ws2812.c

```
#include <stdio.h>
#include <stdlib.h>

#include "pico/stdlib.h"
#include "hardware/pio.h"
#include "hardware/clocks.h"
#include "ws2812.pio.h"

#define IS_RGBW true
#define NUM_PIXELS 150

#ifdef PICO_DEFAULT_WS2812_PIN
#define WS2812_PIN PICO_DEFAULT_WS2812_PIN
#else
// default to pin 2 if the board doesn't have a default WS2812 pin defined
#define WS2812_PIN 2
#endif

static inline void put_pixel(uint32_t pixel_grb) {
    pio_sm_put_blocking(pio0, 0, pixel_grb << 8u);
}

static inline uint32_t urgb_u32(uint8_t r, uint8_t g, uint8_t b) {
    return
        ((uint32_t) (r) << 8) |
        ((uint32_t) (g) << 16) |
        (uint32_t) (b);
}

void pattern_snakes(uint len, uint t) {
    for (uint i = 0; i < len; ++i) {
        uint x = (i + (t >> 1)) % 64;
        if (x < 10)
            put_pixel(urgb_u32(0xff, 0, 0));
        else if (x >= 15 && x < 25)
            put_pixel(urgb_u32(0, 0xff, 0));
        else if (x >= 30 && x < 40)
            put_pixel(urgb_u32(0, 0, 0xff));
        else
            put_pixel(0);
    }
}

void pattern_random(uint len, uint t) {
    if (t % 8)
        return;
```

this push the value to Tx FIFO will appear on ws2812 pin

left shift for 8 bits

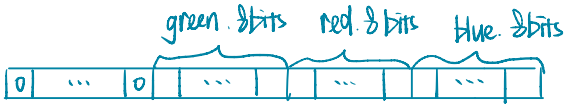
22 send instructions to led

This function is applied to send 24 bit GRB color instruction to pio

left shift for 8 bits

16 bits

To generate a 24-bit color instruction



32bits intotal. but only the 24 bits are color information.

X is the remainder of (i+2t) ÷ 64

green

Red

Blue

This is a pattern (led instruction) to present green. red. blue in order

// if t%8==0, then do nothing

```
    for (int i = 0; i < len; ++i)
        put_pixel(rand());
}
void pattern_sparkle(uint len, uint t) {
    if (t % 8)
        return;
    for (int i = 0; i < len; ++i)
        put_pixel(rand() % 16 ? 0 : 0xffffffff);
}
void pattern_greys(uint len, uint t) {
    int max = 100; // let's not draw too much current!
    t %= max;
    for (int i = 0; i < len; ++i) {
        put_pixel(t * 0x10101);
        if (++t >= max) t = 0;
    }
}

typedef void (*pattern)(uint len, uint t);
const struct {
    pattern pat;
    const char *name;
} pattern_table[] = {
        {pattern_snakes,  "Snakes!"},
        {pattern_random,  "Random data"},
        {pattern_sparkle, "Sparkles"},
        {pattern_greys,   "Greys"},
};

int main() {
    //set_sys_clock_48();
    stdio_init_all();
    printf("WS2812 Smoke Test, using pin %d", WS2812_PIN);

    // todo get free sm
    PIO pio = pio0;
    int sm = 0;
    uint offset = pio_add_program(pio, &ws2812_program);
    ws2812_program_init(pio, sm, offset, WS2812_PIN, 800000, IS_RGBW);

    int t = 0;
    while (1) {
        int pat = rand() % count_of(pattern_table);
        int dir = (rand() >> 30) & 1 ? 1 : -1;
        puts(pattern_table[pat].name);
        puts(dir == 1 ? "(forward)" : "(backward)");
```

// rand() is used to generate a random number. thus the led instruction is random.
⇒ this pattern let the led present randomly

If rand()%16≠0 then put_pixel(0). if rand()%16=0, then put_pixel(0xffffffff). which is the white light

// t is the remainder of t% max

structure ⇒ {pat, name}

there are four patterns in this structure

① initialize all the present standard stdio types that are linked into the binary.

