# 드론 통신과 PID 튜닝

An **Unmanned aerial vehicle** (UAV) is a Unmanned Aerial Vehicle. UAVs include both autonomous (means they can do it alone) drones and remotely piloted vehicles (RPVs). A UAV is capable of controlled, sustained level flight and is powered by a jet, reciprocating, or electric engine.

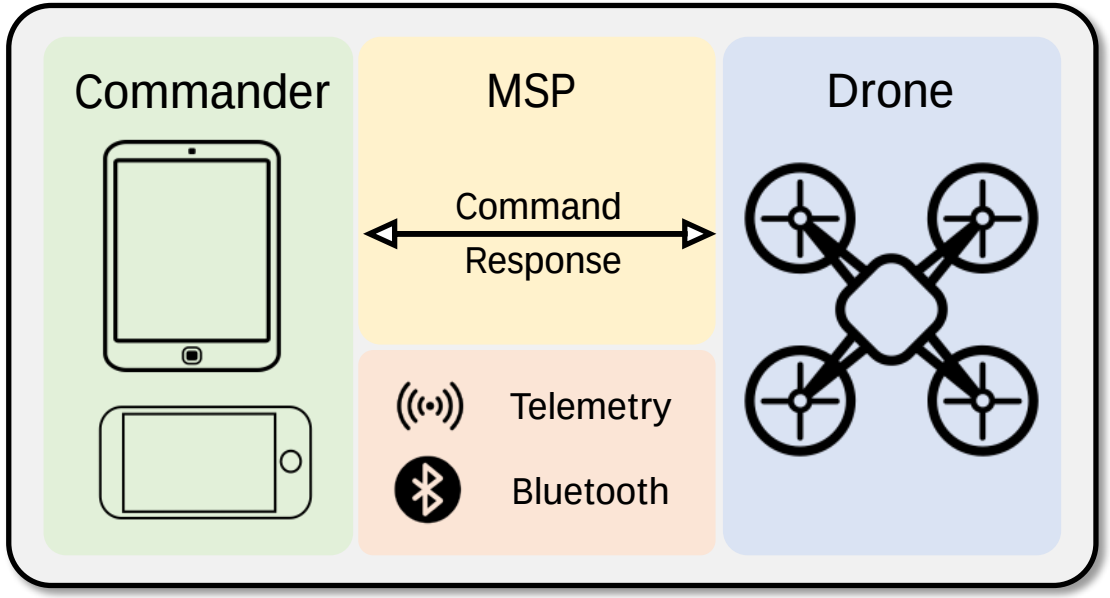

# Multi-Wii 프로토콜

# MSP 란?



- Multi-Wii
  - Wii 게임기용 Nunchuck의 센서를 이용하여 개발을 시작한 드론 오픈소스
- MSP(Multi-Wii Serial Protocol)
  - Multiwii 용 직렬통신 프로토콜
  - Tablet, Smartphone, PC와
    - 조정 명령 전송
    - 드론 상태 모니터링
    - 주요 설정
  - Bluetooth 또는 Telemetry로 이용

Nintendo Wii Nunchuck

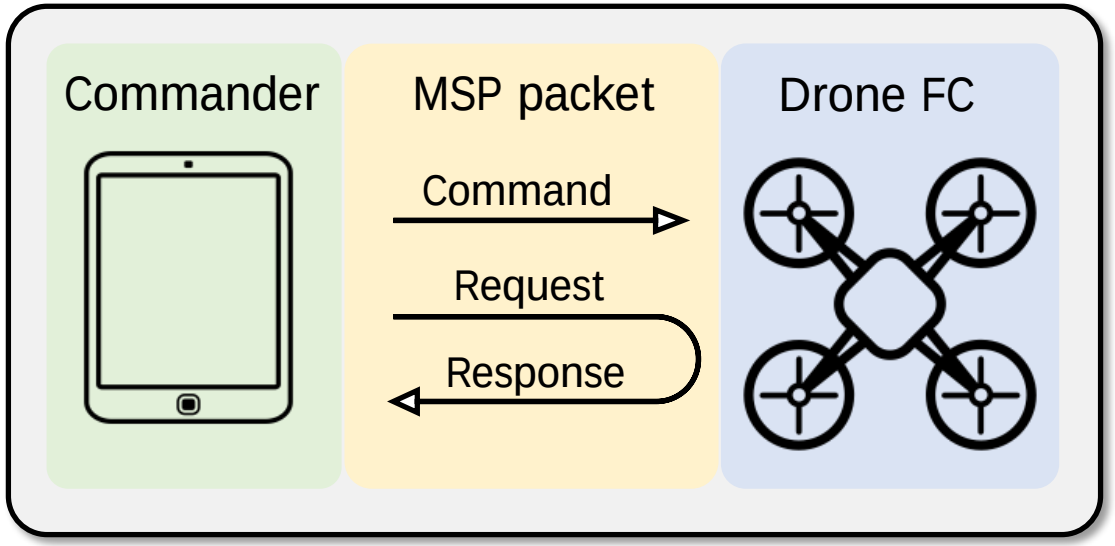


# MSP 개요



## MSP 패킷 종류

- 명령 전송(Command)
  - Commander → Drone FC
- 데이터 요청(Request)
  - Commander → Drone FC
- 응답(Response to Request)
  - Drone FC → Commander



# 명령 전송 패킷

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## 명령 전송

- Commander → Drone FC
- 패킷


  - Header
    - $ M : preamble
    - < : 방향 Commander → 드론 표시
    - Size(N): Payload의 바이트 수
    - Type(T): 명령의 종류
  - BCC(Block Check Code): 데이터 무결성 확인, XOR사용

# 데이터 요청 패킷

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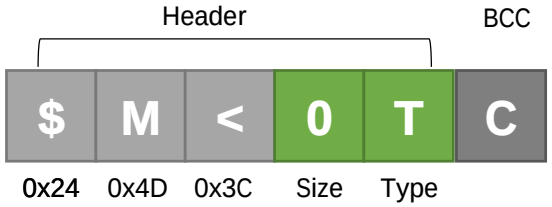
## 데이터 요청 전송

- Commander → Drone FC
- 패킷




  - Header
    - $ M : preamble
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    - Size(N): Payload의 바이트 수
    - Type(T): 명령의 종류
  - BCC: 데이터 무결성 확인, XOR사용

# 응답 패킷

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## 응답

- Drone FC → Commander
- 패킷


  - Header
    - $ M : preamble
    - > : 방향  드론 → Commander
    - Size(N): Payload의 바이트 수
    - Type(T): 명령의 종류
  - BCC(Block Check Code): 데이터 무결성 확인, XOR사용

# BCC 계산 방법

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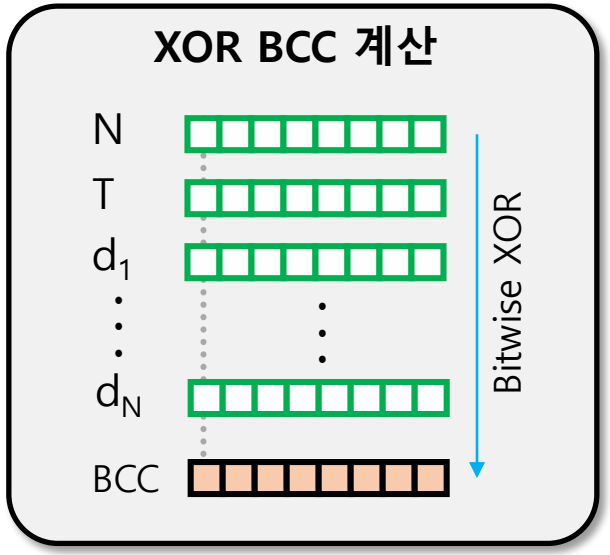
## XOR BCC

- 헤더와 BBC를 제외한 Size, Type, Payload 를 비트 단위 Excusive Or

C = bitwise XOR( Size N | Type T | Payload N -bytes )

- 오류 확인 방법
  - 계산 BCC와 수신된 BCC 비교
    - 일치하면 통신 에러 없다고 판단.



# 명령 타입

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## 대표 명령 타입(T)

- 번호에 따른 구분
  - 100번대: 정보 요청
    - Response 있음.
    - ex: MSP_RAW_IMU
      MSP_RAW_GPS
  - 200번대: 명령 전송
    - Response 없음
    - ex: MSP_SET_RAW_RC
      MSP_SET_PID

| 요청 명령 | 번호 | 명령 전송 | 번호 |
|---|---|---|---|
| MSP_IDENT | 100 | MSP_SET_RAW_RC | 200 |
| MSP_STATUS | 101 | MSP_SET_RAW_GPS | 201 |
| MSP_RAW_IMU | 102 | MSP_SET_PID | 202 |
| MSP_SERVO | 103 | MSP_SET_BOX | 203 |
| MSP_MOTOR | 104 | MSP_SET_RC_TUNING | 204 |
| MSP_RC | 105 | MSP_ACC_CALIBRATION | 205 |
| MSP_RAW_GPS | 106 | MSP_MAG_CALIBRATION | 206 |
| MSP_COMP_GPS | 107 | MSP_SET_MISC | 207 |
| MSP_ATTITUDE | 108 | MSP_RESET_CONF | 208 |
| MSP_ALTITUDE | 109 | MSP_SELECT_SETTING | 210 |
| MSP_ANALOG | 110 | MSP_SET_HEAD | 211 |
| MSP_RC_TUNING | 111 | MSP_SET_SERVO_CONF | 212 |
| MSP_PID | 112 | MSP_SET_MOTOR | 214 |
| MSP_BOX | 113 | MSP_BIND | 241 |
| MSP_MISC | 114 | MSP_EEPROM_WRITE | 250 |
| MSP_MOTOR_PINS | 115 | MSP_DEBUGMSG | 253 |
| MSP_BOXNAMES | 116 | MSP_DEBUG | 254 |
| MSP_PIDNAMES | 117 | | |
| MSP_SERVO_CONF | 120 | | |


