Smart Software Project

Lecture: Week 10

Infrared Sensors

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Today

- Review
  - Ultrasonic Sensors

- SmartCAR Infrared Sensors

- Announcement

Class Schedule

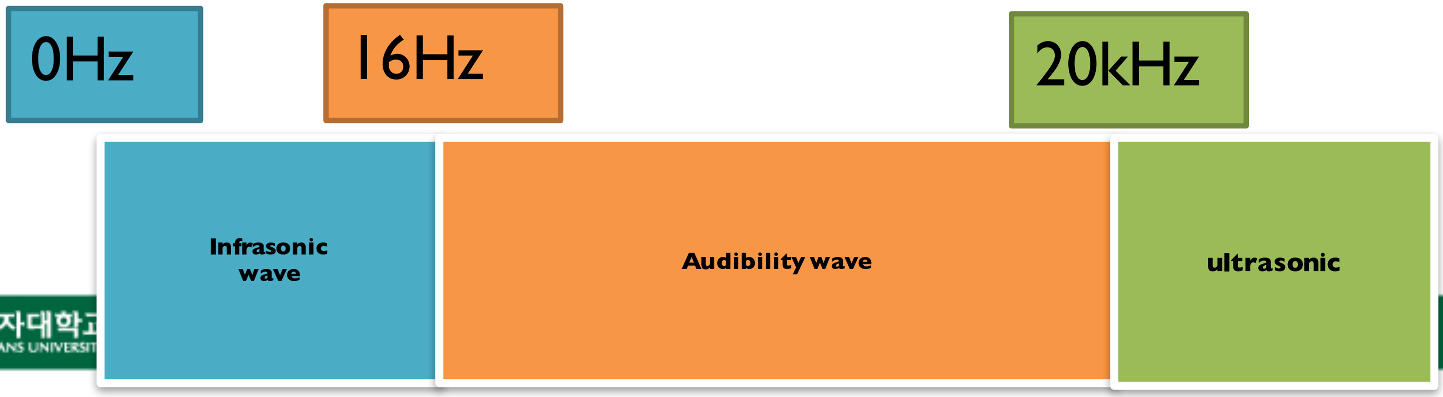
Week	Lecture Contents	Lab Contents
Week 1	Course introduction	Arduino introduction: platform & programming environment
Week 2	Embedded system overview & source management in collaborative repository (using GitHub)	Lab 1: Arduino Mega 2560 board & SmartCAR platform
Week 3	ATmega2560 Micro-controller (MCU): architecture & I/O ports, Analog vs. Digital, Pulse Width Modulation	Lab 2: SmartCAR LED control
Week 4	Analog vs. Digital & Pulse Width Modulation	Lab 3: SmartCAR motor control (Due: HW on creating project repository using GitHub)
Week 5	ATmega2560 MCU: memory, I/O ports, UART	Lab 4: SmartCAR control via Android Bluetooth
Week 6	ATmega2560 UART control & Bluetooth communication between Arduino platform and Android device	Lab 5: SmartCAR control through your own customized Android app (Due: Project proposal)
Week 7	Midterm exam	
Week 8	ATmega2560 Timer, Interrupts & Ultrasonic sensors	Lab 6: SmartCAR ultrasonic sensing
Week 9	Infrared sensors & Buzzer	Lab 7: SmartCAR infrared sensing
Week 10	Acquiring location information from Android device & line tracing	Lab 8: Implementation of line tracer
Week 11	Gyroscope, accelerometer, and compass sensors	Lab 9: Using gyroscope, accelerometer, and compass sensors
Week 12	Project	Team meeting (for progress check)
Week 13	Project	Team meeting (for progress check)
Week 14	Course wrap-up & next steps	
Week 15	Project presentation & demo I (Due: source code, presentation slides, & poster slide)	Project presentation & demo II
Week 16	Final week (no final exam)	

Today

- **Review**
  - Ultrasonic Sensors
- SmartCAR Infrared Sensors
- Announcement

Ultrasonic wave

- Ultrasonic wave?
  - Sound wave with high frequency
  - Sound wave
    - Sound is transmitted through gases, plasma, and liquids
    - Audible wave
      - 20Hz~20kHz spectrum
    - Ultrasonic wave
      - Frequency spectrum where human cannot hear
  - Spectrum



