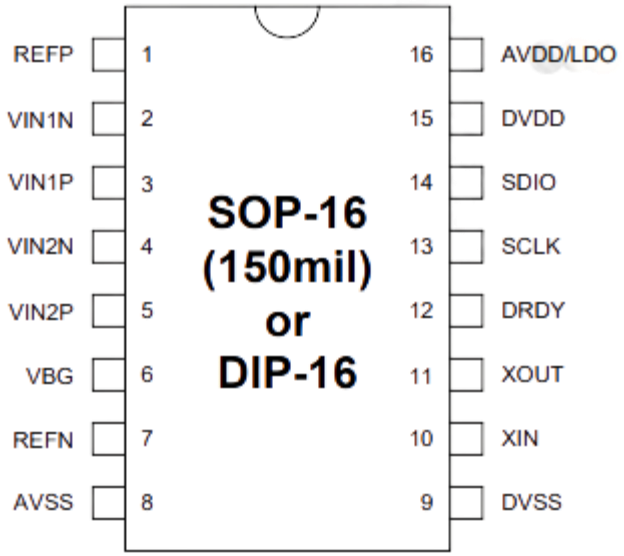


Nuvoton NAU7802
Pin Configuration

PIN DESCRIPTION

Pin No.	Pin Name	Type	DESCRIPTIONS
1	REFP	AI	Positive reference input
2	VIN1N	AI	Inverting Input #1
3	VIN1P	AI	Non-Inverting Input #1
4	VIN2N	AI	Inverting Input #2
5	VIN2P	AI	Non-Inverting Input #2
6	VBG	A	High impedance Reference Voltage Output and Bypass
7	REFN	AI	Negative Reference Input
8	AVSS	P	Analog Ground
9	DVSS	P	Digital ground
10	XIN	I	External crystal oscillator input. Typically 4.9152 MHz
11	XOUT	O	External crystal oscillator output.
12	DRDY	O	Data Ready Output indicating a conversion is complete and new data are available for readout. (CMOS Driver high / low)
13	SCLK	I	Serial Data Clock Input (CMOS open drain output)
14	SDIO	I/O	Data Input / Output for serial communication with host (CMOS open drain output)
15	DVDD	P	Digital power supply: 2.7V ~ 5.5V
16	AVDD/LDO	P	Analog power supply: 1. From programmable LDO output, low ESR 1 ohm or less capacitor recommended 2. LDO off: external power supply: 2.7V ~ 5.5V

- Note : **TYPE P**: Power, **AI**: Analog input, **AO**: Analog output, **I**: input, **O**: output, **I/O**: bi-directional