② the pin is defined as "2" in the begin.
print the content in the queto

③ get the free pio ⇒ pio0

define integer sm=0

find location (offset) in the instruction memory

④ there is enough space. remember(this function is in pio.c file) this location

find free space pio0

⑤ initialize the ws2812_program

jump to this function. (ws2812.h)

⑲ puts pattern structure

⑳ puts direction.
if direction == 1. "(forward)", else "(backward)"

```
      for (int i = 0; i < 1000; ++i) {
        pattern_table[pat].pat(NUM_PIXELS, t); ㉑ jump to pattern functions and send led instructions
        sleep_ms(10);
        t += dir;
      }
    }
}
```

ws2812.pio.h

```
#pragma once

#if !PICO_NO_HARDWARE
#include "hardware/pio.h"
#endif

// ------ //
// ws2812 //
// ------ //

#define ws2812_wrap_target 0
#define ws2812_wrap 3

#define ws2812_T1 2
#define ws2812_T2 5
#define ws2812_T3 3

static const uint16_t ws2812_program_instructions[] = {
        //     .wrap_target                    Δ
    0x6221, //  0: out    x, 1         side 0 [2]  Delay cycles
    0x1123, //  1: jmp    !x, 3         side 1 [1]
    0x1400, //  2: jmp    0            side 1 [4]
    0xa442, //  3: nop                 side 0 [4]
        //     .wrap
};  // Instructions defined for ws2812-program

#if !PICO_NO_HARDWARE
static const struct pio_program ws2812_program = {
    .instructions = ws2812_program_instructions,
    .length = 4,
    .origin = -1,
};
```

```
static inline pio_sm_config ws2812_program_get_default_config(uint offset) {
    pio_sm_config c = pio_get_default_sm_config();
    sm_config_set_wrap(&c, offset + ws2812_wrap_target, offset + ws2812_wrap);
    sm_config_set_sideset(&c, 1, false, false);
    return c;
}

#include "hardware/clocks.h"
static inline void ws2812_program_init(PIO pio, uint sm, uint offset, uint pin, float freq, bool rgbw) {
    pio_gpio_init(pio, pin);
    pio_sm_set_consecutive_pindirs(pio, sm, pin, 1, true);
    pio_sm_config c = ws2812_program_get_default_config(offset);
    sm_config_set_sideset_pins(&c, pin);
    sm_config_set_out_shift(&c, false, true, rgbw ? 32 : 24);
    sm_config_set_fifo_join(&c, PIO_FIFO_JOIN_TX);
    int cycles_per_bit = ws2812_T1 + ws2812_T2 + ws2812_T3;
    float div = clock_get_hz(clk_sys) / (freq * cycles_per_bit);
    sm_config_set_clkdiv(&c, div);
    pio_sm_init(pio, sm, offset, &c);
    pio_sm_set_enabled(pio, sm, true);
}
#endif
```

⑨ get default state machine config. in pio.h

⑩ set up wrap_target & wrap

⑪ set sideset

pio.h

⑥ Initialize the gpio pins. connect PIO to the pad. set this pin's GPIO function

⑦ Set state machine pin directions to output at the PIO

⑧ Set up sm configration

⑫ (pio.h) set up sideset_pins, to start at "pin". eg. side_set 3. "pin" "pin+1" "pin+2"

⑬ set up out shift

⑭ set up fifo.

⑮ calculation of div

$$div = \frac{clock}{freq * cycles\_per\_bit}$$

⑯⑰⑱ set up & initialize the state machine.

Slow the state machines execution down

load configuration. jump to the start of program

Set the machine running

Output shift register ⇒ System → TX FIFO → OSR → Pins

Input shift register ⇒ Pins → ISR → RX FIFO → System

pull instructions: remove a 32-bit word from the Tx FIFO and place into OSR

out instructions: shift data from OSR to other destinations, 1, 2 ... 32 bits at a time.

SM will automatically refill the OSR from the FIFO on an "out" instruction.