```
/*************************************************************************************
   Slotcar Race Controller for PCLapCounter Software

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   Arduino MEGA 2560 based slotcar race controller. Capture start/finish signals,
   controls the power relays as well as any signal LEDs and manages external buttons.

   See http://pclapcounter.be/arduino.html for the input/output protocol.

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   Date  : 2016-10-14

   Revision History
   __________ ____________________ _______________________________________________________
   2016-10-25 Gabriel Inäbnit      Removed false start init button - no longer needed
   2016-10-24 Gabriel Inäbnit      Fix false start GO command with HW false start enabled
   2016-10-22 Gabriel Inäbnit      HW false start enable/disable, penalty, reset
   2016-10-21 Gabriel Inäbnit      false start detection and penalty procedure
   2016-10-18 Gabriel Inäbnit      external buttons handling added
   2016-10-14 Gabriel Inäbnit      initial version
 *************************************************************************************/

/*************************************************************************************
   Symbol definitions
 *************************************************************************************/
#define LANE_1 2
#define LANE_2 3
#define LANE_3 21
#define LANE_4 20
#define LANE_5 19
#define LANE_6 18

#define SL_1_ON  "SL011"
#define SL_1_OFF "SL010"
#define SL_2_ON  "SL021"
#define SL_2_OFF "SL020"
#define SL_3_ON  "SL031"
#define SL_3_OFF "SL030"
#define SL_4_ON  "SL041"
#define SL_4_OFF "SL040"
#define SL_5_ON  "SL051"
#define SL_5_OFF "SL050"

#define GO_ON       "SL061"
#define GO_OFF      "SL060"
#define STOP_ON     "SL071"
#define STOP_OFF    "SL070"
#define CAUTION_ON  "SL081"
#define CAUTION_OFF "SL080"

#define PWR_ON    "PW001"
#define PWR_OFF   "PW000"
#define PWR_1_ON  "PW011"
#define PWR_1_OFF "PW010"
#define PWR_2_ON  "PW021"
#define PWR_2_OFF "PW020"
#define PWR_3_ON  "PW031"
#define PWR_3_OFF "PW030"
#define PWR_4_ON  "PW041"
#define PWR_4_OFF "PW040"
#define PWR_5_ON  "PW051"
#define PWR_5_OFF "PW050"
#define PWR_6_ON  "PW061"
#define PWR_6_OFF "PW060"

#define LED_1 5
#define LED_2 6
#define LED_3 7
#define LED_4 8
#define LED_5 9

#define LED_GO 10
#define LED_STOP 11
#define LED_CAUTION 12

#define PWR_ALL 30
```

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#define PWR_1   31
#define PWR_2   32
#define PWR_3   33
#define PWR_4   34
#define PWR_5   35
#define PWR_6   36

#define FS_0 22
#define FS_1 23
#define FS_2 24
#define FS_3 25

/*****************************************************************************************
   Global variables
 *****************************************************************************************/
const unsigned int serialSpeed = 57600;
const char lapTime[][7] =
{
  "[SF01$",
  "[SF02$",
  "[SF03$",
  "[SF04$",
  "[SF05$",
  "[SF06$"
};

unsigned long falseStartPenaltyBegin;
const unsigned long delayMillis[] =
{ // index
  0L, // 0
  1000L, // 1
  2000L, // 2
  3000L, // 3
  4000L, // 4
  5000L, // 5
  6000L, // 6
  7000L  // 7
};
byte delayMillisIndex = 0;

/*****************************************************************************************
   Class Race
 *****************************************************************************************/
#define RACE_SETUP 0
#define RACE_STARTED 1
#define RACE_FINISHED 3
#define RACE_PAUSED 4
#define CLOCK_REMAINING_TIME 'R'
#define CLOCK_ELAPSED_TIME 'E'
#define CLOCK_SEGMENT_REMAINING_TIME 'S'
#define LAPS_REMAINING 'L'

class Race {
  protected:
    volatile byte state;
    char clockType;
  public:
    Race() {
      state = RACE_FINISHED;
    }
    bool isStarted() {
      return state ≡ RACE_STARTED;
    }
    bool isPaused() {
      return state ≡ RACE_PAUSED;
    }
    bool isFinished () {
      return state ≡ RACE_FINISHED;
    }
    bool isInitialized() {
      return state ≡ RACE_SETUP;
    }
    void init() {
      state = RACE_SETUP;
    }
    void start() {
      state = RACE_STARTED;
    }
    void pause() {
      state = RACE_PAUSED;
    }
    void finish() {
      state = RACE_FINISHED;
    }
};

/*****************************************************************************************
   Class Race instantiations
 *****************************************************************************************/
Race race;