Nuvoton NAU7802
Write / Read Sequence

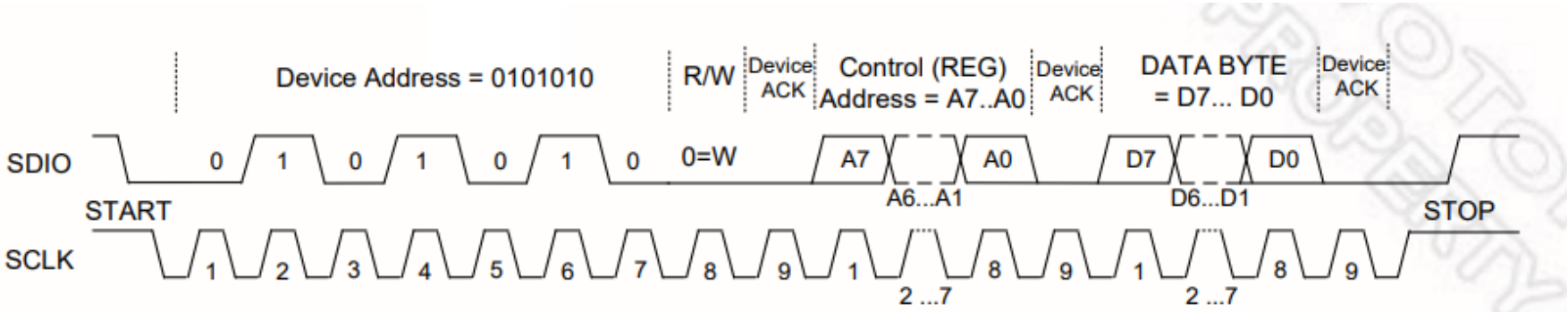


Figure 5: Single Write Sequence

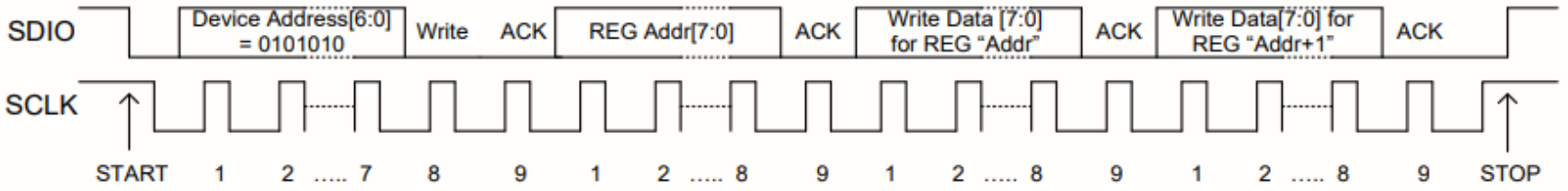


Figure 6: Burst Write Sequence

Nuvoton NAU7802
Write / Read Sequence

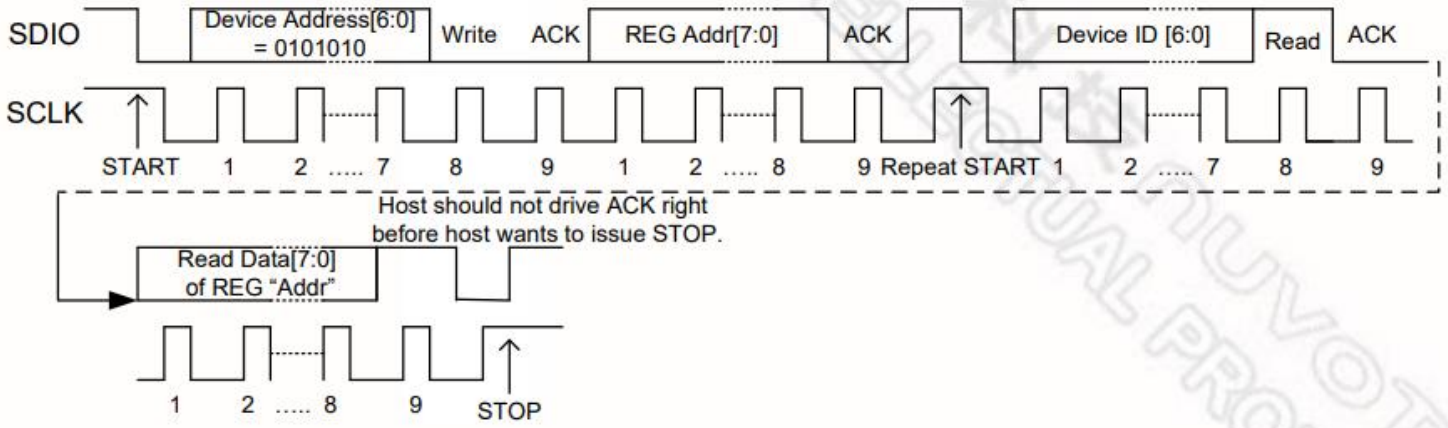


Figure 7: Single Read Sequence

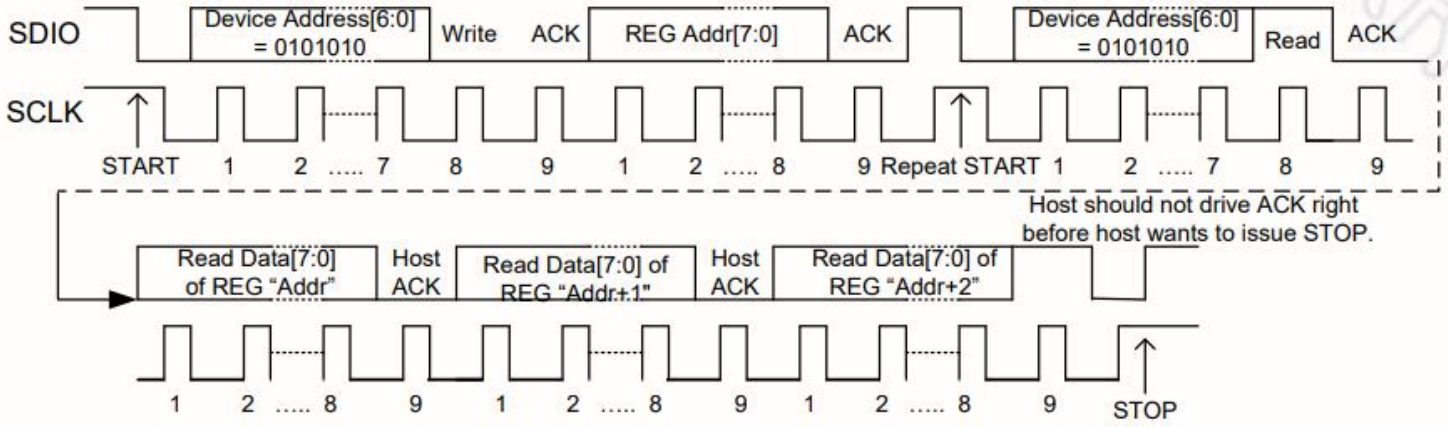


Figure 8: Burst Read Sequence

Nuvoton NAU7802
Register Setting

Address	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default
0x00	PU_CTRL	AVDDS	OSCS	CR	CS	PUR	PUA	PUD	RR	0x00
0x01	CTRL1	CRP		VLDO[2:0]			GAINS[2:0]			0x00
0x02	CTRL2	CHS	CRS[1:0]				CALS	CALMOD[1:0]		0x00
0x03	OCAL1_B2	CH1 OFFSET Calibration[23:16]								0x00
0x04	OCAL1_B1	CH1 OFFSET Calibration[15:8]								0x00
0x05	OCAL1_B0	CH1 OFFSET Calibration[7:0]								0x00
0x06	GCAL1_B3	CH1 GAIN Calibration[31:24]								0x00
0x07	GCAL1_B2	CH1 GAIN Calibration[23:16]								0x80
0x08	GCAL1_B1	CH1 GAIN Calibration[15:8]								0x00
0x09	GCAL1_B0	CH1 GAIN Calibration[7:0]								0x00
0x0A	OCAL2_B2	CH2 OFFSET Calibration[23:16]								0x00
0x0B	OCAL2_B1	CH2 OFFSET Calibration[15:8]								0x00
0x0C	OCAL2_B0	CH2 OFFSET Calibration[7:0]								0x00
0x0D	GCAL2_B3	CH2 GAIN Calibration[31:24]								0x00
0x0E	GCAL2_B2	CH2 GAIN Calibration[23:16]								0x80
0x0F	GCAL2_B1	CH2 GAIN Calibration[15:8]								0x00
0x10	GCAL2_B0	CH2 GAIN Calibration[7:0]								0x00
0x11	I2C Control	CRSD	FDR	SPE/WPD		SI	BOPGA	TS / BGPCP		0x00
0x12	ADCO_B2	ADC_OUT[23:16]								RO
0x13	ADCO_B1	ADC_OUT[15:8]								RO
0x14	ADCO_B0	ADC_OUT[7:0]								RO
0x15	OTP_B1	OTP[15:8]								RO
0x16	OTP_B0	OTP[7:0]								RO
0x1F		Device Revision Code								RO