# MSP 수신 프로그래밍

# 수신 과정

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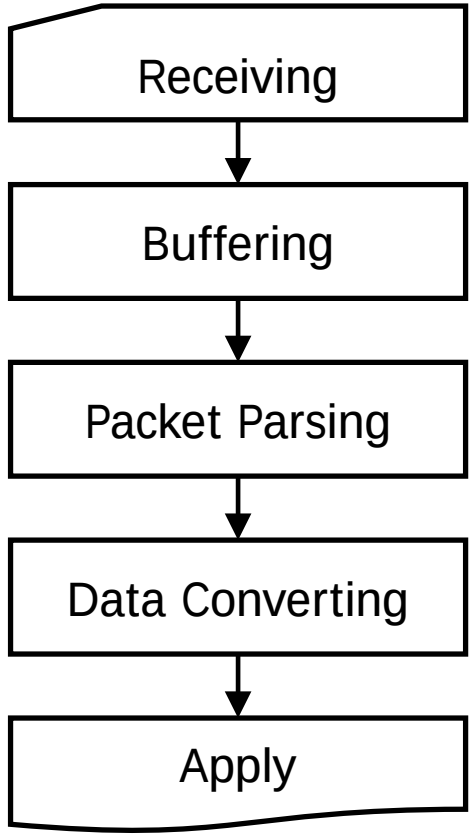
## 주요 절차

- **Buffering**:
  - ring 버퍼로 수신과 처리가 동시에 이뤄지지 않아도 일정 분량 데이터 보관.
  - serialBufferRX[] 에 저장
- **Packet Parsing**:
  - 패킷을 분석하여 데이터의 무결성을 검사하고 유용한 데이터 추출
  - inBuf[] 에 저장
- **Data Converting:**
  - Parsing 된 데이터를 원하는 변수에 맞게 형변환
  - rcSerial[] 에 저장



# Buffering

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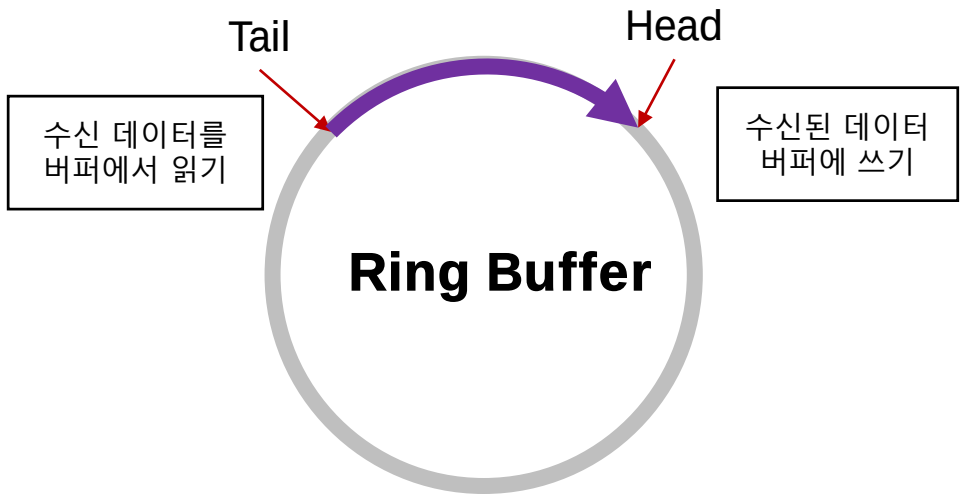
- Buffer의 필요성
  - 수신과 처리가 동시에 일어날 때 유효
  - 처리가 늦어질 때 수신데이터가 싸여 Overrun 상태가 될 수 있음.
  - 유한한 바이트의 버퍼를 사용하여 원활한 처리가 가능하도록 Ring의 형태를 사용함.
  - 실제로는 1차원 배열로 구현




# Ring Buffer구현

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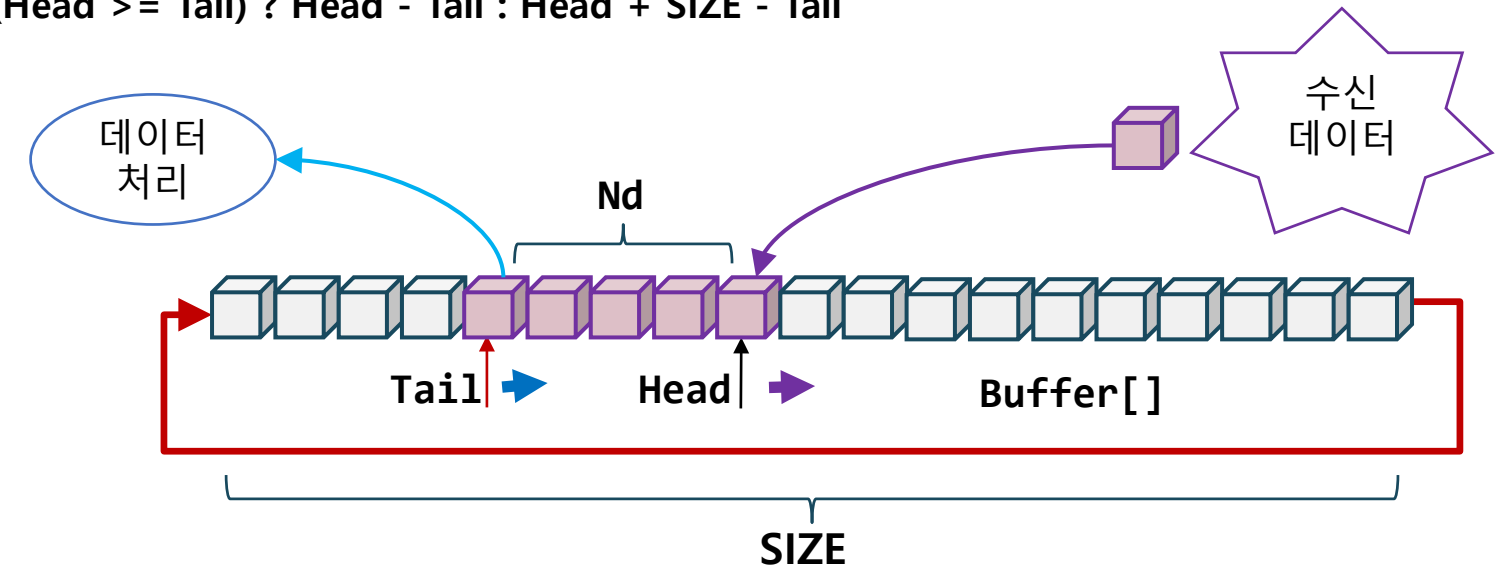
## Ring buffer의 구현

- 1차원 배열을 ring 형태로 사용하고자 Head와 Tail 인덱스를 적용
- 수신 데이터는 head에 놓고 head를 다음 자리로 옮김.
- 데이터 처리는 tail에서 읽고 tail을 다음 자리로 옮김.
- 인덱스는 배열 끝에 도달하면 다시 0으로 보냄.
- Head와 Tail의 차이, 즉 Nd 는 다음과 같이 구할 수 있음.
  - **Nd = (Head >= Tail) ? Head - Tail : Head + SIZE - Tail**



# Ring Buffer구현

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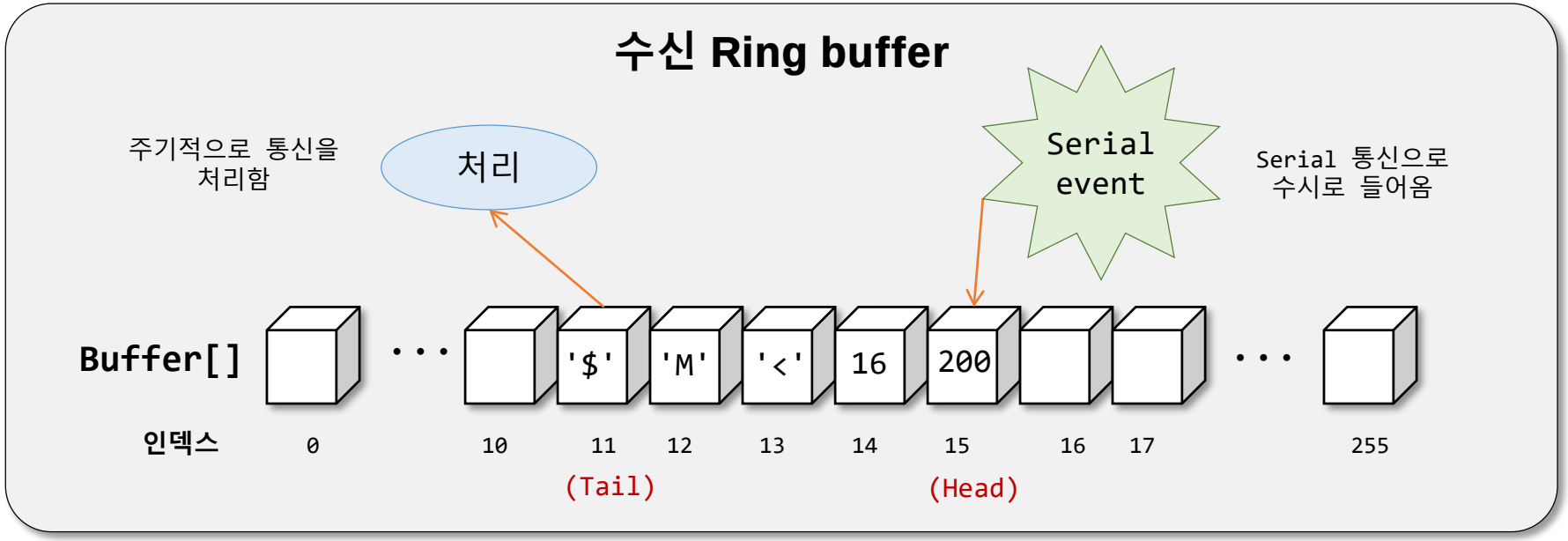
- Ring buffer에 쓰기
  - SerialEvent를 통해 수신 받은 데이터를 버퍼의 head 인덱스를 따라 차례대로 저장.
  - 인덱스는 끝에 도달하면 다시 0으로
- Ring buffer에 읽기
  - 버퍼로부터 데이터를 수신 받은 tail 인덱스로부터 순서대로 읽음.