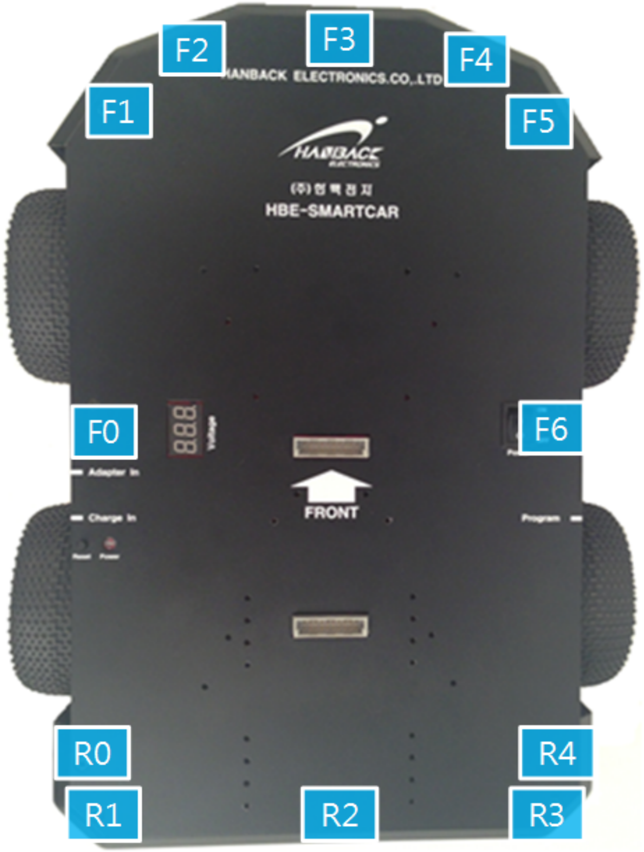
SmartCAR Ultrasonic Sensors

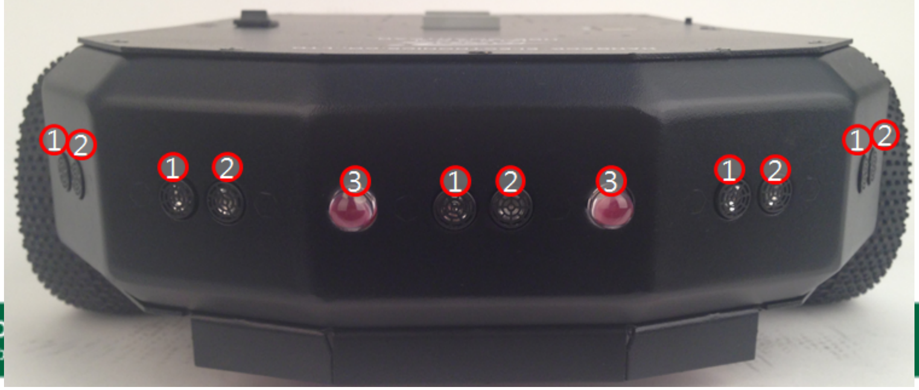
- 12 ultrasonic sensors
  - ① Ultrasonic sensor (Transmitter)

    Transmit an ultrasonic wave to detect an object
  - ② Ultrasonic sensor (Receiver)

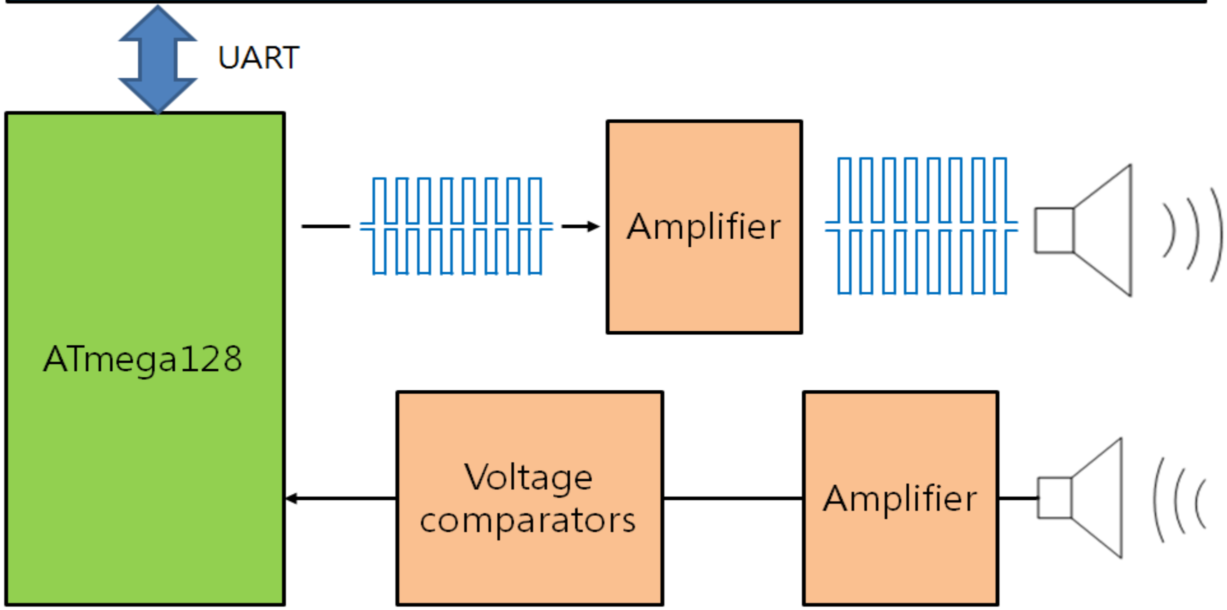
    Receive the ultrasonic wave transmitted from TX

    => Calculates the distance from the TX-RX time diff





Ultrasonic Sensor Hardware Architecture



SmartCAR UART Port Configuration

- UART1 port is used for ultrasonic sensors

UART No.	Name	Port / Number	Etc
UART0	RXD0	PE0 / -	Program port Bluetooth port
	TXD0	PE1 / -	
UART1	RXD1	PD2 / 19	Ultrasonic sensor
	TXD1	PD3 / 18	
UART2	RXD2	PH0 / 17	Extension board 1
	TXD2	PH1 / 16	
UART3	RXD3	PJ0 / 15	Extension board 2
	TXD3	PJ1 / 14	

- Baud rate should be set to 115200bps

Main MCU and ATmega128 Communication

- OFF
  - Stop measuring from the ultrasonic

TX Data Packet (ATmega2560 -> ATmega128)				
Start		ID		CSC
0x76	0x00	0x0F	0x00	0x0F

- CSC : to check error – all ID sum & 0xFF

RX Data Packet (ATmega128 -> ATmega2560)								
Start		ID		DATA				
0x76	0x00	0x1F	0x00	0x00	0x00	0x00	0x00	0x00

DATA							CSC
0x00	0x00	0x00	0x00	0x00	0x00	0x00	

- CSC : to check error – all ID & Data sum & 0xFF

Main MCU and ATmega128 Communication

- Basic
  - Front 3 ultrasonic sensors (F2, F3, F4) & Rear 1 ultrasonic sensor (R2)
  - Send a TX data request packet, and receive a RX data packet for the measurement continuously

TX Data Packet (ATmega2560 -> ATmega128)				
Start		ID		CSC
0x76	0x00	0x10	0x00	0x10

RX Data Packet (ATmega128 -> ATmega2560)								
Start		ID		DATA				
0x76	0x00	0x11	0x00	0x00	0x00	F2	F3	F4
DATA							CSC	
0x00	0x00	0x00	0x00	R2	0x00	0x00		

- F0~6 : distance in front ultrasonic sensors
- R0~4 : distance in rear ultrasonic sensors