Bit	Name	Description
7	AVDDS	**AVDD source select** 1 = Internal LDO 0 = AVDD pin input (default)
6	OSCS	**System clock source select** 1 = External Crystal 0 = Internal RC oscillator (default)
5	CR	**Cycle ready** (Read only Status) 1 = ADC DATA is ready
4	CS	**Cycle start** Synchronize conversion to the rising edge of this register
3	PUR	**Power up ready** (Read Only Status) 1 = Power Up ready 0 = Power down, not ready
2	PUA	**Power up analog circuit** 1 = Power up the chip analog circuits (PUD must be 1) 0 = Power down (default)
1	PUD	**Power up digital circuit** 1 = Power up the chip digital logic 0 = power down (default)
0	RR	**Register reset** 1 = Register Reset, reset all register except RR 0 = Normal Operation (default) RR is a level trigger reset control. RR=1, enter reset state, RR=0, leave reset state back to normal state.

wiringPiI2CWriteReg8(fd, device 주소, bit data)
wiringPiI2CWriteReg8 (fd, 0x00, 0x01);
// RR(1)모든 레지스터 초기화
wiringPiI2CWriteReg8 (fd, 0x00, 0x96);
// RR(0) 표준동작, PUD(1) 디지털회로 전원 ON ,PUA(1) 아날로그회로 전원 ON,CS(1) ADC 변환시작, AVDDS(1) 내부AVDD사용

Nuvoton NAU7802 Register Setting

Bit	Name	Description
7	CRP	**Conversion Ready Pin Polarity (16 Pin Package Only)** 1=CRDY pin is LOW Active (Ready when 0) 0=CRDY pin is High Active(Ready when 1) (default)
6	DRDY_SEL	Select the function of DRDY pin 1: DRDY output the Buffered Crystal Clock if OSCS=1 output the internal OSC clock if OSCS= 0 0: DRDY output the conversion ready (default)
5:3	VLDO	LDO Voltage 111 = 2.4 110 = 2.7 101 = 3.0 100 = 3.3 011 = 3.6 010 = 3.9 001 = 4.2 000 = 4.5 (default)

Bit	Name	Description
5:4	REG_CHPS	Select the CLK_CHP clock frequency.