# Ring Buffer에 쓰기 코드

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- SerialEvent 함수에 구현
  - 수신된 데이터를 링버퍼 serialBufferRX[]에 저장
  - 저장 후 serialHeadRX 를 1 증가
  - RX_BUFFER_SIZE 는 버퍼의 크기

```
void serialEvent(void) {
    // When data is arrived, keep it to the bufferRX[]
  while(Serial.available()) {          // available data >0
    uint8_t h = serialHeadRX;          // temp index h for Head index
    // store data to Buffer and increase index h
    serialBufferRX[h++] = (uint8_t)Serial.read();
    if(h >= RX_BUFFER_SIZE)  h = 0;    // to make ring buffer
    // keep h to seiralHeadRX for the next operations
    serialHeadRX = h;
  }             // repeat till available data ==0
}
```

# Ring Buffer 의 데이터 갯수

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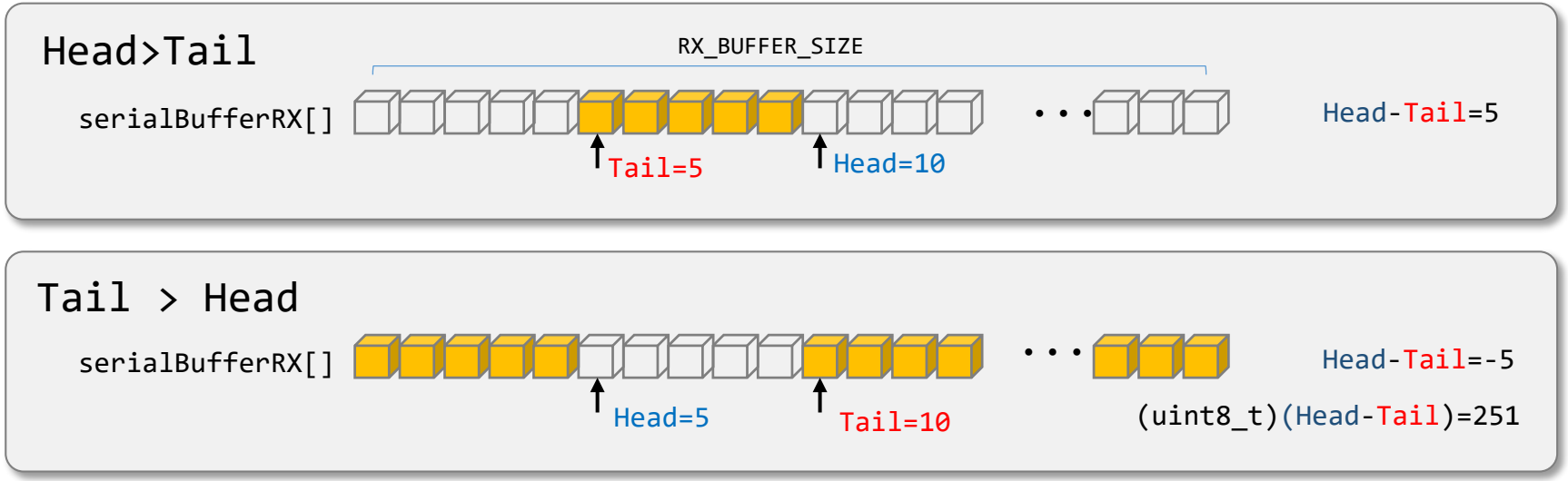
- SerialAvailable[]
  - Head 와 Tail의 차이를 구하여 링 버퍼의 유효한 데이터 계산
  - 2가지 경우




```
uint8_t SerialAvailable(void) {
  return ((uint8_t)(serialHeadRX - serialTailRX)) % RX_BUFFER_SIZE;
  //check (a>=b)? a-b : a+SIZE-b;
}
```

# Ring Buffer 에서 1바이트 읽어내기

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- SerialRead[]
  - 링 버퍼의 tail 에서 1바이트 읽어내기
  - head!=tail 이면
    - t를 1증가 시키고 t>=buffer_size 이면 t=0
      ← 배열에 끝에 도달하면 처음으로
  - head==tail 이면 처리 불가

```
uint8_t SerialRead(void)  {                 // read from seiralHeadRX[]
  uint8_t t = serialTailRX;                 // temp index h for Tail index
  uint8_t c = serialBufferRX[t];            // get a data
  if(serialHeadRX != t) { // to prevent Tail from exceeding Head
    if(++t >= RX_BUFFER_SIZE) t = 0 ;
    // increase 1 and if it exceeds buffer size, t=0 to make ring buffer
    serialTailRX = t ;                      // update seiralTailRX
  }
  return c;
}
```

# 패킷 파싱

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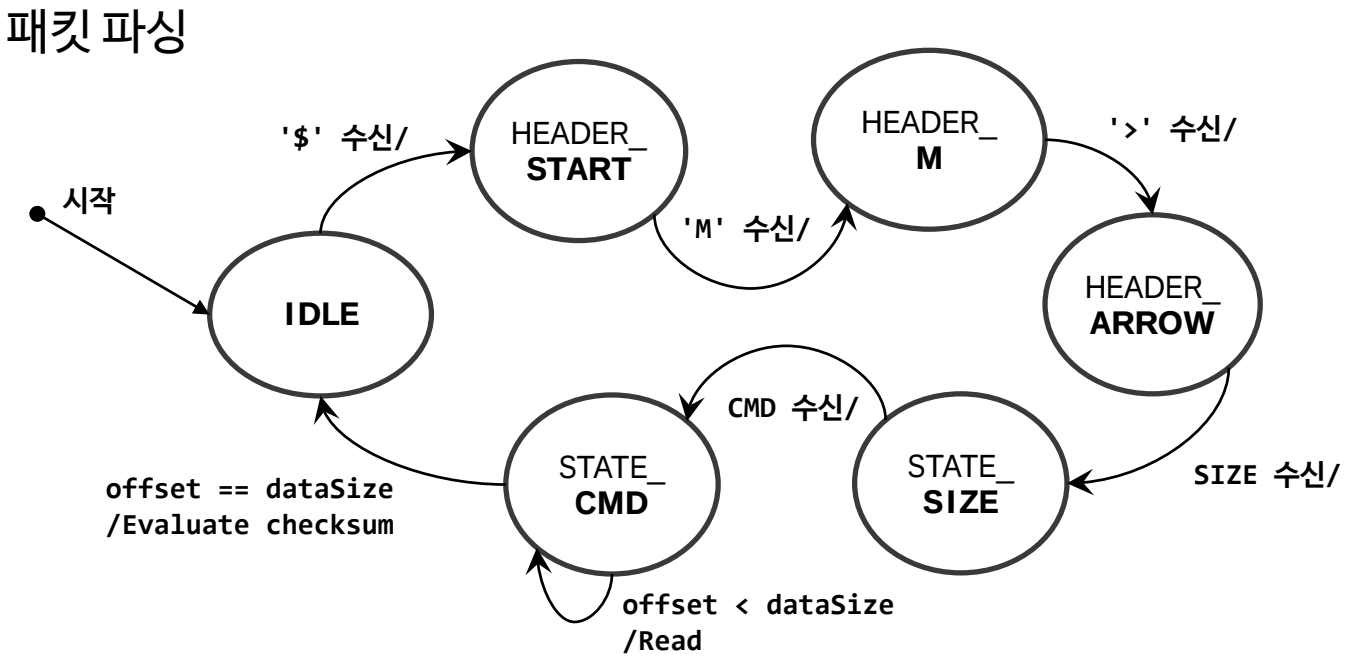
- 파싱에 State diagram 이용
  - 다음과 같은 상태를 정의
    - IDLE, HEADER_START, HEADER_M, HEADER_ARROW, HEADER_SIZE, HEADER_CMD



# 패킷 파싱

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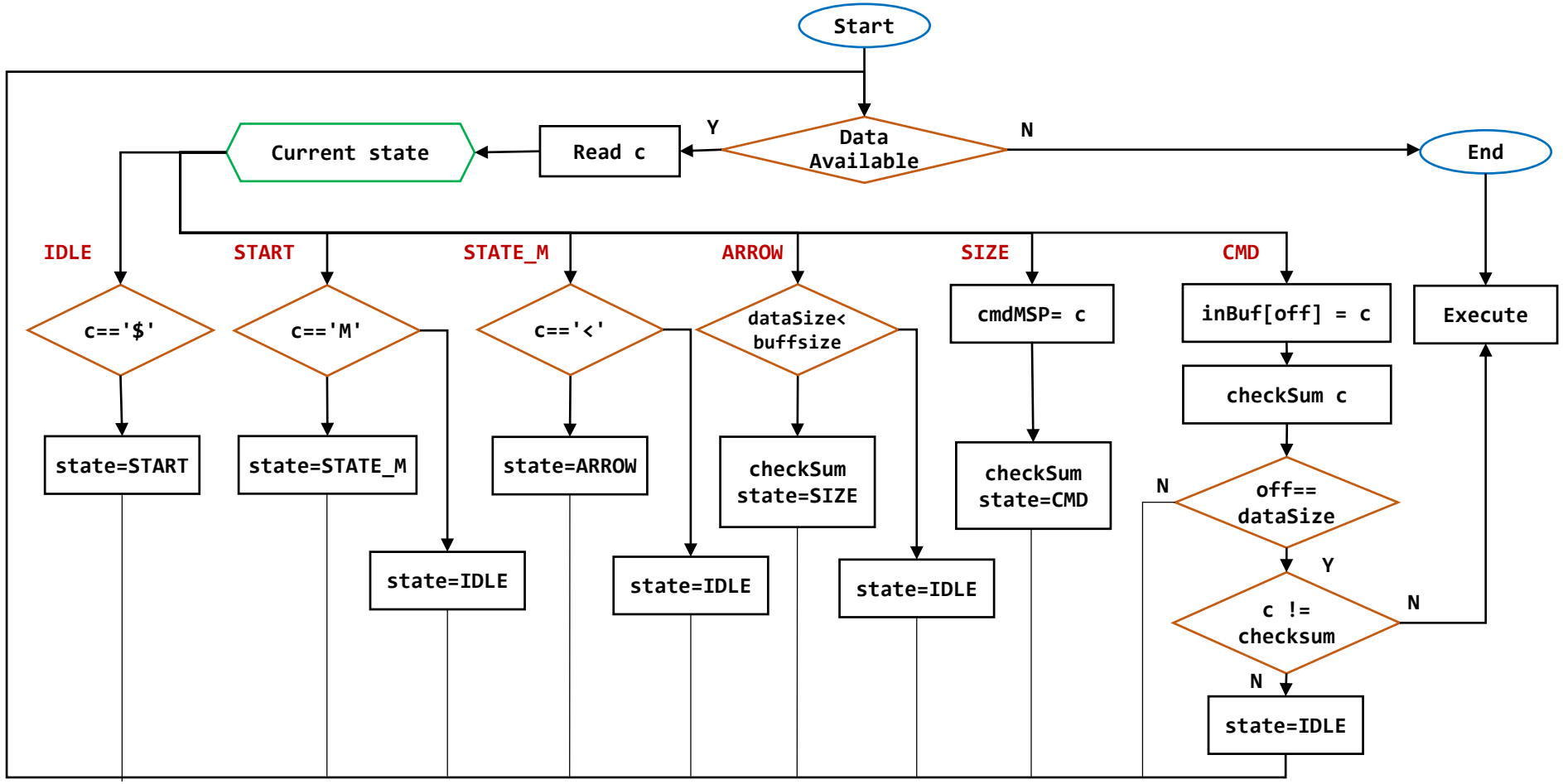
## 순서도



