```
.side_set 1
.define public T1 2
.define public T2 5
.define public T3 3
.wrap_target
bitloop:                                        Data.
                                                0xff0000  0x00ff00
    out x, 1        side 0 [T3 - 1]             L1        L1
    jmp !x do_zero  side 1 [T1 - 1]             L2        L2
do_one:
    jmp bitloop     side 1 [T2 - 1]             L3        L3
do_zero
    nop             side 0 [T2 - 1]             L4        L4
.wrap
```

- What basic circuitry does a WS2812 LED need to operate?
- How do you connect a WS2812 to a microcontroller?
- How does a WS2812 translate bits to color values?
- How do you send a single 1 or 0 bit to the WS2812?
- How many bits does it take to send a single color value?
- What happens if you send more bits than this in a packet?
- How do you tell a WS2812 you're done sending data?
- How do you send data to more than one WS2812 in a chain?

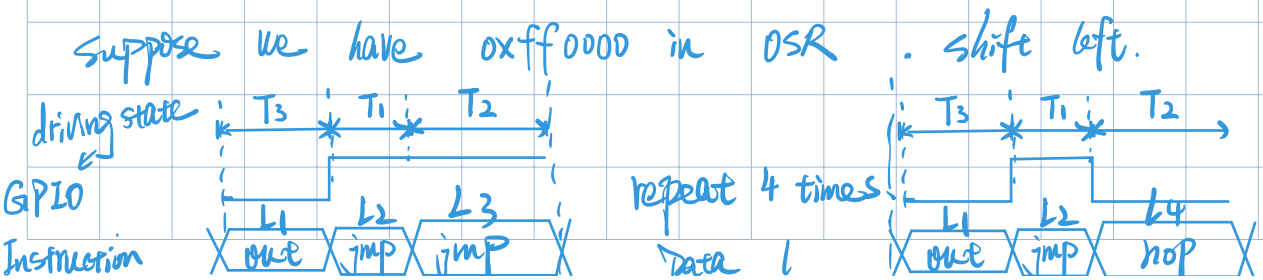
1. digital port data latch, signal reshaping amplification drive circuit, a precision internal oscillator and a 12V voltage programmable constant current control part.
2. Connect DIN in WS2812 with output of pio. Connect VCC in WS2812 with gpio and set it high.
3. It takes GRB in 32 bits.
4. Out x, 1 to send 1 bit. Out x, 0 to send 0 bit to WS2812.
5. 32bits.
6. It will stall and wait for pulling data.

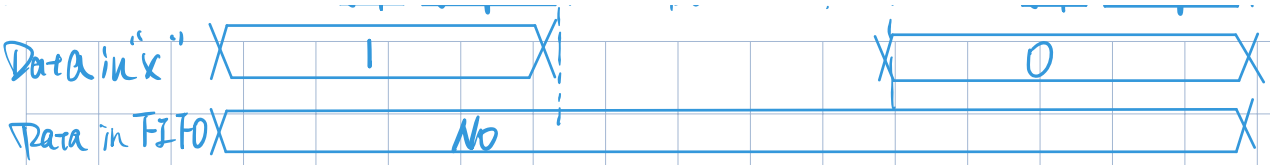
7. Use RET code.

8. Cascade PIX 1 to other PIX using DIN and DO.

Draw a chart

- What's the current instruction? (using your own labels)
- Is there data in the FIFO? y/n
- Is the SM stalled? y/n
- How many delay cycles are left for this instruction?
- What's the value of the output shift register?
- What's the value of the SM "X" variable?
- What state are we driving our LED pin to?





SM stalled: SM will not stall if there is a bit in OSR. Only after we move the 32nd bit to x will we get stalled.

Delay circle: Each operation takes one circle, so for Data 1/0, the delay circle is $T_1+T_2+T_3-3=7$.

For each instruction, it delay T_3-1 for L_1, T_2-1 for L_2, T_3-1 for L_3.