REG_CPHS[1]	REG_CPHS[0]	CLK_CHP clock frequency
0	0	Reserved
0	1	Reserved
1	0	Reserved
1	1	turned off, high ('1') state

Bit	Name	Description
7	CHS	**Analog input channel select** 1 = Ch2 0 = Ch1 (default)
6:4	CRS	**Conversion rate select** 111 = 320SPS 011 = 80SPS 010 = 40SPS 001 = 20SPS 000 = 10SPS (default)
3	CAL_ERR	Read Only calibration result 1: there is error in this calibration 0: there is no error
2	CALS	Write 1 to this bit will trigger calibration based on the selection in CALMOD[1:0] This is an "Action" register bit. When calibration is finished, it will reset to 0 While this bit is still 1, the chip is still calibrating. An I2C write to this bit will be ignored and no additional calibration will be triggered
1:0	CALMOD	11 = Gain Calibration System 10 = Offset Calibration System 01 = Reserved 00 = Offset Calibration Internal (default)

wiringPiI2CWriteReg8 (fd, 0x01, 0x11);
//VLDO 011(3.6V), 실제로 측정되는 값이 3.3V임
wiringPiI2CWriteReg8(fd, 0x02, (Channel<< 7));
//CHS(0)(default)>> CH1,CHS(1)>>CH2
wiringPiI2CWriteReg8 (fd, 0x15, 0x30);
//ADC 레지스터 부분, 클럭을 꺼짐('1')상태 설정

Nuvoton NAU7802 Register

Bit	Name	Description
7	AVDDS	**AVDD source select** 1 = Internal LDO 0 = AVDD pin input (default)
6	OSCS	**System clock source select** 1 = External Crystal 0 = Internal RC oscillator (default)
5	CR	**Cycle ready** (Read only Status) 1 = ADC DATA is ready
4	CS	**Cycle start** Synchronize conversion to the rising edge of this register
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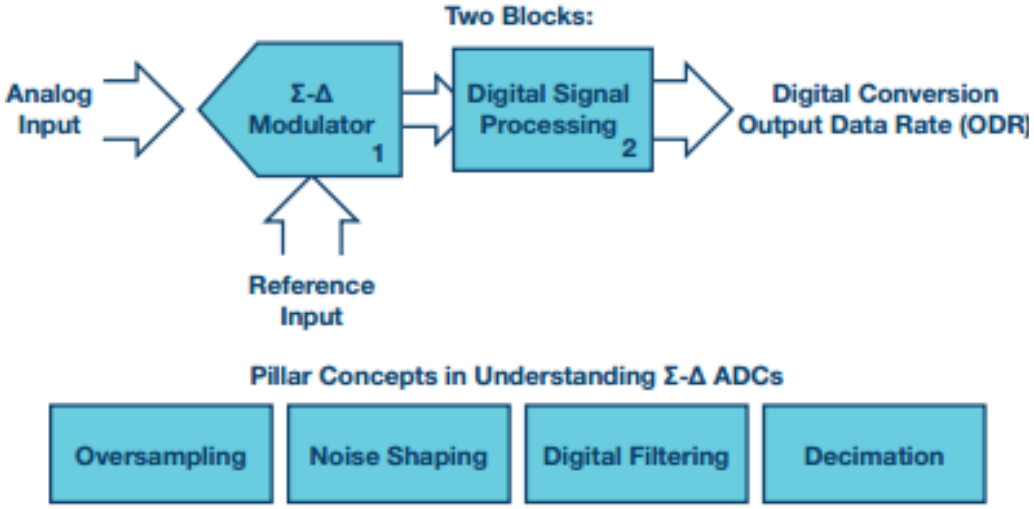
1	PUD	**Power up digital circuit** 1 = Power up the chip digital logic 0 = power down (default)
0	RR	**Register reset** 1 = Register Reset, reset all register except RR 0 = Normal Operation (default) RR is a level trigger reset control. RR=1, enter reset state, RR=0, leave reset state back to normal state.

```
do
{
        st = wiringPiI2CReadReg8(fd,0x00);
}
while( st & 0x28 == 0x00 );
   // CR(1) ADC DATA ready, PUR(1) Power Up
      ready
data_H = wiringPiI2CReadReg8(fd, 0x12);
   //23:16 상위 비트  읽는 순서 중요!
data_M = wiringPiI2CReadReg8(fd, 0x13);
   //15:8 중간 비트
data_L = wiringPiI2CReadReg8(fd, 0x14);
   //7:0 하위 비트
```

11.9 REG0x12-REG0x14: ADC Conversion Result

REG0x12 (Read Only)	ADCO_B2	ADC Conversion Result bit 23 to bit 16
REG0x13 (Read Only)	ADCO_B1	ADC Conversion Result bit 15 to bit 8
REG0x14 (Read Only)	ADCO_B0	ADC Conversion Result bit 7 to bit 0