# 패킷 파싱 코드

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- serialCom 함수에 구현 [1/3]

```
void serialCom(void) {                          // parsing the sequence using protocol
  uint8_t c, availableData;                     // c =current data
  static uint8_t offset;                        // offset in inBuf
  static uint8_t dataLen;                       // Number of data to be recieved
  static uint8_t c_state;                       // current state sved
  uint8_t state;                                // tmep state of protocol
  availableData = SerialAvailable();            // read number of available data
  while(availableData--)  {                     // repeat till availableData=0
      c = SerialRead();                         // read a char
      state = c_state;                          // load current state
      if(state == IDLE) {
        if(c == '$')
          state = HEADER_START;                  // to the next state
      }
      else if(state == HEADER_START) {
        state = (c == 'M') ? HEADER_M : IDLE;
      }
      else if(state == HEADER_M) {
        state = (c == '<') ? HEADER_ARROW : IDLE;  }
```

# 패킷 파싱 코드

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- [2/3]

```
      else if(state == HEADER_ARROW) {    // dataLen received
        if(c > INBUF_SIZE) {             //  dataLen >INBUF_SIZE (64)
          state = IDLE;                  // give up
          continue;                      // exit  if statements
        }
        dataLen = c;                     // update dataLen with new date recieved
        checksum = c;                     // check sum start
        offset = 0;                      // make writing index of inBuf[] 0
        indRX = 0;                       // make reading index of inBuf[] 0
        state = HEADER_SIZE;
      }
      else if(state == HEADER_SIZE) {    // command received
        cmdMSP = c;                      // save command to cmdMSP
        checksum ^= c;                   // compute checksum (XOR)
        state = HEADER_CMD;              // next
      }
```

# 패킷 파싱 코드

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- [3/3]

```
    else if(state == HEADER_CMD) {
        if(offset < dataLen)   {          // updating data if not finished update
          checksum ^= c ;                 // compute checksum
          inBuf[offset++] = c;            // update inBuf
        }
        else {                            // finished
          if(checksum == c)               // checksum match !
            evaluateCommand(cmdMSP);      // execute cmdMSPcommand
          state = IDLE;                   // to the next
          availableData = 0;              // availableData=0 to exit while
        }
      }
      c_state = state;                    // keep cur state to c_state
  }
}
```

# 데이터 변환

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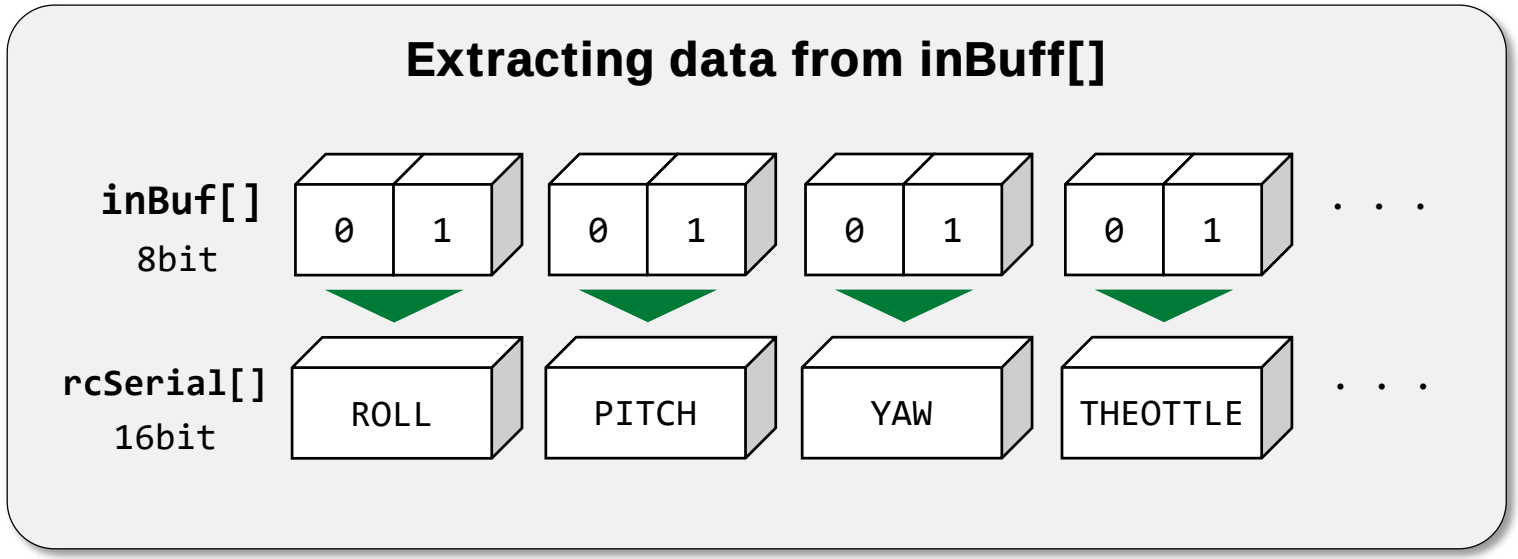
- 8bit 배열 → 16bit 배열
  - uint8_t와 uint16_t 배열의 포인터를 이용



# 데이터 변환

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- evaluateCommand 함수에 구현

```
void evaluateCommand(uint8_t c)  {      // execute command
  switch(c){
    case MSP_SET_RAW_RC:                      // cmdMSP is Drone RC control command
      // update rcSerial[](16 bit)  by reading inBuf[] (8bit).
      s_struct_w((uint8_t*)&rcSerial, 16);
      // Causion:(uint8_t*)&rcSerial  -->
      // the start address of rcSerial in the form of uint8_t*
      Serial.print(rcSerial[ROLL]); Serial.print(",");
      Serial.print(rcSerial[PITCH]);Serial.print(",");
      Serial.print(rcSerial[YAW]);Serial.print(",");
      Serial.println(rcSerial[THROTTLE]);
      break;
    default:                                  // any other commands
      break;
  }
}
```

# 데이터 변환

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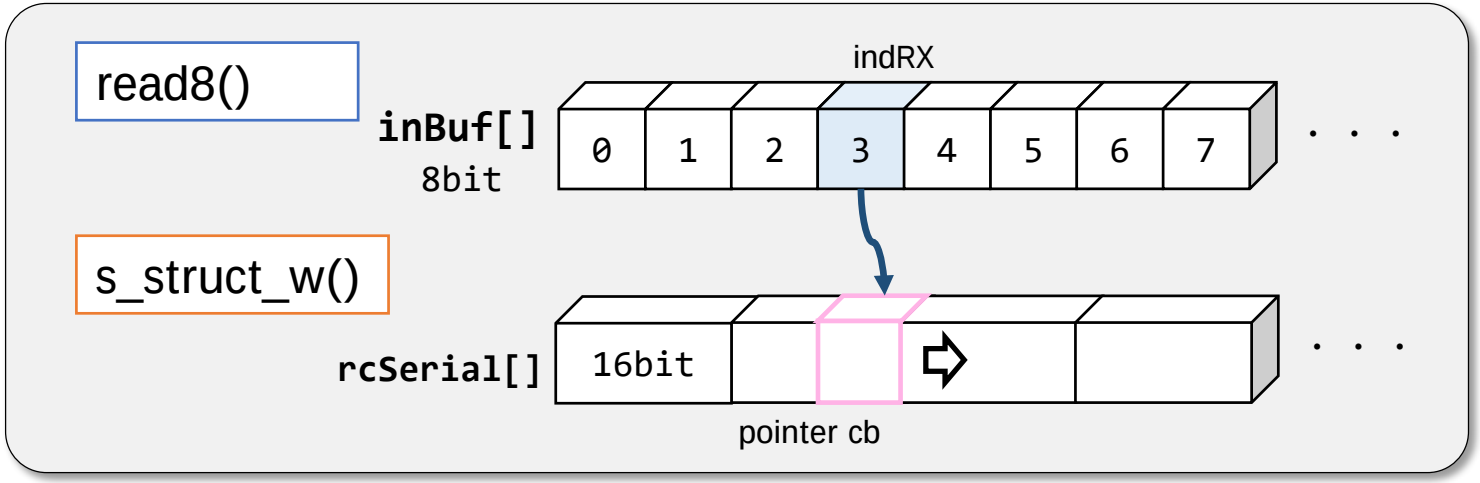
## 형 변환

```
static void s_struct_w(uint8_t *cb,uint8_t siz){
  while(siz--)
    *cb++ = read8();
}
static uint8_t read8(void) {
  return inBuf[indRX++]&0xff;
}
```