Data in OSR: each time we out a bit, we move left and fill 0 for the lase bit

1111 1111 | 0000 0000 | 0000 0000 | 0000 0000

↓ shift left.

1111 1110 | 0000 0000 | 0000 0000 | 0000 0000

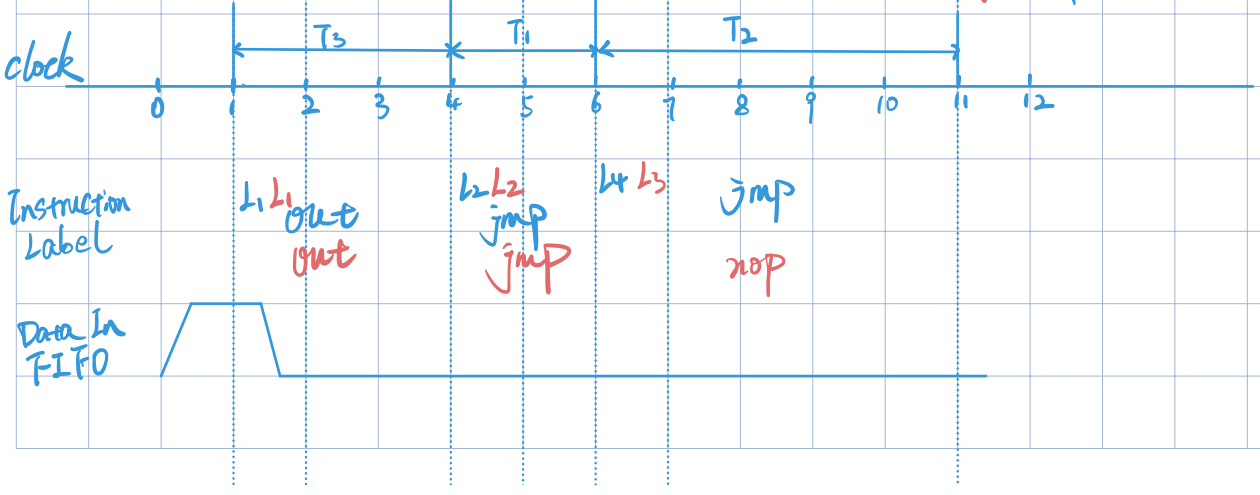
↓ After 32 bit

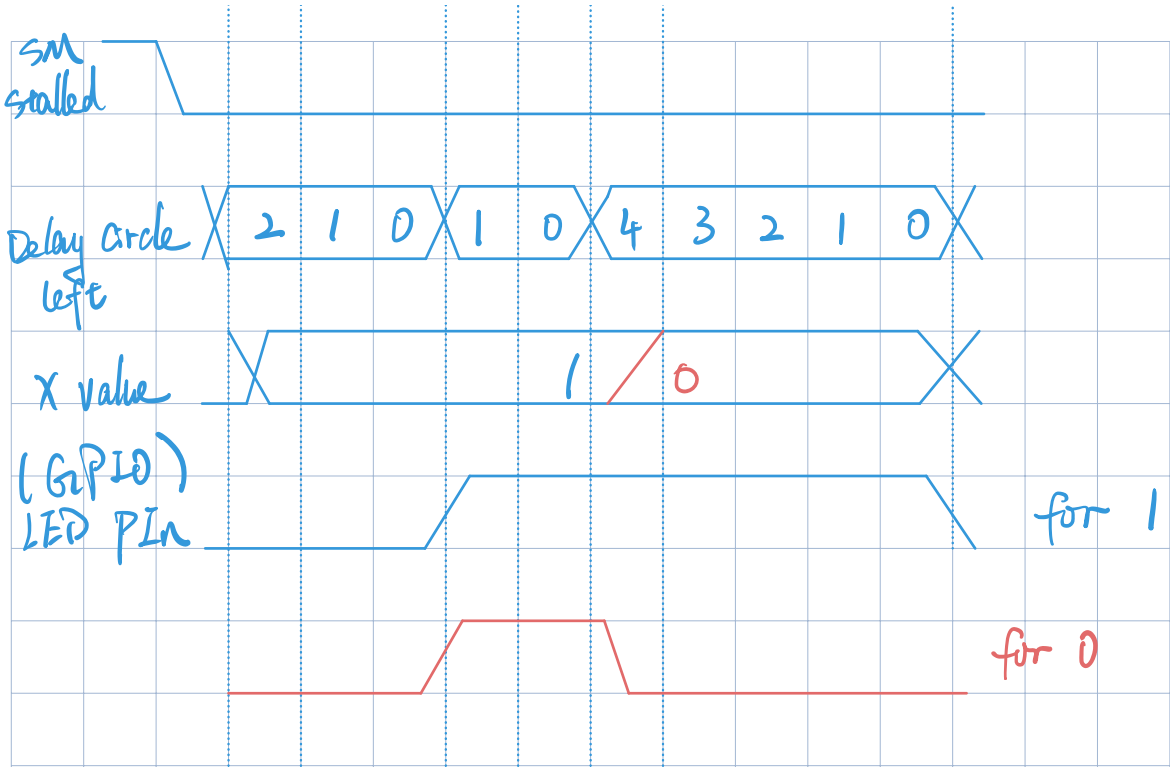
0000 0000 | 0000 0000 | 0000 0000 | 0000 0000