Sigma – Delta ADC



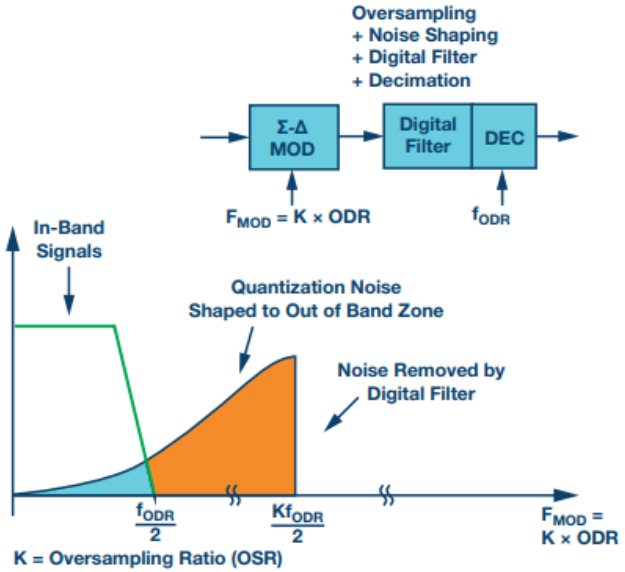
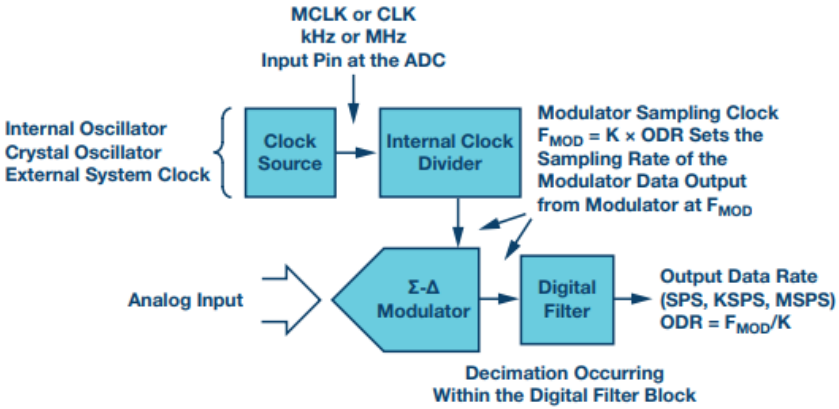
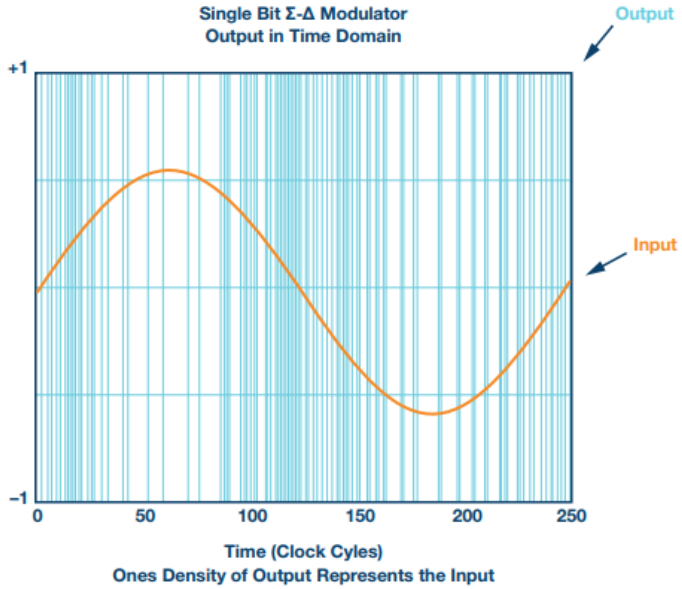


Figure 2c. Σ-Δ ADC scenario. Oversampled and noise shaped, sampling occurring at $F_{MOD} = K \times F_{ODR}$.

Sigma – Delta ADC





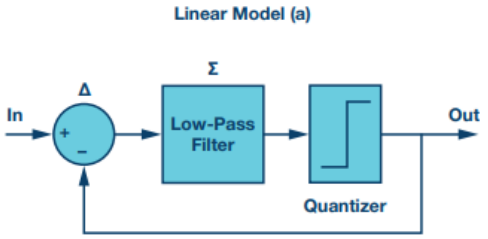
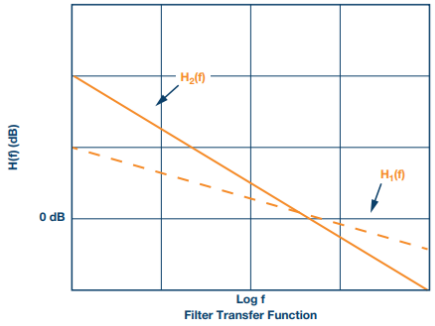
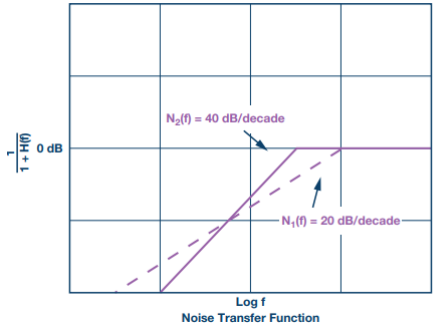
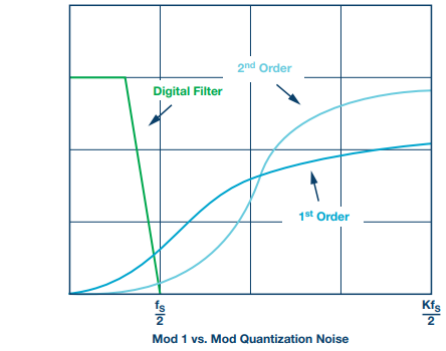