# 수신 과정 정리

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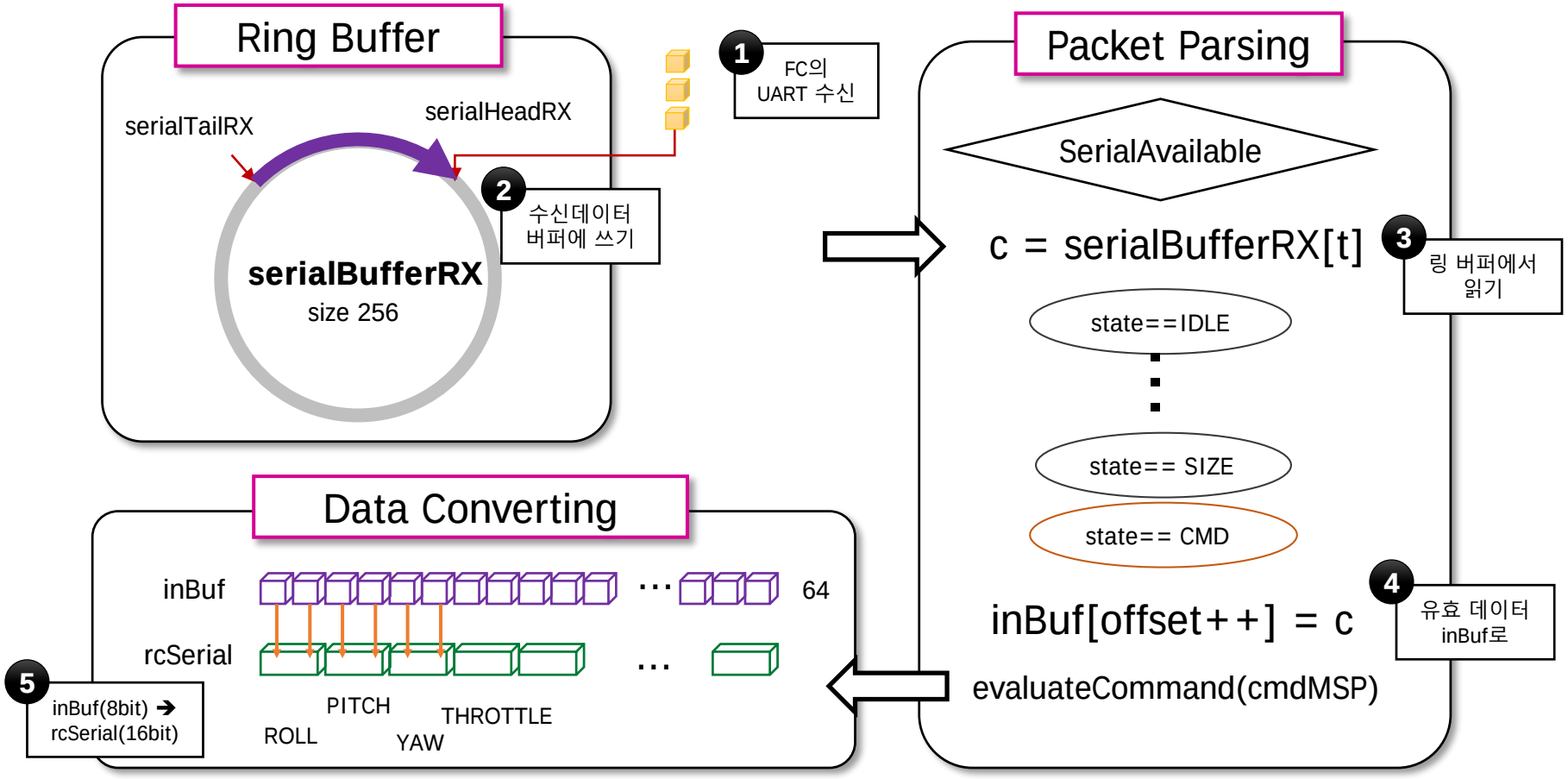
## 데이터 흐름




# 송신 프로그래밍

# 독자 송신 프로토콜

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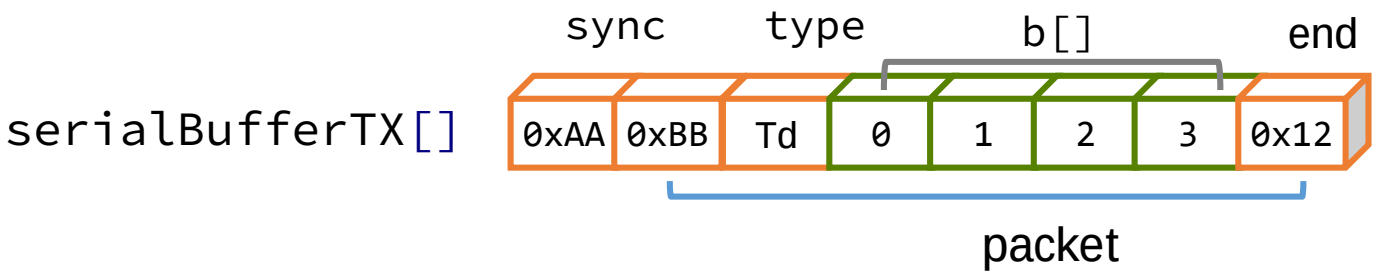
- 송신 프로토콜 필요
  - 컴퓨터에서 PID 튜닝을하려면 내부 계측 값들 실시간으로 읽어야 함
  - Multiwii의 프로토콜의 경우  요청하면 보내는 방식이므로 느림
  - 요구되는 각도, 각속도 등 정보량이 많기 때문에 순차적 전송
- 프로토콜 설정
  - 1개의 float 값을 4개의 unint8_t 배열 b[] 로 전송



# 데이터 전송 방법

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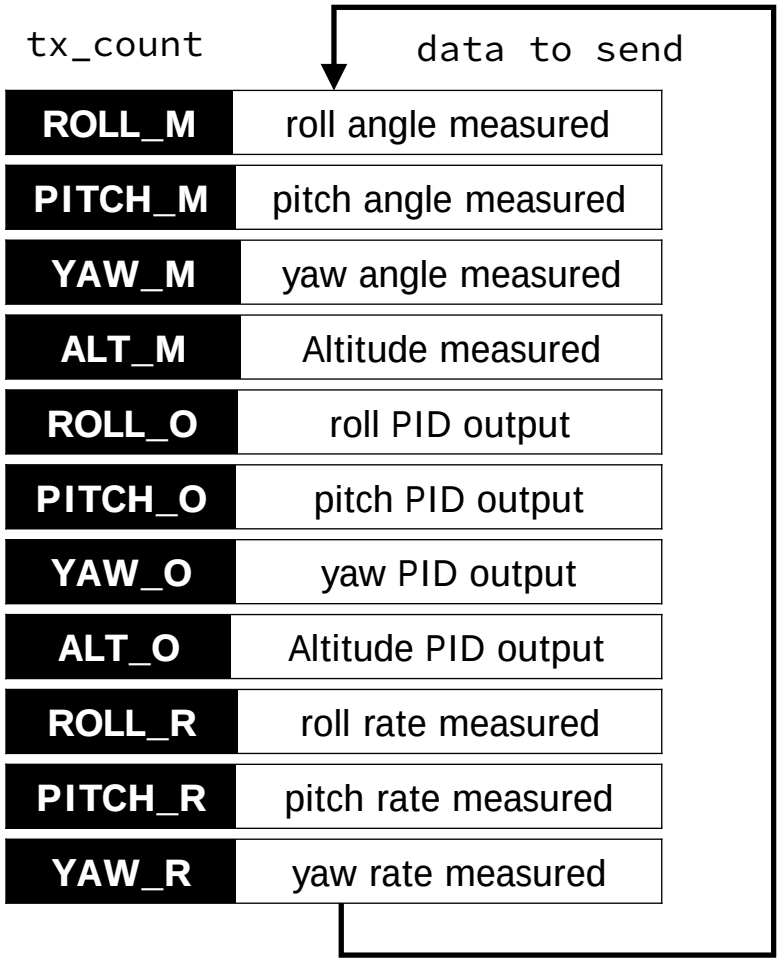
- 방법
  - 매 샘플 마다 한꺼번에 모든 데이터를 전송하면 부하가 많이 걸림.
  - 일련 번호를 주고 샘플 마다 하나씩 전송
    - enum 을 이용 11개의 상태를 만듬.
      - ROLL_M, PITCH_M, YAW_M, ALT_M, ROLL_O, PITCH_O, YAW_O, ALT_O, ROLL_R, PITCH_R, YAW_R
    - 불필요한 내용은 이동하여 시간 단축 가능



# 데이터 전송

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- sendTXdata()함수에 sin,cos 파형 전송구현

```
enum  Packet_n{ROLL_M, PITCH_M, YAW_M, ALT_M, ROLL_O, PITCH_O, YAW_O, ALT_O,
                ROLL_R, PITCH_R, YAW_R };
void Multiwii::sendTXdata(){
  float tx_data;
  static uint16_t k=0;
  switch(tx_count){
    case ROLL_M:
      tx_data=  20.* sin(0.01*k);k++; break; // test function
    case PITCH_M:
      tx_data=20.* sin(0.03*k);k++; break;   // test function
    case YAW_M:
      tx_data=45.* cos(0.03*k);k++; break;   // test function
...
   }
   sendPacket(tx_count, tx_data);
   tx_count++;
   if (tx_count>YAW_M) tx_count=ROLL_M;
}
```

# 데이터 전송

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- sendPacket()함수에 구현

```
void Multiwii::sendPacket(byte n, float f) {
  byte* b = (byte *) &f;
  serialBufferTX[2]=n;
  for(int i=0;i<4;i++)
    serialBufferTX[i+3]=b[i];
   NeoSerial.write(serialBufferTX,8);
}
```

# 데이터 전송

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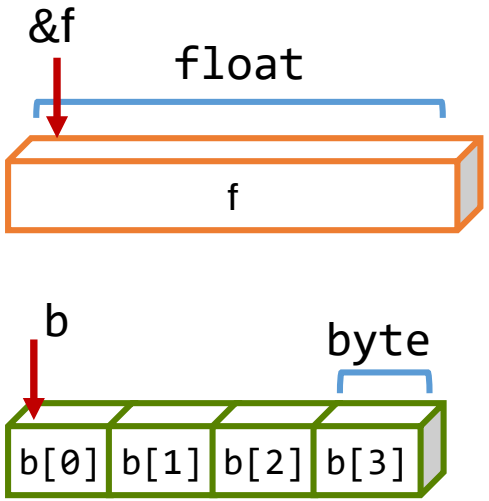
- `byte* b = (byte *) &f;`
  - f의 주소를 byte의 주소로 바꾸어 byte 포인터 b에 대입
  - 그러므로 b가 가리키는 곳은 f의 주소가 됨.
  - 포인터 b는 byte 배열처럼 쓸 수 있게 됨.
  - union 을 사용해도 같은 결과