↓

Stalled and Refill from FIFO

data: 0xff0000 / 0x0000ff ⇒ Blue for "1" and red for "0"






```
.wrap_target                                    Data.
bitloop:                                    0xff0000  0x00ff00
    out x, 1        side 0 [T3 - 1]          L1        L1
    jmp !x do_zero  side 1 [T1 - 1]          L2        L2
do_one:
    jmp bitloop     side 1 [T2 - 1]          L3        L3
do_zero
    nop             side 0 [T2 - 1]          L4        L4
.wrap
```

Explain: The basic idea is to get data from TFIFO and use GPIO (which is controlled by "side-set" bit") to represent "0" or "1"

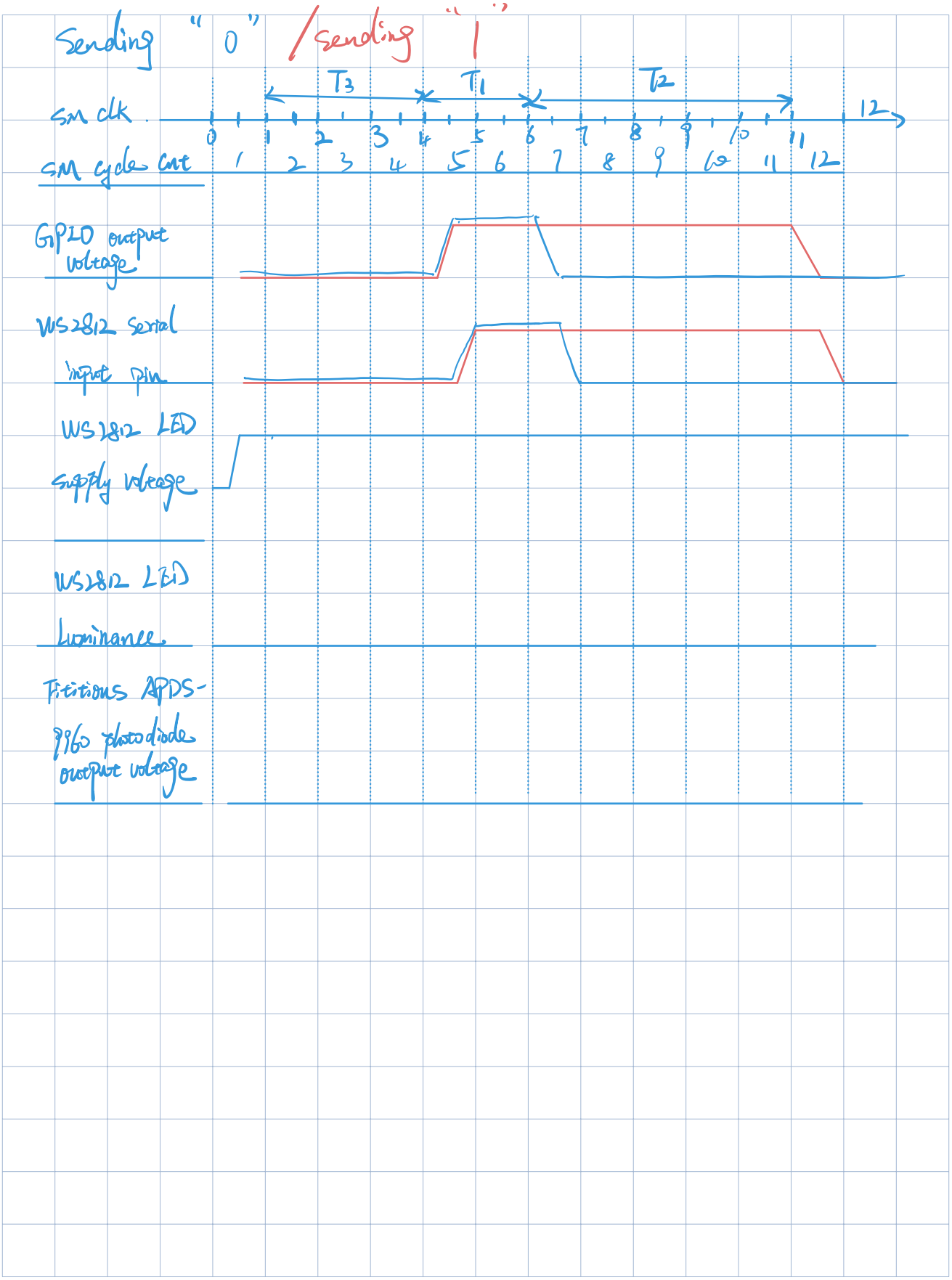
L1: "out" move a bit to x scratch reg. and set "side-set" bit to "low" for T3 clock. The