Main MCU and ATmega128 Communication

- Right
  - Front 5 ultrasonic sensors (F2 ~ F6) & Rear 5 ultrasonic sensors (R0 ~ R4)
  - Send a TX data request packet, and receive a RX data packet for the measurement continuously

TX Data Packet (ATmega2560 -> ATmega128)				
Start		ID		CSC
0x76	0x00	0x20	0x00	0x20

RX Data Packet (ATmega128 -> ATmega2560)								
Start		ID		DATA				
0x76	0x00	0x21	0x00	0x00	0x00	F2	F3	F4
DATA								CSC
F5	F6	R0	R1	R2	R3	R4		

- F0~6 : distance in front ultrasonic sensors
- R0~4 : distance in rear ultrasonic sensors

Main MCU and ATmega128 Communication

- Left
  - Front 5 ultrasonic sensors (F0 ~ F4) & Rear 5 ultrasonic sensors (R0 ~ R4)
  - Send a TX data request packet, and receive a RX data packet for the measurement continuously

TX Data Packet (ATmega2560 -> ATmega128)				
Start		ID		CSC
0x76	0x00	0x30	0x00	0x30

RX Data Packet (ATmega128 -> ATmega2560)								
Start		ID		DATA				
0x76	0x00	0x31	0x00	F0	F1	F2	F3	F4

DATA							CSC
0x00	0x00	R0	R1	R2	R3	R4	

- F0~6 : distance in front ultrasonic sensors
- R0~4 : distance in rear ultrasonic sensors

Main MCU and ATmega128 Communication

- Front
  - Front 7 ultrasonic sensors (F0 ~ F6)
  - Send a TX data request packet, and receive a RX data packet for the measurement continuously

TX Data Packet (ATmega2560 -> ATmega128)				
Start		ID		CSC
0x76	0x00	0x40	0x00	0x40

RX Data Packet (ATmega128 -> ATmega2560)								
Start		ID		DATA				
0x76	0x00	0x41	0x00	F0	F1	F2	F3	F4
DATA							CSC	
F5	F6	0x00	0x00	0x00	0x00	0x00		

- F0~6 : distance in front ultrasonic sensors
- R0~4 : distance in rear ultrasonic sensors

Main MCU and ATmega128 Communication

- Back
  - Front 2 ultrasonic sensors (F0, F6) & Rear 5 ultrasonic sensors (R0 ~ R4)
  - Send a TX data request packet, and receive a RX data packet for the measurement continuously

TX Data Packet (ATmega2560 -> ATmega128)				
Start		ID		CSC
0x76	0x00	0x50	0x00	0x50

RX Data Packet (ATmega128 -> ATmega2560)								
Start		ID		DATA				
0x76	0x00	0x51	0x00	F0	0x00	0x00	0x00	0x00
DATA							CSC	
0x00	F6	R0	R1	R2	R3	R4		

- F0~6 : distance in front ultrasonic sensors
- R0~4 : distance in rear ultrasonic sensors

Main MCU and ATmega128 Communication

- All
  - Front 7 ultrasonic sensors (F0 ~ F6) & Rear 5 ultrasonic sensors (R0 ~ R4)
  - Send a TX data request packet, and receive a RX data packet for the measurement continuously

TX Data Packet (ATmega2560 -> ATmega128)				
Start		ID		CSC
0x76	0x00	0xF0	0x00	0xF0

RX Data Packet (ATmega128 -> ATmega2560)								
Start		ID		DATA				
0x76	0x00	0xF1	0x00	F0	F1	F2	F3	F4
DATA							CSC	
F5	F6	R0	R1	R2	R3	R4		

- F0~6 : distance in front ultrasonic sensors
- R0~4 : distance in rear ultrasonic sensors

SmartCAR Firmware

```
#define NUM_TX_BYTES          5
#define NUM_RX_BYTES          17

unsigned char TX_buf[NUM_TX_BYTES] = {0x76, 0x00, 0xF0, 0x00, 0xF0};
unsigned char TX_stop_buf[NUM_TX_BYTES] = {0x76, 0x00, 0x0F, 0x00, 0x0F};
unsigned char RX_buf[NUM_RX_BYTES];

boolean  ultrasonic_result  = false;

void setup()
{
    int i = 0;
    Serial.begin(115200);

    while (text[i] != '₩0')
        Serial.write(text[i++]);

    Serial.write("Received  cmds: ");

    Serial1.begin(115200);
    //initialize  ports
    pinMode(....);
    ....
    digitalWrite(...);
}
```

SmartCAR Firmware

```
void loop()
{
}

void serialEvent()
{
    int command = Serial.read();

    switch (command)
    {
        case 1:
            move_stop();
            delay(500);

            move_forward();
            break;
        case 2:
            move_stop();
            delay(500);

            turn_left();
            break;
        case 3:
            move_stop();
            delay(500);

            turn_right();
            break;
        case 4:
            move_stop();
            delay(500);

            move_backward();
            break;
```

```
        case 5:
            move_stop();
            break;
        case 6:
            front_led_control(true);
            break;
        case 7:
            front_led_control(false);
            break;
        case 8:
            rear_led_control(true);
            break;
        case 9:
            rear_led_control(false);
            break;
        case 10:
            ultrasonic_sensor_read();
            break;
        default:
            move_stop();
            front_led_control(false);
            rear_led_control(false);
    }
}
```

SmartCAR Firmware

```
void  ultrasonic_sensor_read()
{
    ultrasonic_result  =  false;
    Serial1.write(TX_buf,  NUM_TX_BYTES);
}

void  serialEvent1()
{
    unsigned char z, tmp = 0;
    Serial1.readBytes((char *)RX_buf,  NUM_RX_BYTES);

    if ( (RX_buf[0]  == 0x76) && (RX_buf[1]  == 0x00) &&
              (ultrasonic_result == false) )
    {
        for  (z  =  2; z  <  NUM_RX_BYTES-1; z++)
            tmp  +=  RX_buf[z];

        tmp  =  tmp & 0xFF;

        if  (RX_buf[NUM_RX_BYTES-1]  ==  tmp)
        {
            Serial.println("FRONT");
            for  (z=4; z  <  11; z++)
            {
                Serial.print(" F");
                Serial.print(z-4);
                Serial.print(": ");
                Serial.print(RX_buf[z]);
            }
```

```
            Serial.println("₩nBACK");
            for (z=11; z  <  NUM_RX_BYTES-1; z++)
            {
                Serial.print("  B");
                Serial.print(z-11);
                Serial.print(":  ");
                Serial.print(RX_buf[z]);
            }
        }
        ultrasonic_result  =  true;
        Serial1.write(TX_stop_buf,
                          NUM_TX_BYTES);
    }
}
```

Execute the ultrasonic sensor!