/*****************************************************************************************
   Class Lane
 *****************************************************************************************/
class Lane {
  protected:
    volatile unsigned long start;
    volatile unsigned long finish;
    volatile long count;
    volatile bool reported;
    byte lane;
    byte pin;
    bool falseStart;
    bool hwFalseStartEnabled;
  public:
    Lane(byte setLane) {
      start = 0L;
      finish = 0L;
      count = -1L;
      lane = setLane - 1;
      pin = setLane + 30;
      reported = true;
      falseStart = false;
      hwFalseStartEnabled = false;
    }
    void lapDetected() { // called by ISR, short and sweet
      start = finish;
      finish = millis();
      count++;
      reported = false;
    }
    void reset(bool enableHwFalseStart) {
      reported = true;
      falseStart = false;
      hwFalseStartEnabled = enableHwFalseStart;
      count = -1L;
    }
    void reportLap() {
      if (¬reported) {
        Serial.print(lapTime[lane]);
        Serial.print(finish - start);
        Serial.println(’]’);
        reported = true;
      }
      if (hwFalseStartEnabled) {
        if (¬race.isStarted() ∧ ¬falseStart ∧ (count ≡ 0)) {
          // false start detected,
          // switching lane off immediately
          powerOff();
          falseStart = true;
        }
        // switch power back on after false start penalty served
        if (falseStart ∧
            race.isStarted() ∧
            ((millis() - falseStartPenaltyBegin) > delayMillis[delayMillisIndex])) {
          falseStart = false; // reset false start "fuse"
          powerOn();
        }
      }
    }
    void powerOn() {
      if (¬falseStart) {
        digitalWrite(pin, LOW);
      }
    }
    void powerOff() {
      digitalWrite(pin, HIGH);
    }
    bool isFalseStart() {
      return falseStart;
    }
};

/*****************************************************************************
   Class Lane instantiations
 *****************************************************************************/
Lane lane1(1);
Lane lane2(2);
Lane lane3(3);
Lane lane4(4);
Lane lane5(5);
Lane lane6(6);

/*****************************************************************************
   Class Button - external buttons for PC Lap Counter
 *****************************************************************************/
class Button {
  protected:
    String button;
    byte pin;
    bool reported;
    bool pressed;
    void reportButton() {
      Serial.println(button);
      reported = true;
    }
  public:
    Button(String setButton, byte setPin) {
      button = setButton;
      pin = setPin;
      reported = false;
      pressed = false;
      pinMode(pin, INPUT_PULLUP);
    }
    void isButtonPressed() {
      pressed = ¬digitalRead(pin);
      if (¬reported ∧ pressed) {
        reportButton();
      }
      reported = pressed;
    }
};

/*****************************************************************************
   Class Button instantiations
 *****************************************************************************/
//Button startRace("[BT01]", 41);
//Button restartRace("[BT02]", 42);
Button pauseRace("[BT03]", 43);
Button startPauseRestartRace("[BT04]", 44);
//Button powerOff("[BT05]", 45);
//Button powerOn("[BT06]", 46);
//Button endOfRace("[BT07]", 47);
Button togglePower("[BT08]", 48);
//Button toggleYelloFlag("[BT09]", 49);
//Button stopAndGoLane1("[SG01]", 22);
//Button stopAndGoLane2("[SG02]", 23);
//Button stopAndGoLane3("[SG03]", 24);
//Button stopAndGoLane4("[SG04]", 25);
//Button stopAndGoLane5("[SG05]", 26);
//Button stopAndGoLane6("[SG06]", 27);

/*****************************************************************************
   Class FalseStart - HW solution setup false start enable/disable, detection and penalty
 *****************************************************************************/
class FalseStart {
  protected:
    bool hwFalseStartEnabled;
    void reset() {
      // reset false start flags
      lane1.reset(hwFalseStartEnabled);
      lane2.reset(hwFalseStartEnabled);
      lane3.reset(hwFalseStartEnabled);
      lane4.reset(hwFalseStartEnabled);
      lane5.reset(hwFalseStartEnabled);
      lane6.reset(hwFalseStartEnabled);
    }
  public:
    FalseStart() {
      // empty constructor
    }
    void init() {
      // read pins of 4-bit encoder
      byte mode = ¬digitalRead(FS_0)  |
                  ¬digitalRead(FS_1) << 1 |
                  ¬digitalRead(FS_2) << 2 |
                  ¬digitalRead(FS_3) << 3;
      hwFalseStartEnabled = mode > 7;
      if (hwFalseStartEnabled) { // false start HW enabled
        falseStartPenaltyBegin = 0xFFFFFFFF;
        delayMillisIndex = mode − 8;
      }
      race.finish();
      reset();
    }
};

/*****************************************************************************
   Class FalseStart instantiations
 *****************************************************************************/
FalseStart falseStart;