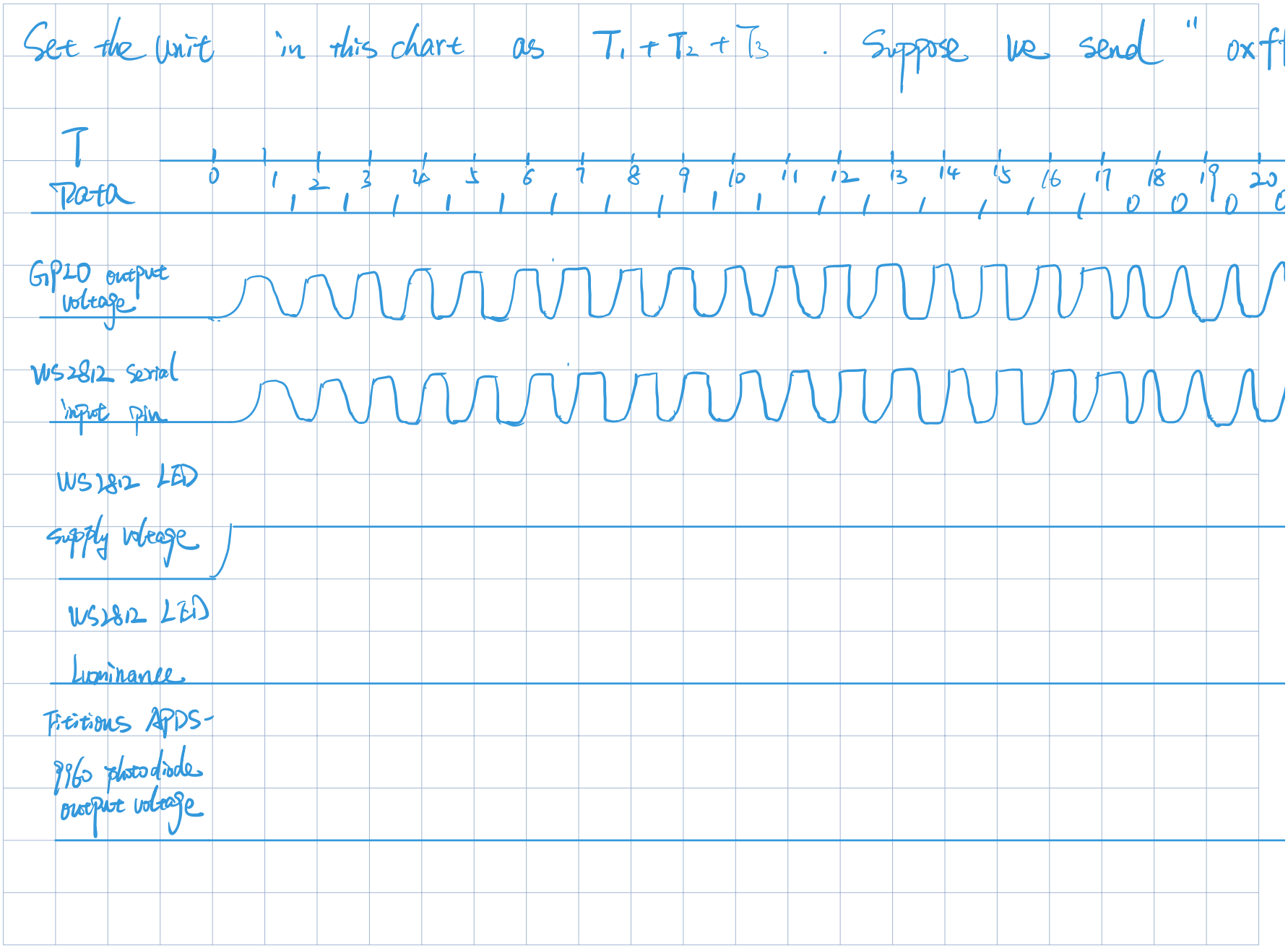
"side-set" drives WS2812 PIN "low" for T_3 clocks.