# Multiwii: Class로 만들기

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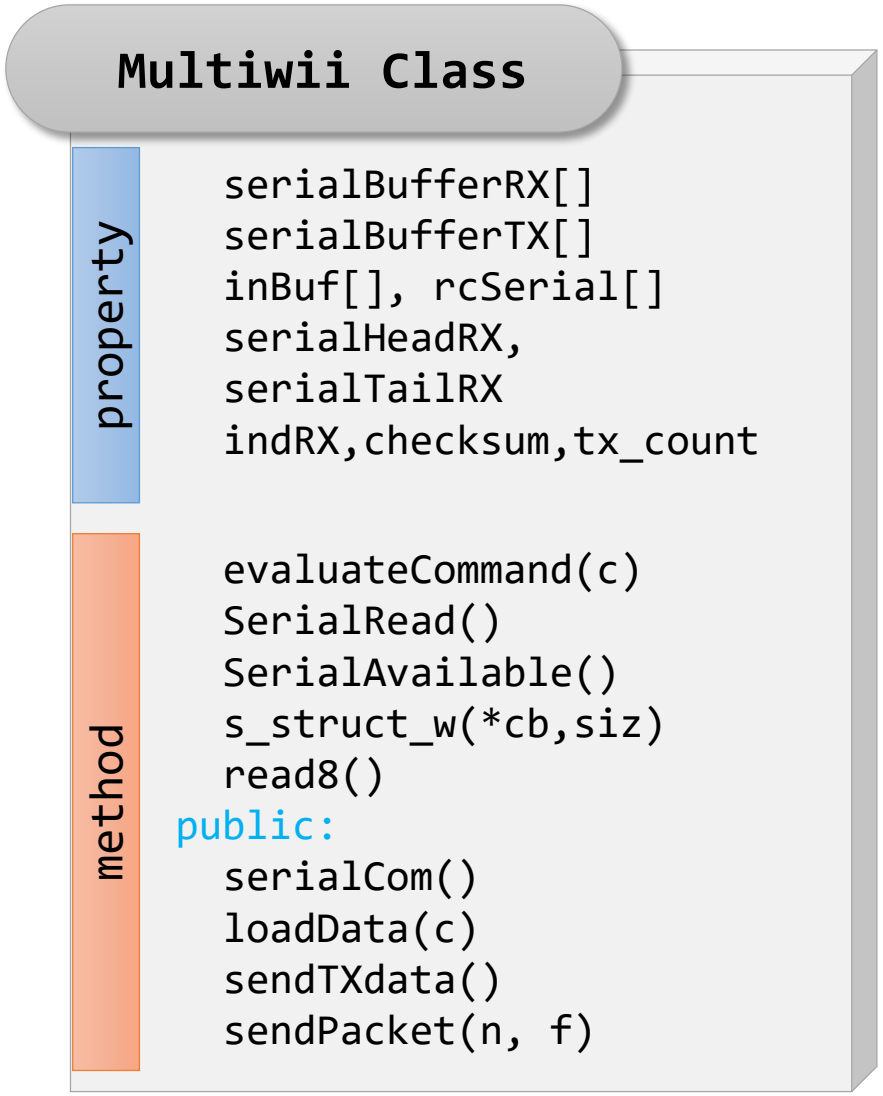
- Multiwii class 정의
  - Property
    - serialBufferRX[]: 수신 링버퍼
    - inBuf[]: 패킷 파싱의 결과
    - rcSerial[]: inbuf에서 변환된 16비트 데이터
  - Method
    - evaluateCommand(c): 커멘드 종류 분석
    - SerialRead(): 링버퍼에서 데이터 읽기
    - SerialAvailable(): 링버퍼의 유효 데이터 갯수 읽기
    - serialCom(): 패킷 파싱
    - loadData(c): 링 버퍼에 수신 데이터 입력



# Multiwii Class 정의

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SerialLib.h [1/2]

```
#include <Arduino.h>
#include <NeoHWSerial.h>
#define RX_BUFFER_SIZE 256                      // size of serialBuffRX
#define TX_BUFFER_SIZE 8
#define INBUF_SIZE 64                           // size of inBuf
#define MSP_SET_RAW_RC 200                      // control command
enum  Packet_n{ROLL_M, PITCH_M, YAW_M, ALT_M,
               ROLL_O, PITCH_O, YAW_O, ALT_O,
               ROLL_R, PITCH_R, YAW_R   };
class Multiwii{
    enum  MSP_protocol_bytes{IDLE, HEADER_START, HEADER_M,
       HEADER_ARROW, HEADER_SIZE, HEADER_CMD}; //state of protocol
    enum rcData{ROLL, PITCH, YAW, THROTTLE, AUX1, AUX2, AUX3,
       AUX4, AUX5, AUX6, AUX7, AUX8};   //contents of pyload
    static uint8_t inBuf[INBUF_SIZE];                   // internal buffer
    static uint8_t indRX;                               // index for reading inBuf
    static uint8_t cmdMSP, checksum;;
    static int16_t rcSerial[8];                         // vales (범위: 1000 ~ 2000)
```

# Multiwii Class 정의

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SerialLib.h [2/2]

```
    static volatile uint8_t serialHeadRX, serialTailRX; // Head,Tail of Ring buffer
    static uint8_t serialBufferRX[RX_BUFFER_SIZE];      // Ring buffer
    static uint8_t serialBufferTX[TX_BUFFER_SIZE];
    static int tx_count;
    void evaluateCommand(uint8_t c);                    // 명령어 추출 함수
    uint8_t SerialRead(void);
    uint8_t SerialAvailable(void);
    static void s_struct_w(uint8_t *cb, uint8_t siz); // 8비트 데이터를 16비트 배열에 저장
    static uint8_t read8(void);                       // inBuf배열의 데이터를 8비트로 읽기
  public:
    void serialCom(void);                             // 패킷 파싱 함수
    void loadData(uint8_t c);
    void sendTXdata();
    void sendPacket(byte n, float f);
};
```

# Multiwii 아두이노

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- Multiwii_test.ino

Multiwii_test.ino

```
#include "serialLib.h"
#define ARDUINO_PLLOTER
#define SERIAL_COM_SPEED 115200                    // 115,200 bps
uint32_t prevTime,intVal=5000;
Multiwii mw;
void setup(void){
  NeoSerial.begin(SERIAL_COM_SPEED);
  NeoSerial.attachInterrupt(uartInt);
  prevTime=micros();
}
void loop(void){
  uint32_t curTime=micros();
  while (curTime-prevTime<intVal) curTime=micros();
  prevTime=curTime;
  mw.serialCom();
  mw.sendTXdata();
}
void uartInt(uint8_t c) {
  mw.loadData(c);
}
```


# PID 튜닝 준비

# PID 튜닝을 위한 구성



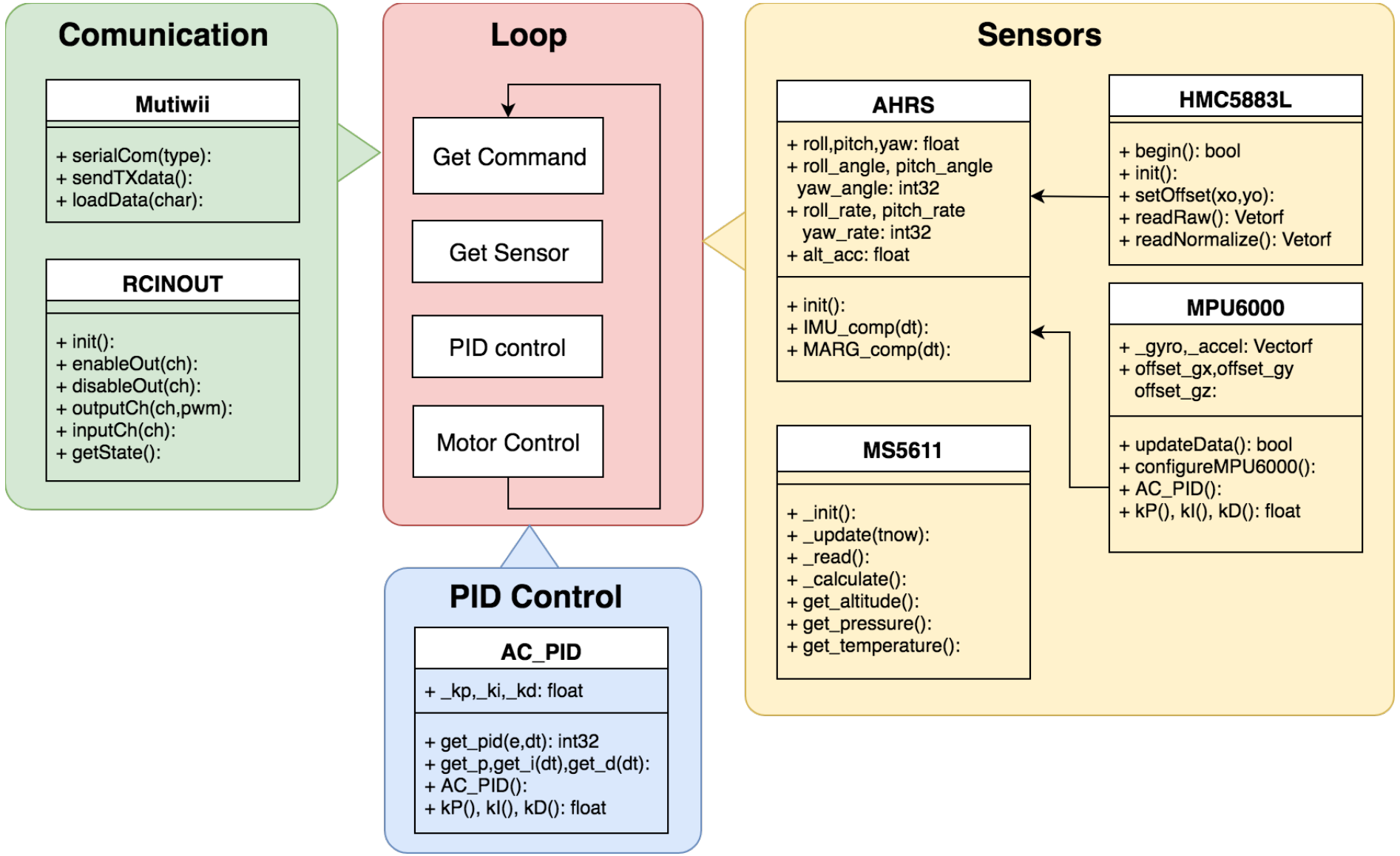
## PID 튜닝을 위한 객체

- Multiwii
  - 실시간 튜닝을 위한 Commander로부터 PID Gain 수신
- RCINOUT
  - RC 송신기로부터의 커맨드를 수신
  - 각 모터의 속도 지령 PWM 발생
- AC_PID
  - roll, pitch, yaw 각도 및 고도에 대한 PID 알고리즘 적용
- AHRS
  - MPU6000 과 HMC5883L로 부터 현재의 각도, 각속도, 가속도 정보를 얻음
- MS5611
  - Barometer로부터 고도 정보를 얻음