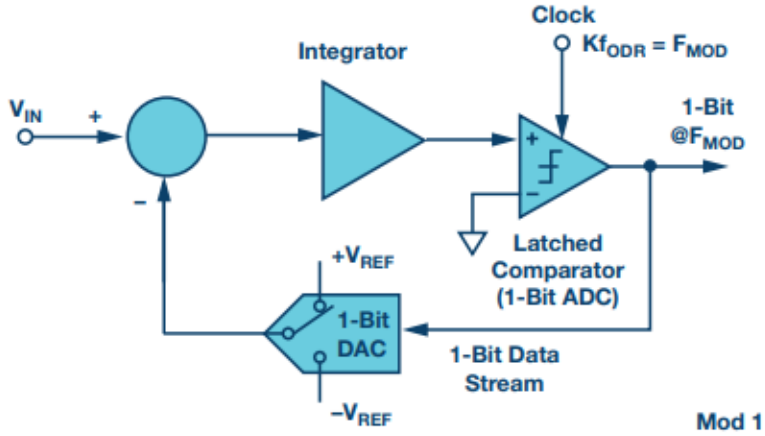
Figure 4. Σ-Δ ones density in response to sine wave input. Linear model (a) of the Mod 1 Σ-Δ loop.

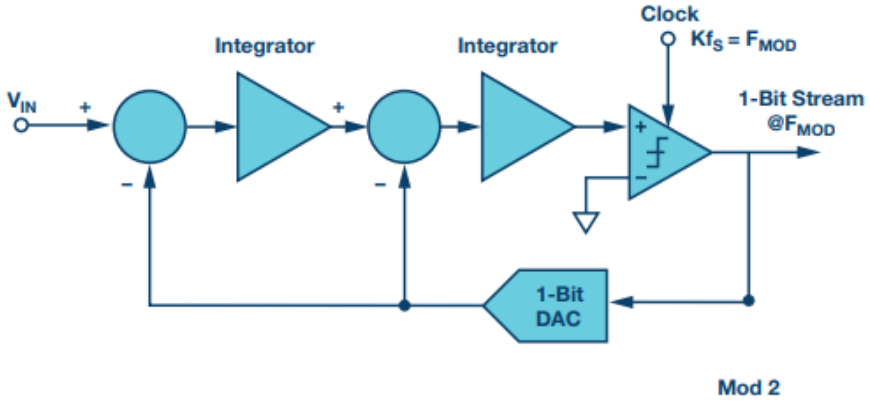
Sigma – Delta ADC











라즈베리 Setup.

명령어	설명
i2cdetect	이 명령어는 i2c버스에 감지되는 슬레이브 장치가 있는지를 검사하기 위해 사용합니다.
i2cdump	지정한 주소값에해당하는 슬레이브의 전체 레지스터값을 읽어와서 출력해 줍니다.
i2cget	이 명령어는 원하는 슬레이브에서 원하는 레지스터값을 읽어올 때 사용합니다.
i2cset	이 명령어는 i2cget 과 반대로 원하는 슬레이브의 레지스터를 지정해서 값을 레지스터의 값을 변경할 때 사용합니다.

```
sudo apt-get install i2c-tools
```

```
pi@hyojin:~ $ ls -l /dev/i2c*
crw-rw---- 1 root i2c 89,  1 Jan 23 22:49 /dev/i2c-1
crw-rw---- 1 root i2c 89, 20 Jan 23 22:49 /dev/i2c-20
crw-rw---- 1 root i2c 89, 21 Jan 23 22:49 /dev/i2c-21
```

```
pi@hyojin:~ $ lsmod | grep i2c
i2c_bcm2835            16384  0
i2c_brcmstb            16384  0
i2c_dev                20480  0
pi@hyojin:~ $ i2cdetect -y 1
     0  1  2  3  4  5  6  7  8  9  a  b  c  d  e  f
00:                         -- -- -- -- -- -- -- --
10: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
20: -- -- -- -- -- -- -- -- -- -- 2a -- -- -- -- --
30: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
40: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
50: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
60: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
70: -- -- -- -- -- -- -- --
```

라즈베리 Setup.