/*****************************************************************************
   initializations and configurations of I/O pins
 *****************************************************************************/
void setup() {
  // interrup pins
  pinMode(LANE_1, INPUT_PULLUP);
  pinMode(LANE_2, INPUT_PULLUP);
  pinMode(LANE_3, INPUT_PULLUP);
  pinMode(LANE_4, INPUT_PULLUP);
  pinMode(LANE_5, INPUT_PULLUP);
  pinMode(LANE_6, INPUT_PULLUP);
  // input pins
  pinMode(FS_0, INPUT_PULLUP);
  pinMode(FS_1, INPUT_PULLUP);
  pinMode(FS_2, INPUT_PULLUP);
  pinMode(FS_3, INPUT_PULLUP);
  // output pins
  pinMode(LED_1, OUTPUT);
  pinMode(LED_2, OUTPUT);
  pinMode(LED_3, OUTPUT);
  pinMode(LED_4, OUTPUT);
  pinMode(LED_5, OUTPUT);
  pinMode(LED_GO, OUTPUT);
  pinMode(LED_STOP, OUTPUT);
  //  pinMode(LED_CAUTION, OUTPUT);
  pinMode(PWR_ALL, OUTPUT);
  pinMode(PWR_1, OUTPUT);
  pinMode(PWR_2, OUTPUT);
  pinMode(PWR_3, OUTPUT);
  pinMode(PWR_4, OUTPUT);
  pinMode(PWR_5, OUTPUT);
  pinMode(PWR_6, OUTPUT);
  // turn all LEDs off (HIGH = off)
  digitalWrite(LED_1, HIGH);
  digitalWrite(LED_2, HIGH);
  digitalWrite(LED_3, HIGH);
  digitalWrite(LED_4, HIGH);
  digitalWrite(LED_5, HIGH);
  digitalWrite(LED_GO, HIGH);
  digitalWrite(LED_STOP, HIGH);
  //  digitalWrite(LED_CAUTION, HIGH);
  digitalWrite(PWR_ALL, HIGH);
  digitalWrite(PWR_1, HIGH);
  digitalWrite(PWR_2, HIGH);
  digitalWrite(PWR_3, HIGH);
  digitalWrite(PWR_4, HIGH);
  digitalWrite(PWR_5, HIGH);
  digitalWrite(PWR_6, HIGH);
  // shake the dust off the relays
  jiggleRelays();
  delay(1000);
  // initialize globals
  falseStart.init();
  relaysOn(LOW); // switch all power relays on (LOW = on)
  // all defined, ready to read/write from/to serial port
  Serial3.begin(serialSpeed);
  while (¬Serial3) {
    // // wait..
  }
  Serial.begin(serialSpeed);
  while (¬Serial) {
    ; // wait for serial port to connect. Needed for native USB
  }
}

#define CLICK 10

void jiggleRelays() {
  relaysOn(LOW);
  delay(CLICK);
  relaysOn(HIGH);
  delay(222);
  relaysOn(LOW);
  delay(CLICK);
  relaysOn(HIGH);
  delay(111);
  relaysOn(LOW);
  delay(CLICK);
  relaysOn(HIGH);
  delay(111);
  relaysOn(LOW);
  delay(CLICK);
  relaysOn(HIGH);
  delay(222);
  relaysOn(LOW);
  delay(CLICK);
  relaysOn(HIGH);
  delay(444);
  relaysOn(LOW);
  delay(CLICK);
  relaysOn(HIGH);
  delay(222);
  relaysOn(LOW);
  delay(CLICK);
  relaysOn(HIGH);
}

void relaysOn (bool onOff) {
  digitalWrite(PWR_1, onOff);
  digitalWrite(PWR_2, onOff);
  digitalWrite(PWR_3, onOff);
  digitalWrite(PWR_4, onOff);
  digitalWrite(PWR_5, onOff);
  digitalWrite(PWR_6, onOff);
}

void attachAllInterrupts() {
  attachInterrupt(digitalPinToInterrupt(LANE_1), lapDetected1, RISING);
  attachInterrupt(digitalPinToInterrupt(LANE_2), lapDetected2, RISING);
  attachInterrupt(digitalPinToInterrupt(LANE_3), lapDetected3, RISING);
  attachInterrupt(digitalPinToInterrupt(LANE_4), lapDetected4, RISING);
  attachInterrupt(digitalPinToInterrupt(LANE_5), lapDetected5, RISING);
  attachInterrupt(digitalPinToInterrupt(LANE_6), lapDetected6, RISING);
}

void detachAllInterrupts() {
  detachInterrupt(digitalPinToInterrupt(LANE_1));
  detachInterrupt(digitalPinToInterrupt(LANE_2));
  detachInterrupt(digitalPinToInterrupt(LANE_3));
  detachInterrupt(digitalPinToInterrupt(LANE_4));
  detachInterrupt(digitalPinToInterrupt(LANE_5));
  detachInterrupt(digitalPinToInterrupt(LANE_6));
}
```

