```
// ---------------------------------------------- //
// This file is autogenerated by pioasm; do not edit! //
// ---------------------------------------------- //

#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
    0x6221, //  0: out    x, 1         side 0 [2]
    0x1123, //  1: jmp    !x, 3        side 1 [1]
    0x1400, //  2: jmp    0            side 1 [4]
    0xa442, //  3: nop                 side 0 [4]
        //     .wrap
};
```

Check if build is targetting RP2040 device. If not, include the header file "hardware/pio.h".

Variable definations

Time T1

Time T2

Time T3

Program instruction set.

```
#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);
}
```

get default configuration of state machine in variable c of type pio_sm_config.

memory address to wrap to

set wrap address in a sm configuration

Instruction memory address after which to set the program counter to wrap target if instruction doesn't update program counter

set sideset option in a sm configuration

configure a GPIO to be used by pio

set pin direction to o/p at PIO

Get default configuration using generated function

set pin in a state machine configuration

tells if we have RGBW led or RGB led. false for shift to right. True for auto pull

set up fifo joining in a sm configuration

Number of cycles to output 1 bit

Slow down sm's execution time to achieve correct bit rate

set the sm clock devides

Load our configuration & jump at the start address

offset

set the state machine running (Enable it)

```
#endif

// ---------- //
// ws2812_parallel //
// ---------- //

#define ws2812_parallel_wrap_target 0
#define ws2812_parallel_wrap 3

#define ws2812_parallel_T1 2
#define ws2812_parallel_T2 5
#define ws2812_parallel_T3 3

static const uint16_t ws2812_parallel_program_instructions[] = {
        //     .wrap_target
    0x6020, //  0: out    x, 32
    0xa10b, //  1: mov    pins, !null       [1]
    0xa401, //  2: mov    pins, x           [4]
    0xa103, //  3: mov    pins, null        [1]
        //     .wrap
};

#if !PICO_NO_HARDWARE
static const struct pio_program ws2812_parallel_program = {
    .instructions = ws2812_parallel_program_instructions,
    .length = 4,
    .origin = -1,
};
```

Time T1
Time T2
Time T3

Variable definations

Program instruction set

```
static inline pio_sm_config ws2812_parallel_program_get_default_config(uint offset) {
    pio_sm_config c = pio_get_default_sm_config();
    sm_config_set_wrap(&c, offset + ws2812_parallel_wrap_target, offset + ws2812_parallel_wrap);
    return c;
}


#include "hardware/clocks.h"

static inline void ws2812_parallel_program_init(PIO pio, uint sm, uint offset, uint pin_base, uint
pin_count, float freq) {
    for(uint i=pin_base; i<pin_base+pin_count; i++) {
        pio_gpio_init(pio, i);
    }
    pio_sm_set_consecutive_pindirs(pio, sm, pin_base, pin_count, true);
    pio_sm_config c = ws2812_parallel_program_get_default_config(offset);
    sm_config_set_out_shift(&c, true, true, 32);
    sm_config_set_out_pins(&c, pin_base, pin_count);
    sm_config_set_set_pins(&c, pin_base, pin_count);
    sm_config_set_fifo_join(&c, PIO_FIFO_JOIN_TX);
    int cycles_per_bit = ws2812_parallel_T1 + ws2812_parallel_T2 + ws2812_parallel_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
```

Get default configuration of sm in variable c of type pio_sm_config

set wrap address in a sm configuration

configure multiple GPIO pins to be used by PIO

set pin direction to o/p at PIO

Get default configuration

using generated function

Tells if we have 32 bits. setup out shifting parameter in sm configuration

set the 'out' pins in a state machine configuration

set 'set' pins in a sm configuration

setup FIFO joining in a sm configuration

Number of cycles in a sm configuration

slow down sm's execution time to achieve correct bitrate

set the sm clock divider

Load our configuration & jump at the start address offset

set the state machine running (Enable it)

```
/**
 * Copyright (c) 2020 Raspberry Pi (Trading) Ltd.
 *
 * SPDX-License-Identifier: BSD-3-Clause
 */

#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) {
```

Include header files

Micro IS_RGBW is defined as true & NUM_PIXELS is defined as 150. This won't change in thrgout code

Checks if there's an WS2812 PIN by default - If there's, then a new macro WS2812_PIN will get the vale. Otherwise Pin 2 of the board will be defined as WS2812_PIN

write a word of data in SM's TXFIFO. Block if FIFO is full.

Pio instance

SM

Left shift pixel value by 8 to get 24 bits at top

returns 32 bits with grb pixel value

```
  return
      ((uint32_t) (r) << 8) |
      ((uint32_t) (g) << 16) |
      (uint32_t) (b);
}
```

Left shift 'r' value by 8 bits
leftshift 'g' value by 16 bits
} OR value & Return 32 bits with 8 bits of 'g', 'r' & 'b' values. rest 8 bits are 0's

```
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);
  }
}
```

← Reminder of expression
← 'Red' value highest while 'G' & 'B' lowest
← 'G' value highest while 'R' & 'B' lowest
← 'B' value highest while 'R' & 'G' lowest
← Clear LEDs

```
void pattern_random(uint len, uint t) {
  if (t % 8)
    return;
  for (int i = 0; i < len; ++i)
    put_pixel(rand());
}
```

← If 't' is divisible by 8, then get out of function
} otherwise put random pixel values

```
void pattern_sparkle(uint len, uint t) {
  if (t % 8)
```

← If 't' is divisible by 8, then get out of the function

```
        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);
```

→ If random number is divisible by 16, led on, otherwise off.

→ t = t % max

← put pixel value

→ if t value exceeds max the make t = 0

Pattern table

→ Initialize all of present standard stdio types that are linked into binary

← Displays which pin is default 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)");
      for (int i = 0; i < 1000; ++i) {
        pattern_table[pat].pat(NUM_PIXELS, t);
        sleep_ms(10);
        t += dir;
      }
    }
}
```

Chooses which PIO instance to be used from 2 available

state machine is set to be 0

find allocation where there is enough space for our program.

Instantiate an instance of driver program

assign random number in range 0 to (sizeC pattern_table) − 1], i.e. 4

check if logical & of 1 and right shift of random number true 1, otherwise −1

write string to stdout

If dir is 1 write forward string to stdout otherwise backword

pattern function calling

10 ms halt

add direction value to "t"