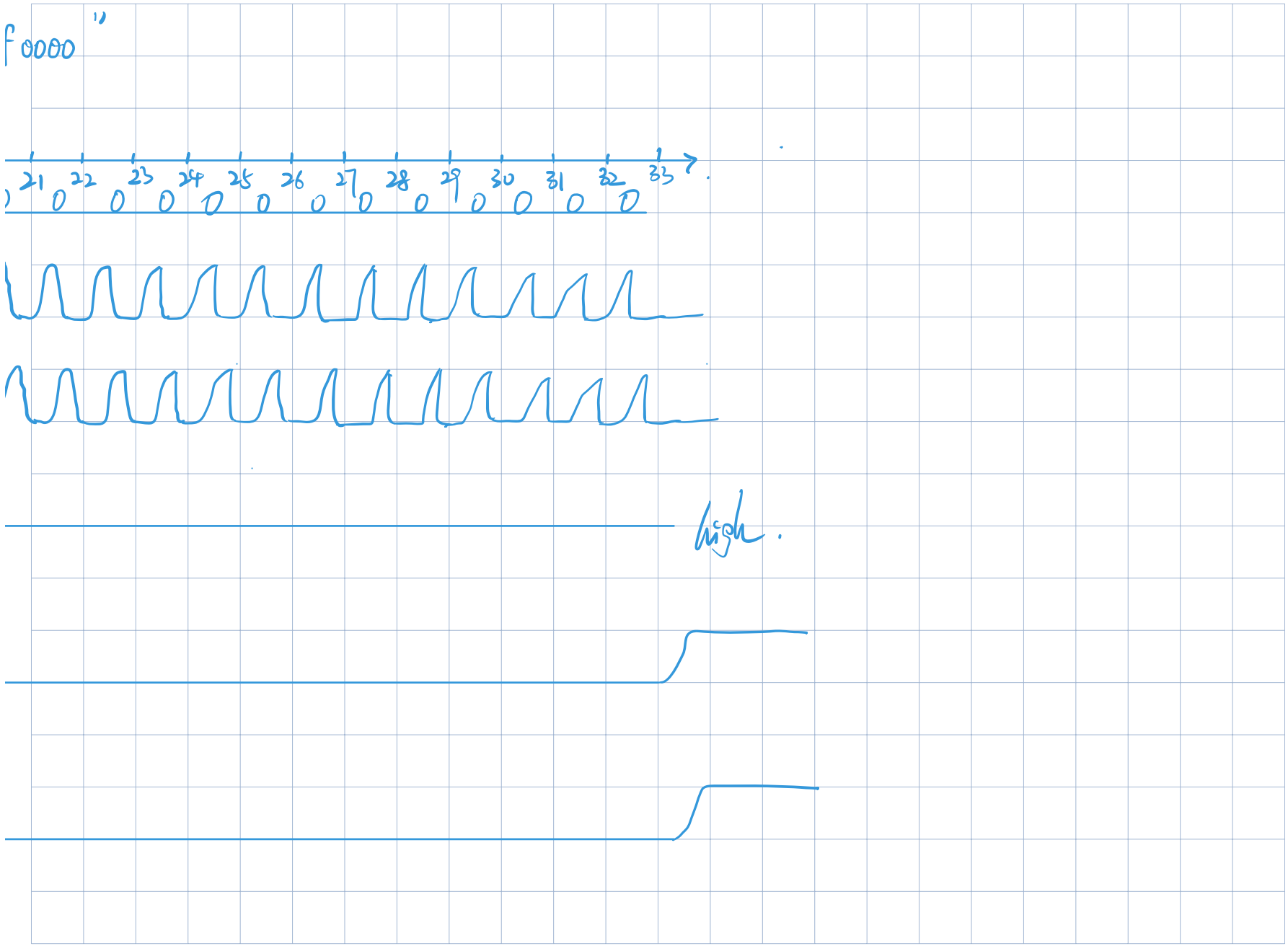
L_2: "jmp" jumps to the corresponding branch. and set "side-set" bit to "high" for T_1 clocks. The "side-set" drives WS2812 PIN "high" for T_1 clocks.

L_3: If X = 1, then we get to L_3 from L_2
"jmp" jumps to "bitloop" to get next bit.
Set "side-set" bit to "high" for T_2 clock. The "side-set" drives WS2812 PIN "high" for T_2 clocks.

L_4: If X = 0, then we get to L_4 from L_2
"nop" does noting and loops to .warp_target.
Set "side-set" bit to "low" for T_2 clock. The "side-set" drives WS2812 PIN "low" for T_2 clocks.


Sending "0"
Sending "1"
T3
T1
T2
sm clk
0 1 2 3 4 5 6 7 8 9 10 11 12
SM cycle cnt
1 2 3 4 5 6 7 8 9 10 11 12
GPIO output voltage
WS2812 serial input pin
WS2812 LED supply voltage
WS2812 LED Luminance
Fitions APDS-9960 photodiode output voltage


Set the unit in this chart as $T_1 + T_2 + T_3$. Suppose we send "0xf
T
Data
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
GPIO output voltage
WS2812 serial input pin
WS2812 LED supply voltage
WS2812 LED Luminance.
Fitions APDS-9960 photodiode output voltage


f 0000
21 22 23 24 25 26 27 28 29 30 31 32 33
0 0 0 0 0 0 0 0 0 0 0 0 0
high.