Measure only once and then disable the ultrasonic sensor!

Today

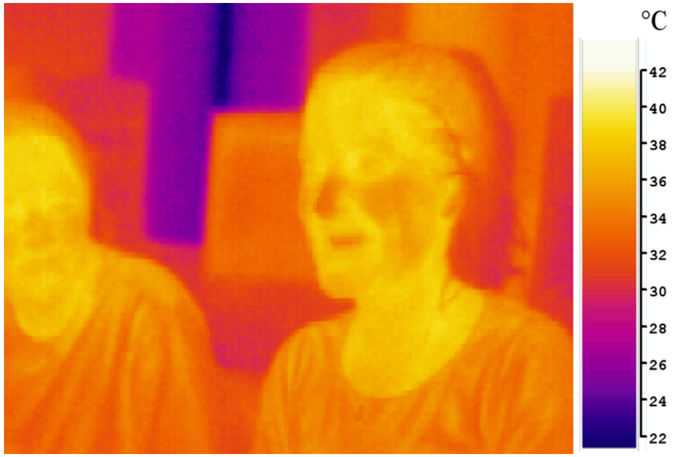
- Review
  - Ultrasonic Sensors

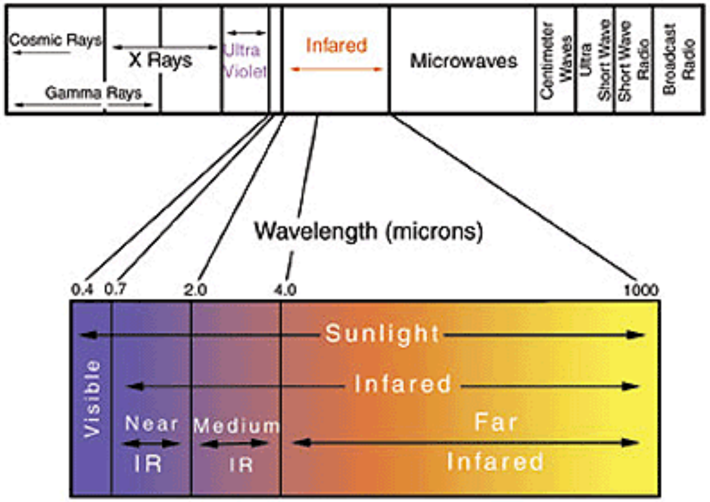
- **SmartCAR Infrared Sensors**

- Announcement

Infrared Light

- Infrared light
  - Electromagnetic radiation with longer wavelengths
  - Wavelength: 0.75 μm ~ 1 mm
  - Beyond red light in light spectrum
  - Most of thermal radiation emitted by objects near room temperature is infrared
    - ~ Few μm: near IR
    - > 25μm : far IR
    - In between: medium IR

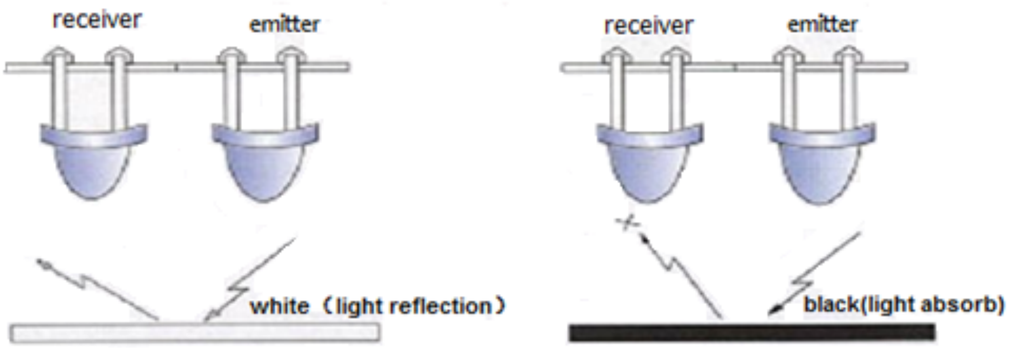




Infrared Sensors in SmartCAR

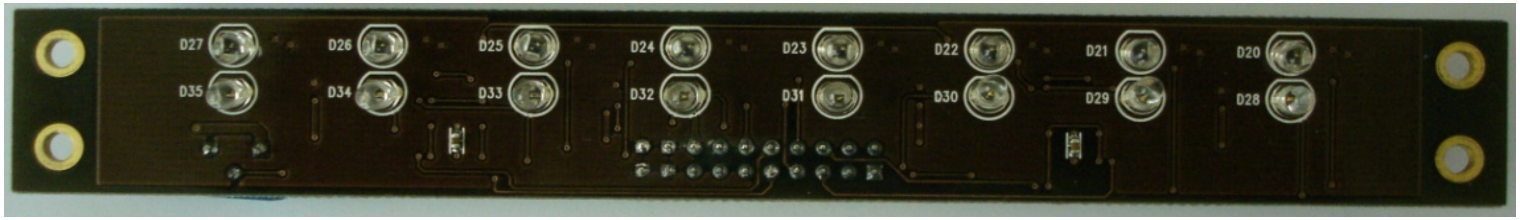
- Infrared sensors in SmartCAR
  - Emitter
    - Infrared Diode(EL-8L): electrical signal to infrared light
  - Receiver
    - Phototransistor(ST-8L): infrared light to electrical signal