- int wiringPiI2CSetup(int devld);

반환값 : 표준리눅스 파일, -1이면 오류
devld : 연결할 장치의 ID=슬레이브 장치의 주소

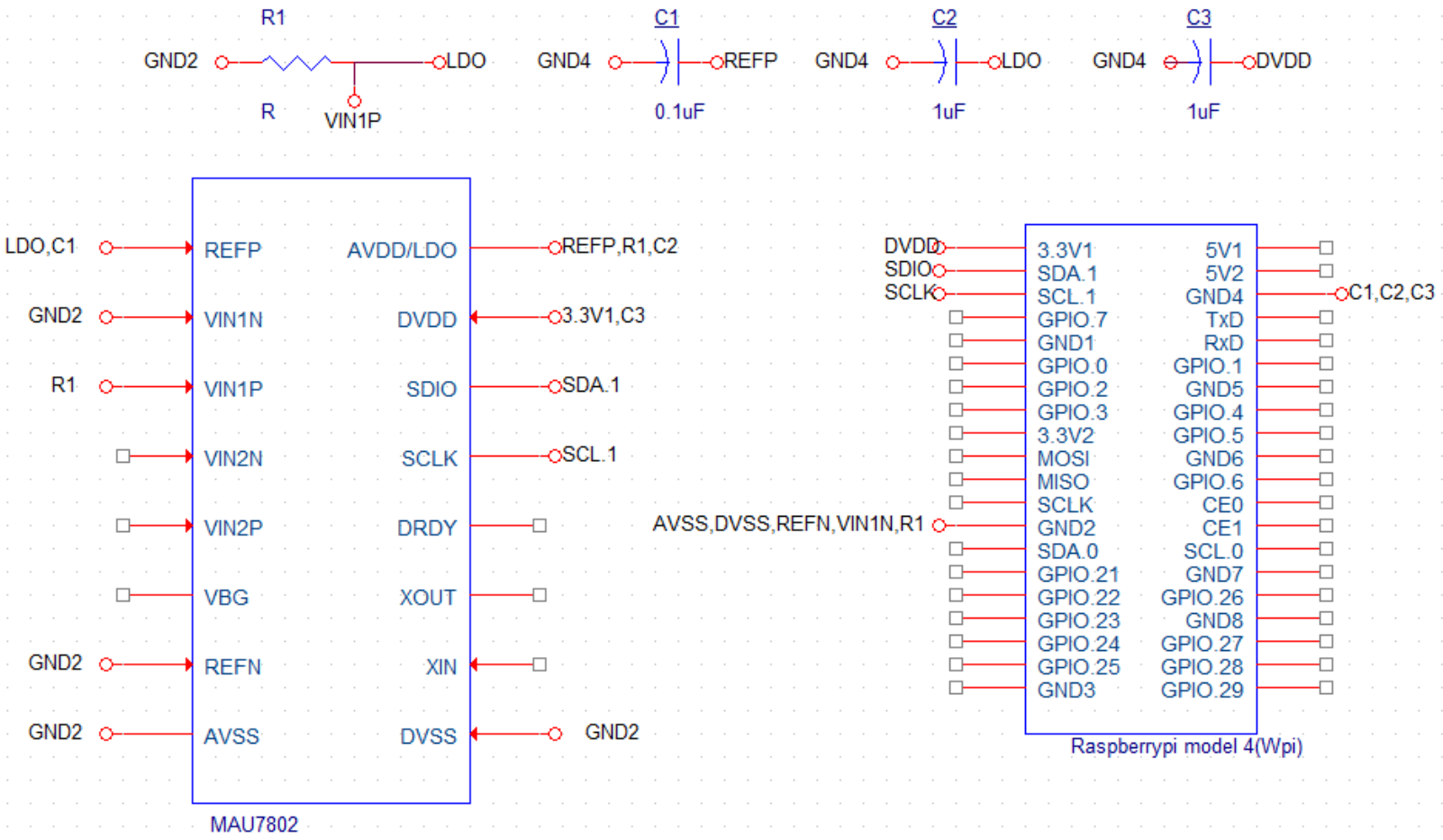
- int wiringPiI2CRead(int fd);

- int wiringPiI2CWrite(int fd, int data);