# PID 튜닝을 위한 구성

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

- 주요 Class
  - Multiwii
  - RCINOUT
  - AC_PID
  - AHRS
  - MS5611



# AHRS Class 만들기

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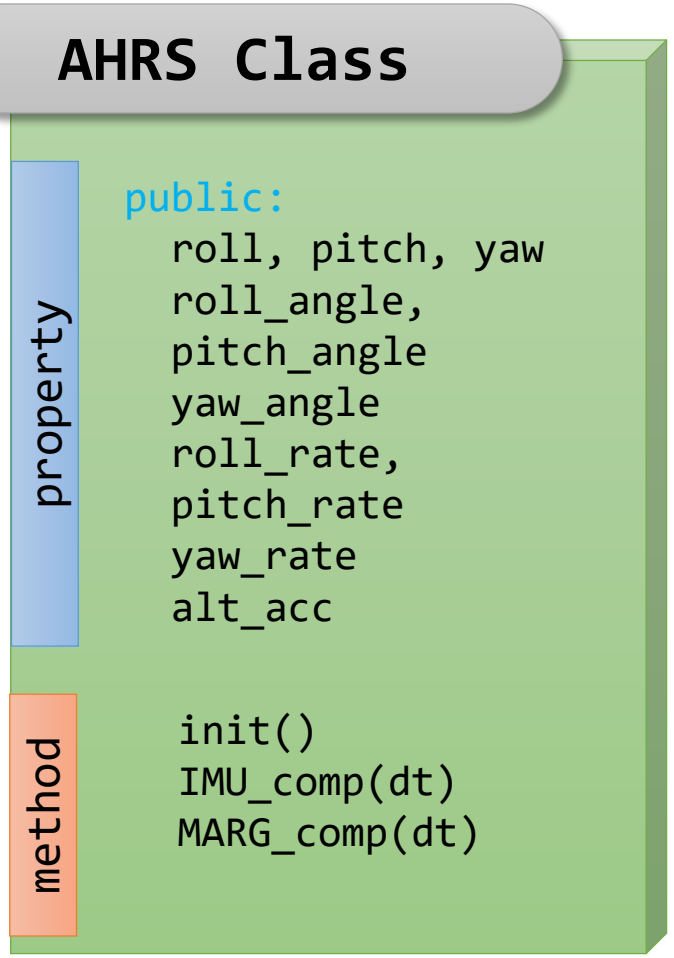
## AHRS Class

- Property
  - roll, pitch, yaw : radian 단위의 각도
  - roll_angle, pitch_angle, yaw_angle:
    - degree x100 의 32bit 정수
  - roll_rate, pitch_rate, yaw_rate:
    - degree/sec x100 의 32bit 정수
  - alt_acc: m/s² 단위의 z 방향 가속도
- Method
  - init(): 초기화 및 설정
  - IMU_comp(dt):
    - IMU 만으로 roll, pitch를 구하는 필터 계산
  - MARG_comp(dt):
    - Magnetometer를 포함하여 roll,pitch,yaw 모두 구함



# AHRS Class 헤더

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

- Class 정의

AHRS.h

```
#ifndef AHRS_H
#define AHRS_H
#include "MPU6k.h"
#include "HMC5883L.h"
#include "common.h"
#include <SPI.h>
#define ALPHA 0.92
class AHRS{
public:
  void IMU_comp(float dt);
  void MARG_comp(float dt);
  void init();
  float  roll, pitch,  yaw;
  float  alt_acc;
  int32_t   roll_angle, pitch_angle, yaw_angle;
  int32_t   roll_rate, pitch_rate, yaw_rate;
};
#endif
```

# AHRS Class C++ file

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## Class 구현

AHRS.cpp [1/3]

```
#include "AHRS.h"
extern MPU6000 mpu;
HMC5883L hmc;
void AHRS::init(){
  pinMode(BARO_CS_PIN, OUTPUT);  pinMode(12, OUTPUT);
  pinMode(MPU6K_CS_PIN, OUTPUT); digitalWrite(MPU6K_CS_PIN, HIGH);
  digitalWrite(BARO_CS_PIN, HIGH);   //Deselect Barometer
  SPI.begin();
  SPI.beginTransaction(SPISettings(8000000, MSBFIRST, SPI_MODE0));delay(100);
  mpu.configureMPU6000();  // configure chip
  while (!hmc.begin()) delay(500);
  hmc.init();
}
void AHRS::IMU_comp(float dt){
  mpu.updateData( );
  Vectorf m = hmc.readNormalize();
  float accAngleX=-atan2(mpu._accel.y,-mpu._accel.z);
```

# AHRS Class C++ file

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

- Class 구현

AHRS.cpp [2/3]

```
  float accAngleX=-atan2(mpu._accel.y,-mpu._accel.z);
  float srtAccXY=sqrt(mpu._accel.y*mpu._accel.y+mpu._accel.z*mpu._accel.z);
  float accAngleY=atan2(mpu._accel.x,srtAccXY);
    // complementary filter roll, pitch
  roll=ALPHA* (roll+mpu._gyro.x*dt)+(1-ALPHA)*accAngleX;
  pitch=ALPHA* (pitch+mpu._gyro.y*dt)+(1-ALPHA)*accAngleY;
  roll_angle=roll*DEG100;  pitch_angle=pitch*DEG100;
  roll_rate=mpu._gyro.x*DEG100;   pitch_rate=mpu._gyro.y*DEG100;
  yaw_rate=mpu._gyro.z*DEG100;  alt_acc=-mpu._accel.z-9.1;
}
 void AHRS::MARG_comp(float dt){
   mpu.updateData( );
  Vectorf m = hmc.readNormalize();
  float accAngleX=-atan2(mpu._accel.y,-mpu._accel.z);
  float srtAccXY=sqrt(mpu._accel.y*mpu._accel.y+mpu._accel.z*mpu._accel.z);
  float accAngleY=atan2(mpu._accel.x,srtAccXY);
```

# AHRS Class C++ file

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## Class 구현

AHRS.cpp [2/3]

```
  // complementary filter roll, pitch
  roll=ALPHA* (roll+mpu._gyro.x*dt)+(1-ALPHA)*accAngleX;
  pitch=ALPHA* (pitch+mpu._gyro.y*dt)+(1-ALPHA)*accAngleY;
  // magnetometer --> heading angle
  float xd=-m.y, yd=m.x, zd=-m.z;// internal HMC
  //compensate heading angle to remove roll, pitch effects
  float s_r=sin(roll), c_r=cos(roll),s_p=sin(pitch),c_p=cos(pitch);
  float xh=xd*c_p+yd*s_r*s_p+zd*c_r*s_p;
  float yh=yd*c_r+zd*s_r;
  float heading = atan2(yh, xh);
  // complementary filter yaw
  yaw=ALPHA*(yaw+mpu._gyro.z*dt)+(1-ALPHA)*heading;
  roll_angle=roll*DEG100;   pitch_angle=pitch*DEG100;
  yaw_angle=yaw*DEG100;   roll_rate=mpu._gyro.x*DEG100;
  pitch_rate=mpu._gyro.y*DEG100;   yaw_rate=mpu._gyro.z*DEG100;
  alt_acc=-mpu._accel.z-9.1;
}
```

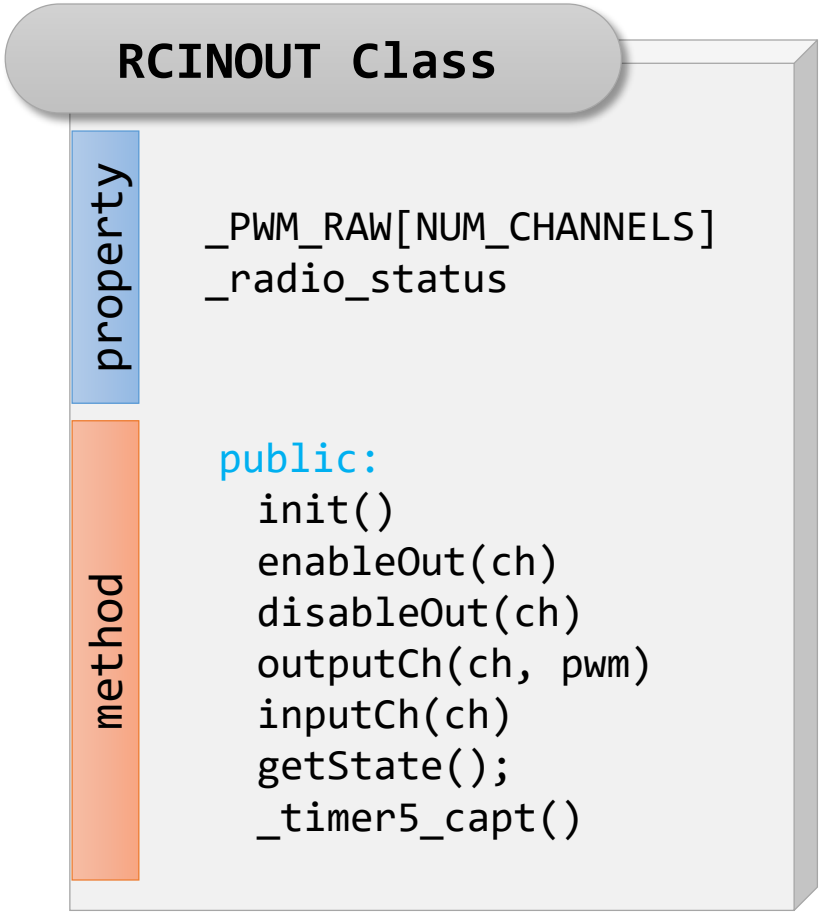

# RC Input Output Class

# RCINOUT class

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

## RCINOUT Class

- Property
  - _PWM_RAW[NUM_CHANNELS]: PWM측정값을 보관
  - _radio_status: 측정 frame 완성 flag
- Method
  - init(): 타이머 등 설정
  - enableOut(ch): 해당채널의 PWM출력을 활성화
  - disableOut(ch): 해당채널의 PWM출력을 비활성화
  - inputCh(ch): 해당채널의 PWM 값 반환
  - getState(): 채널 데이터 읽기 완료면 True 반환
  - _timer5_capt(): Timer5 캡춰



# 헤더파일

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

- 주요 내용
  - 클래스 선언

rcInOut.h

```
#ifndef __RCINOUT_H__
#define __RCINOUT_H__
#define NUM_CHANNELS 8
#define MIN_PULSEWIDTH 900
#define MAX_PULSEWIDTH 2100
#include <Arduino.h>
class RCINOUT{
   volatile uint16_t _PWM_RAW[NUM_CHANNELS]
          = {2400,2400,2400,2400,2400,2400,2400,2400};
    volatile uint8_t _radio_status=0;
  public:
    void outputCh(unsigned char ch, uint16_t pwm);
    void enableOut(uint8_t ch);
    void disableOut(uint8_t ch);
    void init();
    unsigned char getState(void);
    uint16_t inputCh(unsigned char ch);
    void _timer5_capt(void);
};
#endif
```