  - 1) Infrared light transmitted at Infrared Diode is reflected from the surrounding object
    2) The reflected light is detected at Phototransistor(ST-8L)
  - The amount of detected light at receiver varies depending on the darkness level of the reflected surface
  - Functionality
    - Detect line status in the bottom using 8 sets of infrared sensors
    - Based on these inputs, motors will be controlled



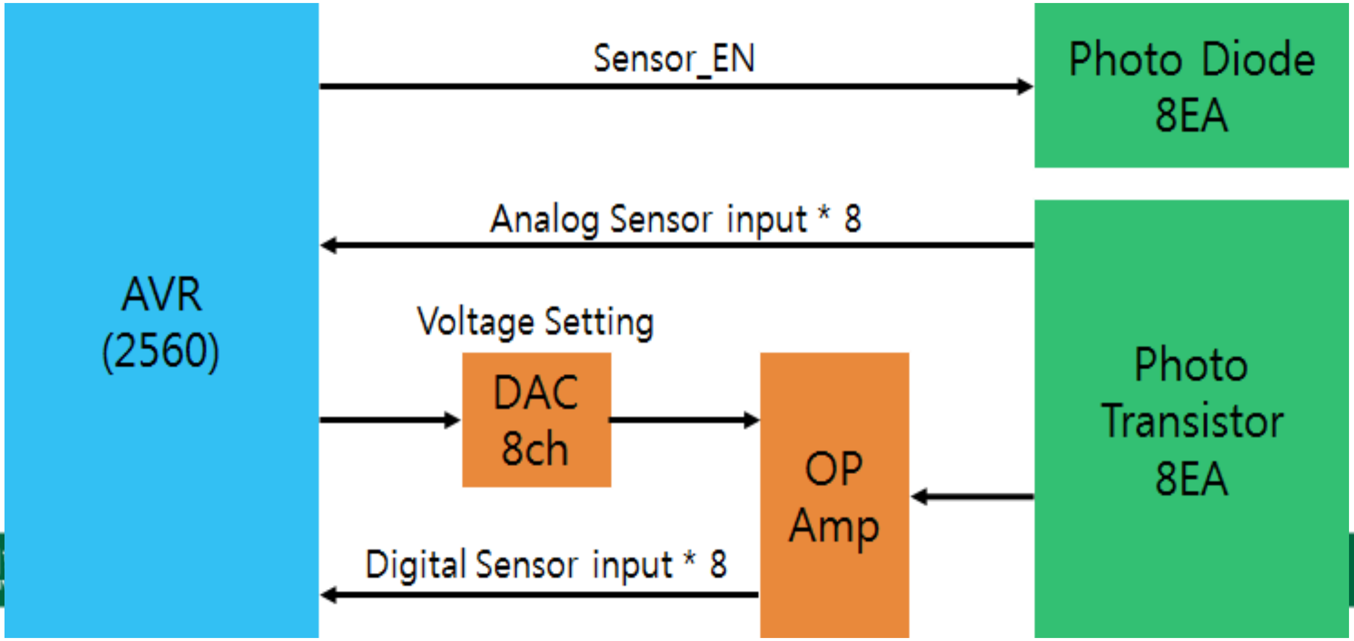
Infrared Sensors in SmartCAR

- Infrared sensors in SmartCAR
  - Functionality
    - Detect line status in the bottom using 8 sets of infrared sensors
    - Based on these inputs, motors will be controlled



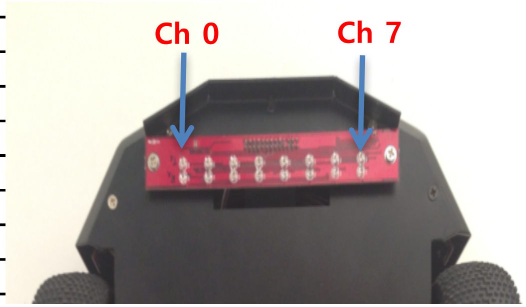
Infrared Sensors in SmartCAR

- Sensor_EN
  - Enable infrared sensors
- Analog sensor input
  - Measure infrared level in analog
- Digital sensor input
  - measure infrared level in digital
- Block diagram of infrared sensors in SmartCAR



SmartCAR Infrared Sensor Port Configuration

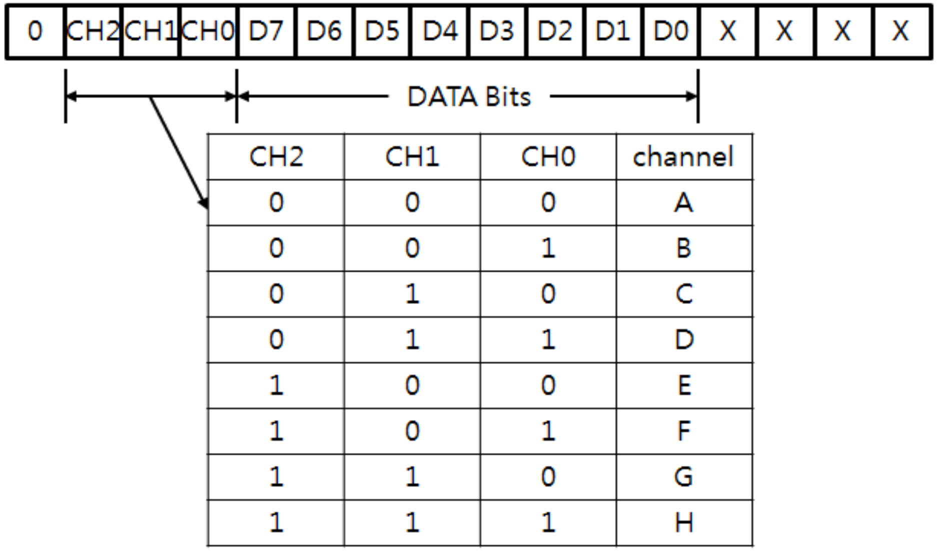
Type	Name	Port / Number	Etc
Digital Input	SENSOR_1 (LEFTMOST)	PC7 / 30	
	SENSOR_2	PC6 / 31	
	SENSOR_3	PC5 / 32	
	SENSOR_4	PC4 / 33	
	SENSOR_5	PC3 / 34	
	SENSOR_6	PC2 / 35	
	SENSOR_7	PC1 / 36	
	SENSOR_8 (RIGHTMOST)	PC0 / 37	
Analog Input	SENA_1 (LEFTMOST)	PF0 / A0	
	SENA_2	PF1 / A1	
	SENA_3	PF2 / A2	
	SENA_4	PF3 / A3	
	SENA_5	PF4 / A4	
	SENA_6	PF5 / A5	
	SENA_7	PF6 / A6	
	SENA_8 (RIGHTMOST)	PF7 / A7	
	SEN_EN	PA4 / 26	
DAC	S_DIN	PL7 / 42	
	S_SCLK	PL6 / 43	
	S_SYNCN	PL5 / 44	