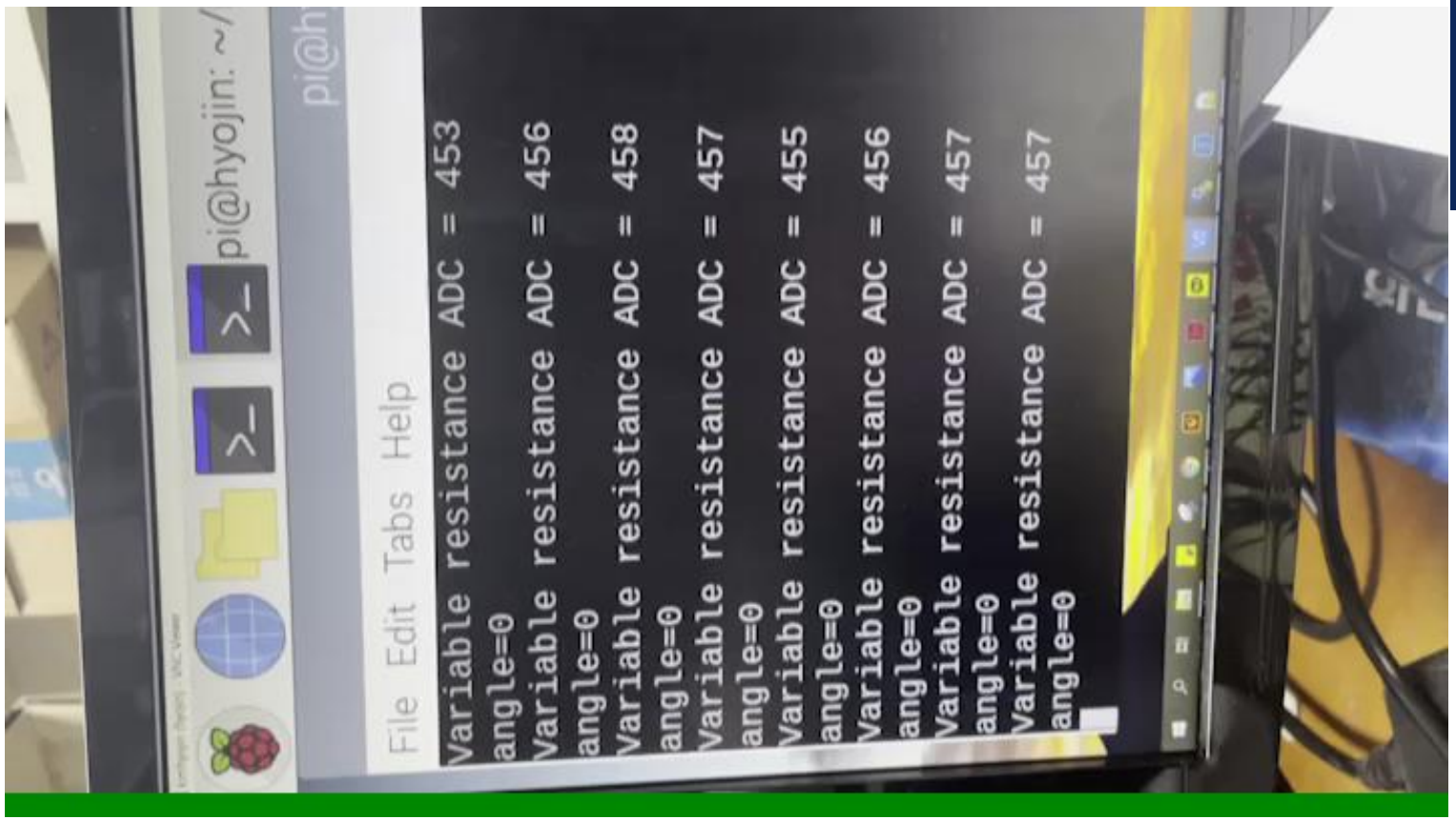
- int wiringPiI2CWriteReg8(int fd, int reg, int data);
- int wiringPiI2CWriteReg16(int fd, int reg, int data);

- int wiringPiI2CReadReg8(int fd, int reg);
- int wiringPiI2CReadReg16(int fd, int reg);;

회로도


R1
GND2
R
VIN1P
LDO
C1
GND4
0.1uF
REFP
C2
GND4
1uF
LDO
C3
GND4
1uF
DVDD
LDO,C1
REFP
AVDD/LDO
REFP,R1,C2
GND2
VIN1N
DVDD
3.3V1,C3
R1
VIN1P
SDIO
SDA.1
VIN2N
SCLK
SCL.1
VIN2P
DRDY
VBG
XOUT
GND2
REFN
XIN
GND2
AVSS
DVSS
GND2
MAU7802
DVDD
SDIO
SCLK
AVSS,DVSS,REFN,VIN1N,R1
3.3V1
SDA.1
SCL.1
GPIO.7
GND1
GPIO.0
GPIO.2
GPIO.3
3.3V2
MOSI
MISO
SCLK
GND2
SDA.0
GPIO.21
GPIO.22
GPIO.23
GPIO.24
GPIO.25
GND3
5V1
5V2
GND4
TxD
RxD
GPIO.1
GND5
GPIO.4
GPIO.5
GND6
GPIO.6
CE0
CE1
SCL.0
GND7
GPIO.26
GND8
GPIO.27
GPIO.28
GPIO.29
C1,C2,C3
Raspberrypi model 4(Wpi)

구동영상



문제
I2C(온습도센서), PWM(소프트웨어)로 온도에 따라 각도 변화


감사합니다.