```
/*******************************************************************************
   Interrup Service Routines (ISR) definitions
 *******************************************************************************/
void lapDetected1() {
  lane1.lapDetected();
}
void lapDetected2() {
  lane2.lapDetected();
}
void lapDetected3() {
  lane3.lapDetected();
}
void lapDetected4() {
  lane4.lapDetected();
}
void lapDetected5() {
  lane5.lapDetected();
}
void lapDetected6() {
  lane6.lapDetected();
}

/*******************************************************************************
   Main loop
 *******************************************************************************/
void loop() {
  detachAllInterrupts();
  while (Serial.available()) // was if -> read one command per cycle -> no difference
  {
    Serial.readStringUntil('[');
    {
      String output;
      output = Serial.readStringUntil(']');
      Serial3.println(output);
      if (output ≡ "RC0E00:00:00") {
        falseStart.init();
      } else if (output ≡ SL_1_ON) {
        digitalWrite(LED_1, LOW);
      } else if (output ≡ SL_1_OFF) {
        digitalWrite(LED_1, HIGH);
      } else if (output ≡ SL_2_ON) {
        digitalWrite(LED_2, LOW);
      } else if (output ≡ SL_2_OFF) {
        digitalWrite(LED_2, HIGH);
      } else if (output ≡ SL_3_ON) {
        digitalWrite(LED_3, LOW);
      } else if (output ≡ SL_3_OFF) {
        digitalWrite(LED_3, HIGH);
      } else if (output ≡ SL_4_ON) {
        digitalWrite(LED_4, LOW);
      } else if (output ≡ SL_4_OFF) {
        digitalWrite(LED_4, HIGH);
      } else if (output ≡ SL_5_ON) {
        digitalWrite(LED_5, LOW);
      } else if (output ≡ SL_5_OFF) {
        digitalWrite(LED_5, HIGH);
      } else if (output ≡ GO_ON) { // race start
        falseStartPenaltyBegin = millis();
        race.start();
        digitalWrite(LED_GO, LOW);
      } else if (output ≡ GO_OFF) {
        digitalWrite(LED_GO, HIGH);
      } else if (output ≡ STOP_ON) {
        digitalWrite(LED_STOP, LOW);
      } else if (output ≡ STOP_OFF) {
        digitalWrite(LED_STOP, HIGH);
      } else if (output ≡ PWR_ON) {
        digitalWrite(PWR_ALL, LOW);
      } else if (output ≡ PWR_OFF) {
        digitalWrite(PWR_ALL, HIGH);
      } else if (output ≡ PWR_1_ON) {
        lane1.powerOn();
      } else if (output ≡ PWR_1_OFF) {
        lane1.powerOff();
      } else if (output ≡ PWR_2_ON) {
        lane2.powerOn();
      } else if (output ≡ PWR_2_OFF) {
        lane2.powerOff();
      } else if (output ≡ PWR_3_ON) {
        lane3.powerOn();
      } else if (output ≡ PWR_3_OFF) {
        lane3.powerOff();
      } else if (output ≡ PWR_4_ON) {
        lane4.powerOn();
      } else if (output ≡ PWR_4_OFF) {
        lane4.powerOff();
      } else if (output ≡ PWR_5_ON) {
        lane5.powerOn();
      } else if (output ≡ PWR_5_OFF) {
        lane5.powerOff();
      } else if (output ≡ PWR_6_ON) {
        lane6.powerOn();
      } else if (output ≡ PWR_6_OFF) {
        lane6.powerOff();
      }
    }
  }
  /** report lap if necessary */
  lane1.reportLap();
  lane2.reportLap();
  lane3.reportLap();
  lane4.reportLap();
  lane5.reportLap();
  lane6.reportLap();
  /** any buttons pressed */
  //  startRace.isButtonPressed();
  //  restartRace.isButtonPressed();
  pauseRace.isButtonPressed();
  startPauseRestartRace.isButtonPressed();
  //  powerOff.isButtonPressed();
  //  powerOn.isButtonPressed();
  //  endOfRace.isButtonPressed();
  togglePower.isButtonPressed();
  //  toggleYelloFlag.isButtonPressed();
  //  stopAndGoLane1.isButtonPressed();
  //  stopAndGoLane2.isButtonPressed();
  //  stopAndGoLane3.isButtonPressed();
  //  stopAndGoLane4.isButtonPressed();
  //  stopAndGoLane5.isButtonPressed();
  //  stopAndGoLane6.isButtonPressed();
  delay(3);
  attachAllInterrupts();
}
```