- 30~37: ports to read digital values at receiver based on reference voltage set-up in OP AMP
- A0~A7: ports to read analog values at receiver
- 26: enable infrared emitter - '1' turning on emitter
- 42~44: ports for configuring reference voltage in Serial DAC
  - Configure reference voltages for 8 pins in OP AMP

Serial DAC Control

- Serial DAC Data Format (16-bit integer)



0	CH2	CH1	CH0	D7	D6	D5	D4	D3	D2	D1	D0	X	X	X	X

CH2	CH1	CH0	channel
0	0	0	A
0	0	1	B
0	1	0	C
0	1	1	D
1	0	0	E
1	0	1	F
1	1	0	G
1	1	1	H

  - CH2, CH1, CH0: channel data to select one among A ~ H
  - DAC data bits should be sent one-by-one from MSB (Most Significant Bit) first
  - Last 4 bits: garbage data

Serial DAC Control

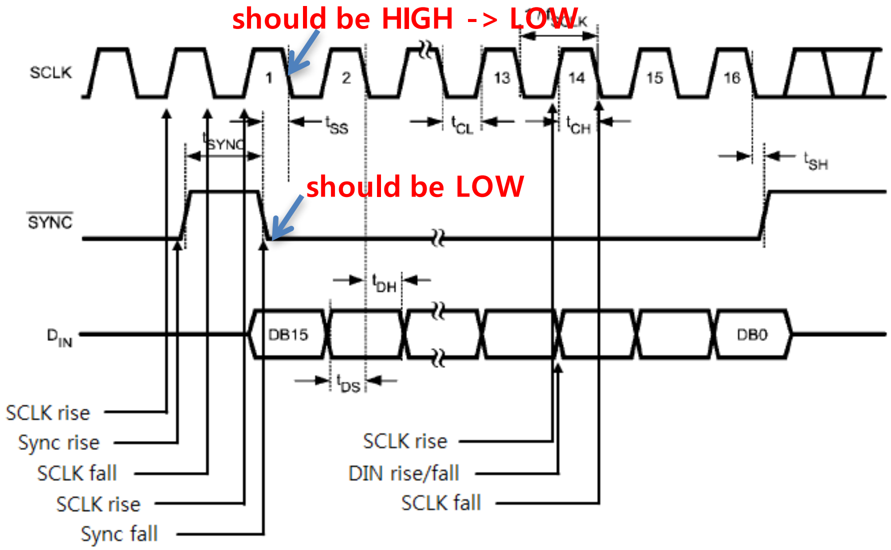
```
void DAC_CH_Write(unsigned int ch, unsigned int da)
{
    unsigned int data = ((ch << 12) & 0x7000) |
                        ((da << 4) & 0x0FF0);
    DAC_setting(data);
}

void DAC_setting(unsigned int data)
{
   int z;

   digitalWrite(S_SCLK,HIGH);
   delayMicroseconds(1);
   digitalWrite(S_SCLK,LOW);
   delayMicroseconds(1);
   digitalWrite(S_SYNCN,LOW);
   delayMicroseconds(1);
   for(z=15;z>=0;z--)
   {
     digitalWrite(S_DIN,(data>>z)&0x1);
     digitalWrite(S_SCLK,HIGH);
     delayMicroseconds(1);
     digitalWrite(S_SCLK,LOW);
     delayMicroseconds(1);
   }
   digitalWrite(S_SYNCN,HIGH);
}
```

12 4

0	CH2	CH1	CH0	D7	D6	D5	D4	D3	D2	D1	D0	X	X	X	X

DATA Bits

CH2	CH1	CH0	channel
0	0	0	A
0	0	1	B
0	1	0	C
0	1	1	D
1	0	0	E
1	0	1	F
1	1	0	G
1	1	1	H