# C++파일

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

- 주요 내용
  - outputCh()
    - PWM 출력
  - enableOut()
    - PWM 출력 활성화

rcInOut.cpp

```
void RCINOUT::outputCh(unsigned char ch, uint16_t pwm){
  pwm=constrain(pwm,MIN_PULSEWIDTH,MAX_PULSEWIDTH);
  pwm<<=1;    // pwm*2; Regiter 2000 ~ 4000
 switch(ch)   {
    case 0:  OCR1B=pwm; break;  // out1
    case 1:  OCR1A=pwm; break;  // out2
    case 2:  OCR4C=pwm; break;  // out3
    case 3:  OCR4B=pwm; break;  // out4
    case 4:  OCR4A=pwm; break;  // out5
 }
}
void RCINOUT::enableOut(uint8_t ch){
  switch(ch) {
    case 0: TCCR1A |= (1<<COM1B1); break; // CH_1 : OC1B
    case 1: TCCR1A |= (1<<COM1A1); break; // CH_2 : OC1A
    case 2: TCCR4A |= (1<<COM4C1); break; // CH_3 : OC4C
    case 3: TCCR4A |= (1<<COM4B1); break; // CH_4 : OC4B
    case 4: TCCR4A |= (1<<COM4A1); break; // CH_5 : OC4A
 }
}
```

# C++파일

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- 주요 내용
  - disableOut()
    - PWM 출력 비활성화
  - init()
    - 타이머 설정
    - Timer1

rcInOut.cpp

```
void RCINOUT::disableOut(uint8_t ch) {
  switch(ch) {
    case 0: TCCR1A &= ~(1<<COM1B1); break; // CH_1 : OC1B
    case 1: TCCR1A &= ~(1<<COM1A1); break; // CH_2 : OC1A
    case 2: TCCR4A &= ~(1<<COM4C1); break; // CH_3 : OC4C
    case 3: TCCR4A &= ~(1<<COM4B1); break; // CH_4 : OC4B
    case 4: TCCR4A &= ~(1<<COM4A1); break; // CH_5 : OC4A
  }
}
void RCINOUT::init(){
  //TIMER1: WGM 1110, TOP=ICR1, CS=2, OUT1,OUT2
  pinMode(12,OUTPUT); // OUT1 (PB6/OC1B)
  pinMode(11,OUTPUT); // OUT2 (PB5/OC1A)
  TCCR1A =((1<<WGM11));
  TCCR1B = (1<<WGM13)|(1<<WGM12)|(1<<CS11);
  ICR1 = 40000; // 0.5us tick => 50hz freq
  OCR1A = 0xFFFF; OCR1B = 0xFFFF;//disable
```

# C++파일

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- 주요 내용
  - init()
    - Timer4- PWM 3ch
    - Timer3- PWM 3ch

rcInOut.cpp

```
//TIMER4: WGM 1110, TOP=ICR4, CS=2, OUT3,OUT4,OUT5
 pinMode(8,OUTPUT); // OUT3 (PH5/OC4C)
 pinMode(7,OUTPUT); // OUT4 (PH4/OC4B)
 pinMode(6,OUTPUT); // OUT5 (PH3/OC4A)
 TCCR4A =((1<<WGM41));
 TCCR4B = (1<<WGM43)|(1<<WGM42)|(1<<CS41);
 OCR4A = 0xFFFF; OCR4B = 0xFFFF; OCR4C = 0xFFFF;
 ICR4 = 40000; // 0.5us tick => 50hz freq
 //TIMER3: WGM 1110, TOP=ICR3, CS=2, OUT6,OUT7,OUT8
 pinMode(3,OUTPUT); // OUT6 (PE5/OC3C)
 pinMode(2,OUTPUT); // OUT7 (PE4/OC3B)
 pinMode(5,OUTPUT); // OUT8 (PE3/OC3A)
 TCCR3A =((1<<WGM31));
 TCCR3B = (1<<WGM33)|(1<<WGM32)|(1<<CS31);
 OCR3A = 0xFFFF; OCR3B = 0xFFFF; OCR3C = 0xFFFF;
 ICR3 = 40000; // 0.5us tick => 50hz freq
```

# C++파일

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- 주요 내용
  - init()
    - Timer5
      - PPM input
      - PWM 2ch

rcInOut.cpp

```
 //TIMER5: WGM 1111, TOP=OCR5A, CS=2, PPM,OUT10,OUT11
  pinMode(48, INPUT);  // PPM Input(PL1/ICP5)
  pinMode(45, OUTPUT); // OUT10 (PL4/OC5B)
  pinMode(44, OUTPUT); // OUT11 (PL5/OC5C)
  TCCR5A =((1<<WGM50)|(1<<WGM51));
  TCCR5B = ((1<<WGM53)|(1<<WGM52)|(1<<CS51)|(1<<ICES5)); //Rising
  OCR5A = 40000; // 0.5us tick => 50hz freq.
  TIMSK5 |= (1<<ICIE5); // Enable Input Capture interrupt
}
```

# C++파일

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

## 주요 내용

- _timer5_capt()
  - input capture interrupt
  - PPM decode

rcInOut.cpp

```
void RCINOUT::_timer5_capt(void) {
  static uint16_t prev_icr;
  static uint8_t frame_idx;
  uint16_t icr, pwidth;
  icr = ICR5;    // copy time stamp
  if ( icr < prev_icr ) {   // TOP = 40000
    pwidth = ( icr + 40000 ) - prev_icr;
  } else {
    pwidth = icr - prev_icr;  }
  if ( pwidth > 8000 ) { // if is blank time
    frame_idx=0;
  } else {
    if ( frame_idx < NUM_CHANNELS ) {
      _PWM_RAW[frame_idx++ ] = pwidth;
      if (frame_idx >= NUM_CHANNELS) {
        _radio_status = 1; // One frame finished
      }    }
  }
  prev_icr = icr; // Save icr for next call.
}
```

# C++파일

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

## 주요 내용

- getState()
  - PPM decode 상태
    - 1: 완료 0: 진행중
- inputCh()
  - PWM 값읽기
- ISR()
  - input capture interrupt

rcInOut.cpp

```
unsigned char RCINOUT::getState(void){
  return _radio_status;
}
uint16_t RCINOUT::inputCh(unsigned char ch){
  uint16_t result;
  cli();    //disable all interrupts
  result = _PWM_RAW[ch];
  sei();  //enabal all interrupts again
  result >>= 1; // convert to us unit
  result = constrain(result,MIN_PULSEWIDTH,MAX_PULSEWIDTH);
  _radio_status = 0; // Radio channel read
  return result;
}
ISR(TIMER5_CAPT_vect) {
    radio._timer5_capt();
}
```

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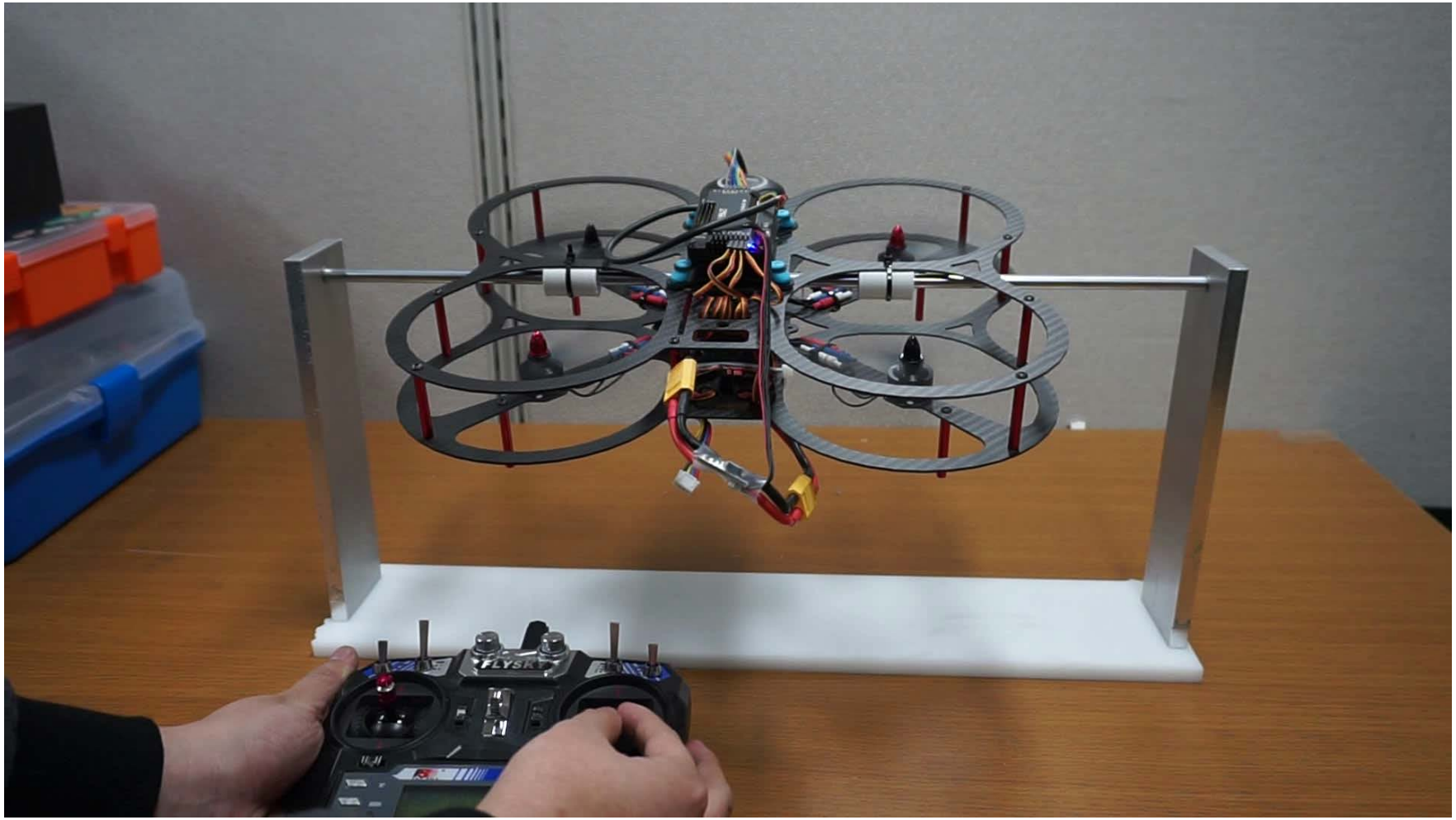

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