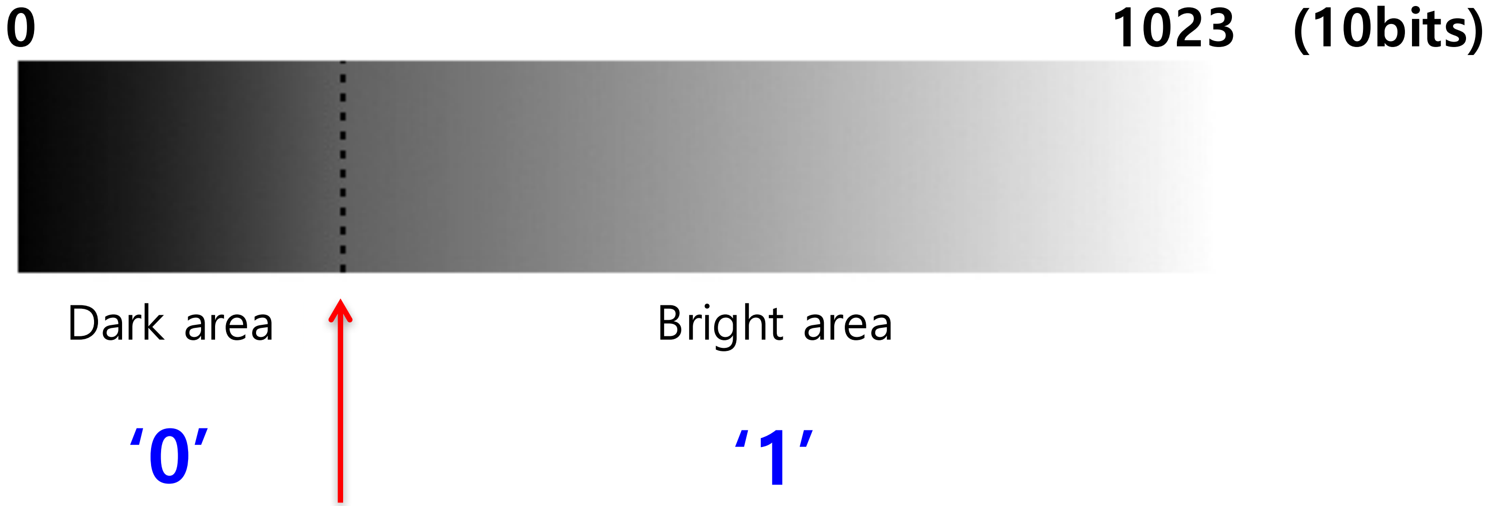


should be HIGH -> LOW

should be LOW

Threshold for Digital Sensor Input Decision

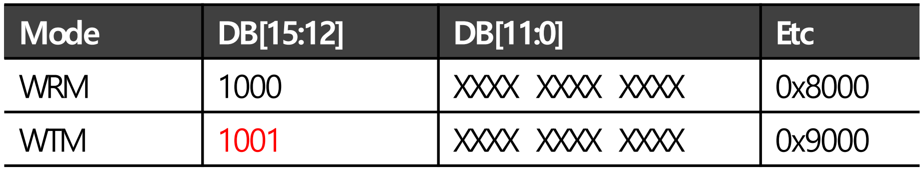
- To divide between dark area and bright area based on a threshold



- Experiment on the analog value on "white"
- Experiment on the analog value on "black"
- Set the average value to DAC

Threshold for Digital Sensor Input Decision

```
#define S_DIN                  42
#define S_SCLK                 43
#define S_SYNCN                44
#define IN_SEN_EN              26

int SensorA[8] = {A0,A1,A2,A3,A4,A5,A6,A7};
int SensorD[8] = {30,31,32,33,34,35,36,37};

void setup()
{
    int z;
    int dac_val_min[8] =
                          {59,94,81,79,166,104,108,77};
    int dac_val_max[8] =
                   {443,627,678,603,957,761,797,559};

    Serial.begin(115200);

    pinMode(IN_SEN_EN,OUTPUT);
    pinMode(S_DIN,OUTPUT);
    pinMode(S_SCLK,OUTPUT);
    pinMode(S_SYNCN,OUTPUT);
    digitalWrite(S_SCLK,LOW);
    digitalWrite(S_SYNCN,HIGH);
    digitalWrite(IN_SEN_EN,HIGH);
```

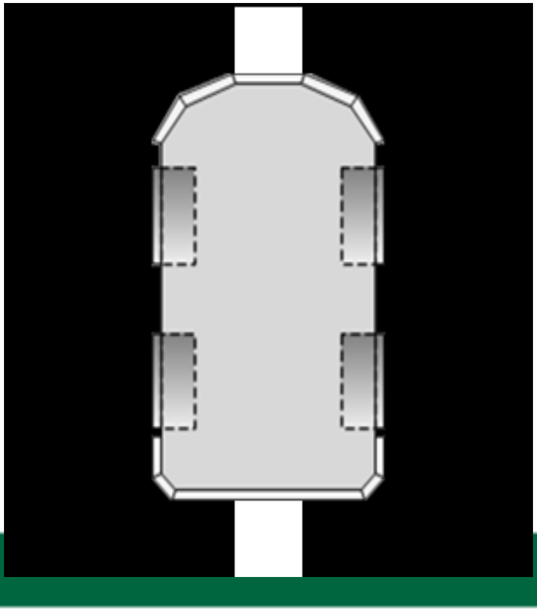


Mode	DB[15:12]	DB[11:0]	Etc
WRM	1000	XXXX XXXX XXXX	0x8000
WTM	1001	XXXX XXXX XXXX	0x9000

```
     for (z=0; z<8; z++)
         pinMode(SensorD[z],  INPUT);

     DAC_setting(0x9000); //for Write-Through  Mode

     for (z=0; z<8; z++)
     {
         int mean_val =
       (dac_val_min[z]+dac_val_max[z])/2;   //10-bit

         DAC_CH_Write(z,  mean_val >> 2);
         //should  be 8-bit
     }
}
```

Example Program

- SmartCAR is on a while track
  - If an infrared sensor is on “black”, it prints out ‘0’ to UART
  - If on “white”, it prints out ‘1’ to UART
    - For example, in the following figure, “0011 1100” or “0001 1000”
      - Left and right sides: ‘0’
      - Center: ‘1’



Print measurements to UART

```
void infrared_sensor_read()
{
    int z;

    for(z=7;z>=0;z--)
    {
        unsigned int val = analogRead(SensorA[z]);

        Serial.print(val);
        Serial.print("  ");
    }

    Serial.println("");

    for(z=7;z>=0;z--)
    {
        unsigned int val = digitalRead(SensorD[z]);
        Serial.print(val);
        Serial.print("  ");
    }
}
```

```
void serialEvent()
{
    int command = Serial.read();

    switch (command)
    {
        ...
        ...
        case 11:
            infrared_sensor_read();
            break;

        default:
    }
}
```

- If the SmartCAR receives a byte of 11, it prints out
  - analog values
  - digital values

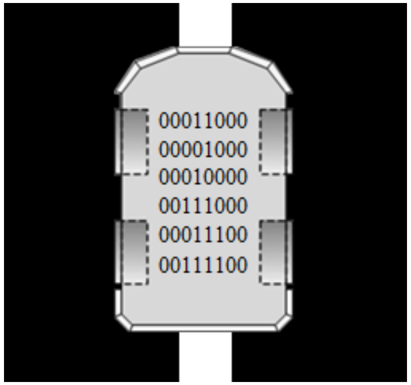
  from 8 infrared sensors

Summary of Steps

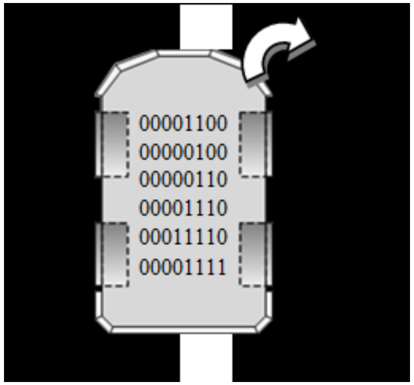
- 1) Run an application to measure analog values
  - Measure Analog Infrared Sensor Value on “White”
  - Measure Analog Infrared Sensor Value on “Black”
- 2) Add the voltage setup for digital in setup()
  - Set up the average value
- 3) Run an application to measure analog values as well as digital values

Line Tracer

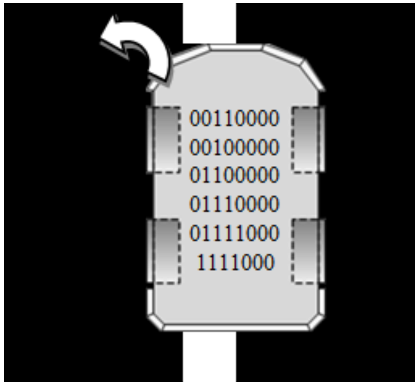
- Line tracing in SmartCAR
  - Infrared sensor data depending on SmartCAR's position



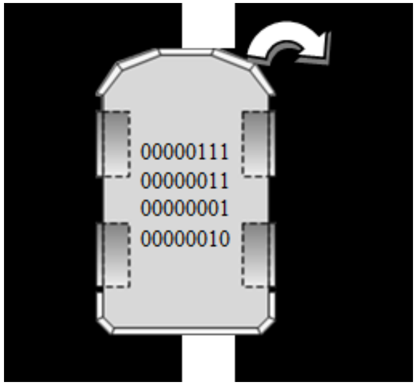
(a) Forward



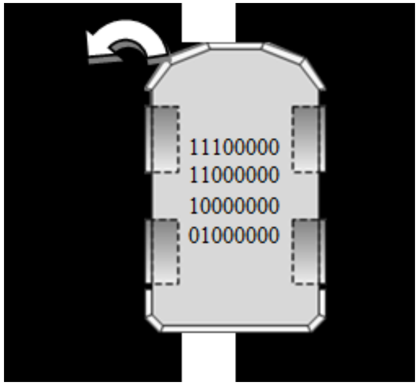
(b) Smooth Right-turn



(c) Smooth Left-turn

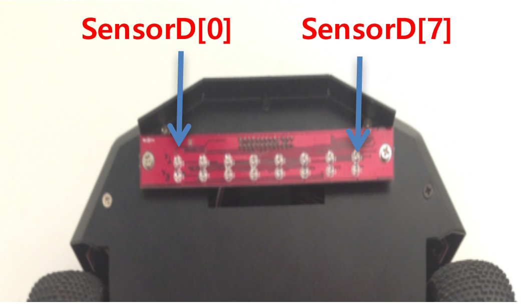


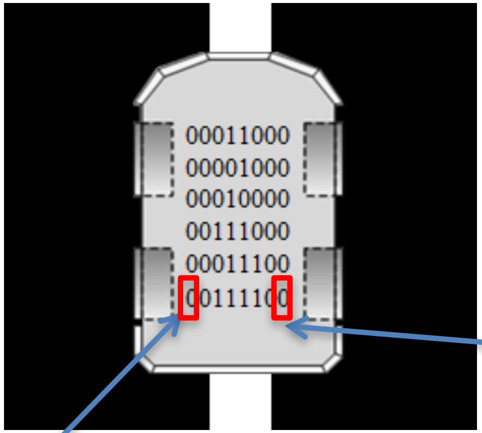
(d) Pivot Right-turn



(e) Pivot Left-turn

Sensor Data





```
...
...

unsigned char sensor_data = 0;
int z;

for(z=0;z<8;z++)
{
        unsigned int val = digitalRead(SensorD[z])
;
        sensor_data |= (val << z);
}
```

SensorD[7]	SensorD[6]	SensorD[5]	SensorD[4]	SensorD[3]	SensorD[2]	SensorD[1]	SensorD[0]

To track black line in white background,

- we should complement the sensor_data (‘1’ to ‘0’, ‘0’ to ‘1’)

```
sensor_data = ~sensor_data;
```

Control Motors w.r.t. Infrared Sensor

- How to control motors w.r.t. sensor_data

Sensor_data	Direction	Speed_data_L	Speed_data_R	Etc
0x18	FORWARD	140	140	Forward
0x10				
0x08				
0x38				
0x1C				
0x3C				
0x0C	RIGHT	200	0	Smooth Right Turn
0x04				
0x06				
0x0E				
0x1E				
0x0F				
0x30	LEFT	0	200	Smooth Left Turn
0x20				
0x60				
0x70				
0x78				
0xF0				
0x07	PIVOT_RIGHT	200	80	Pivot Right Turn
0x03				
0x02				
0x01				
0xC0	PIVOT_LEFT	80	200	Pivot Left Turn
0x40				
0x80				
0xE0				
0x00	STOP	0	0	Stop

Course Announcement

- For lab session, we will cover
  - Infrared sensors

- Next Week
  - Line tracing
  - Acquiring GPS data from Android