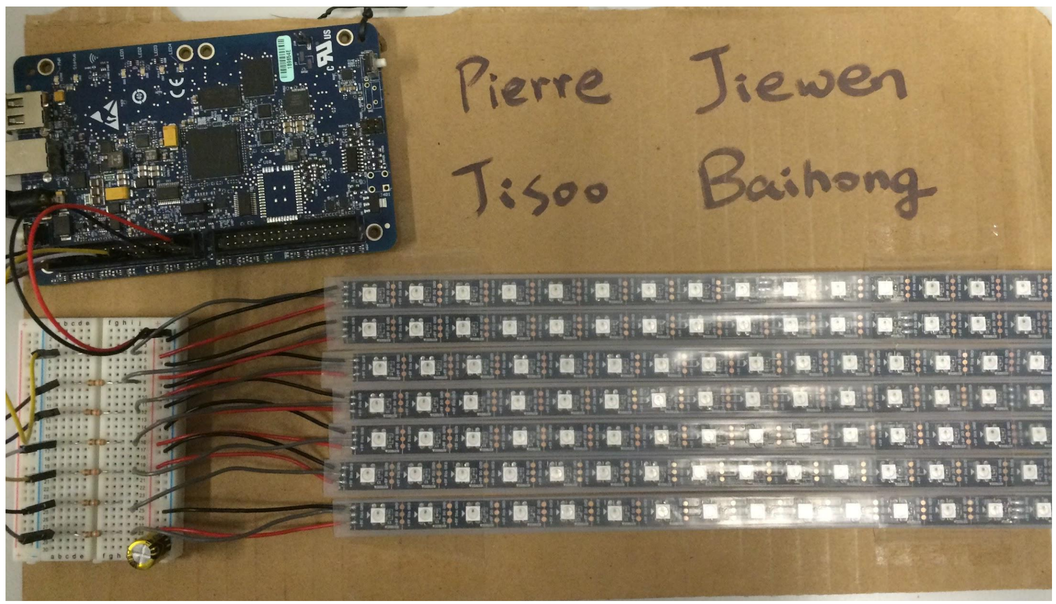
Real-time LED Music Visualizer



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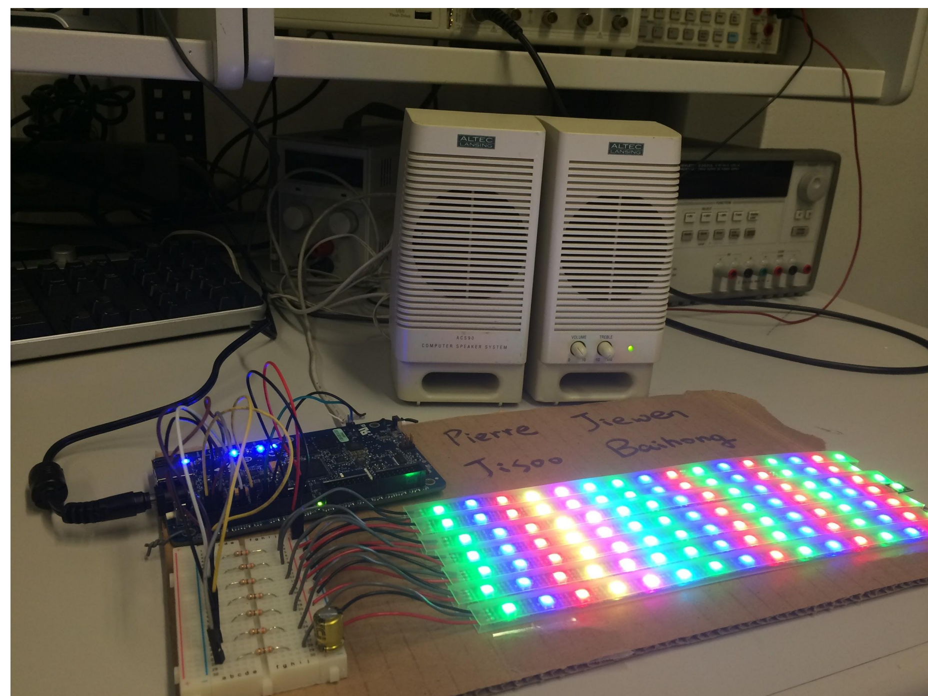
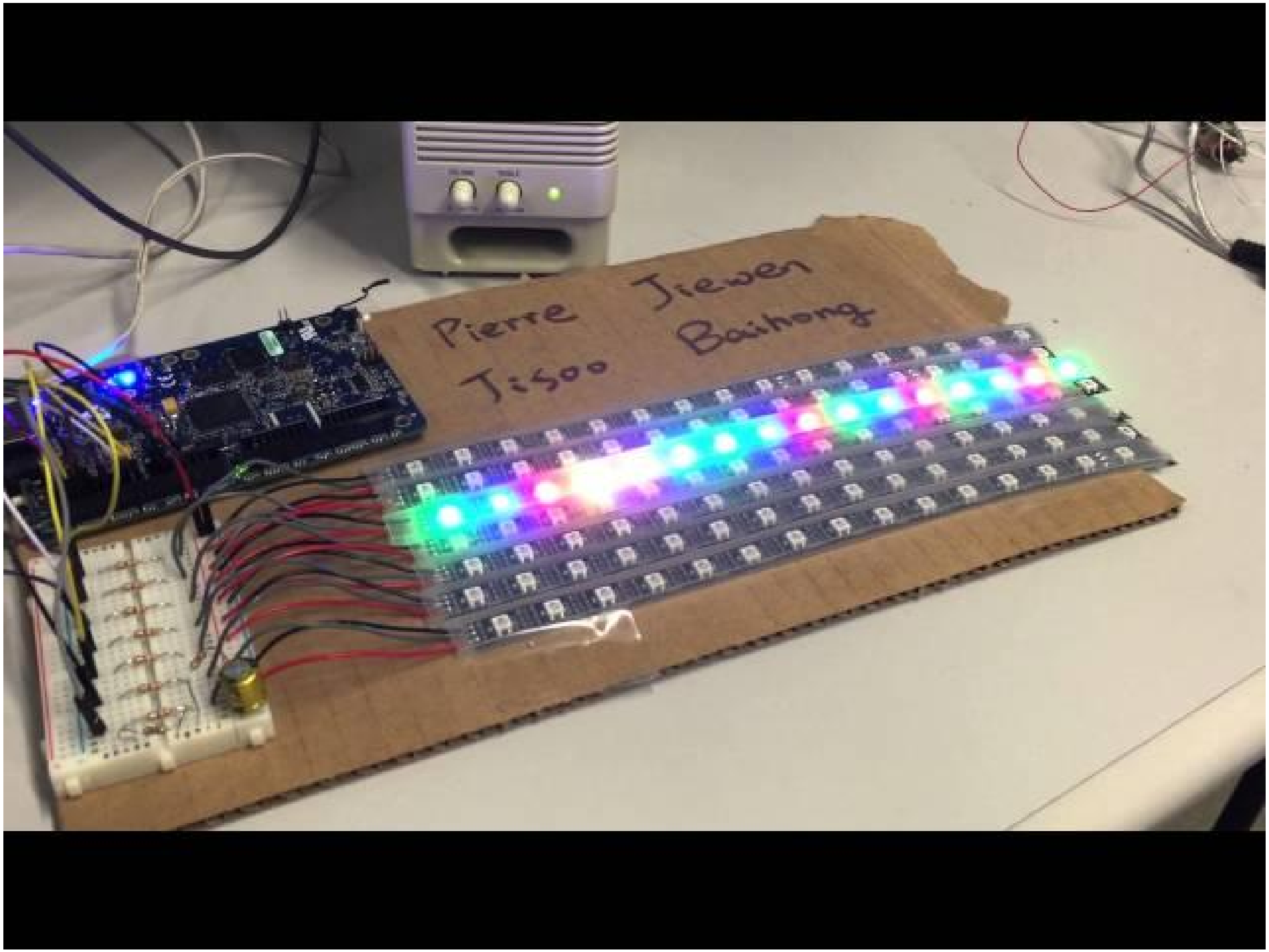
Motivation

- LED Music Visualizer
  - Generating sound with square waves / MIDI
  - 7 LED strips representing different notes
  - Corresponding LED strips glowing with the music

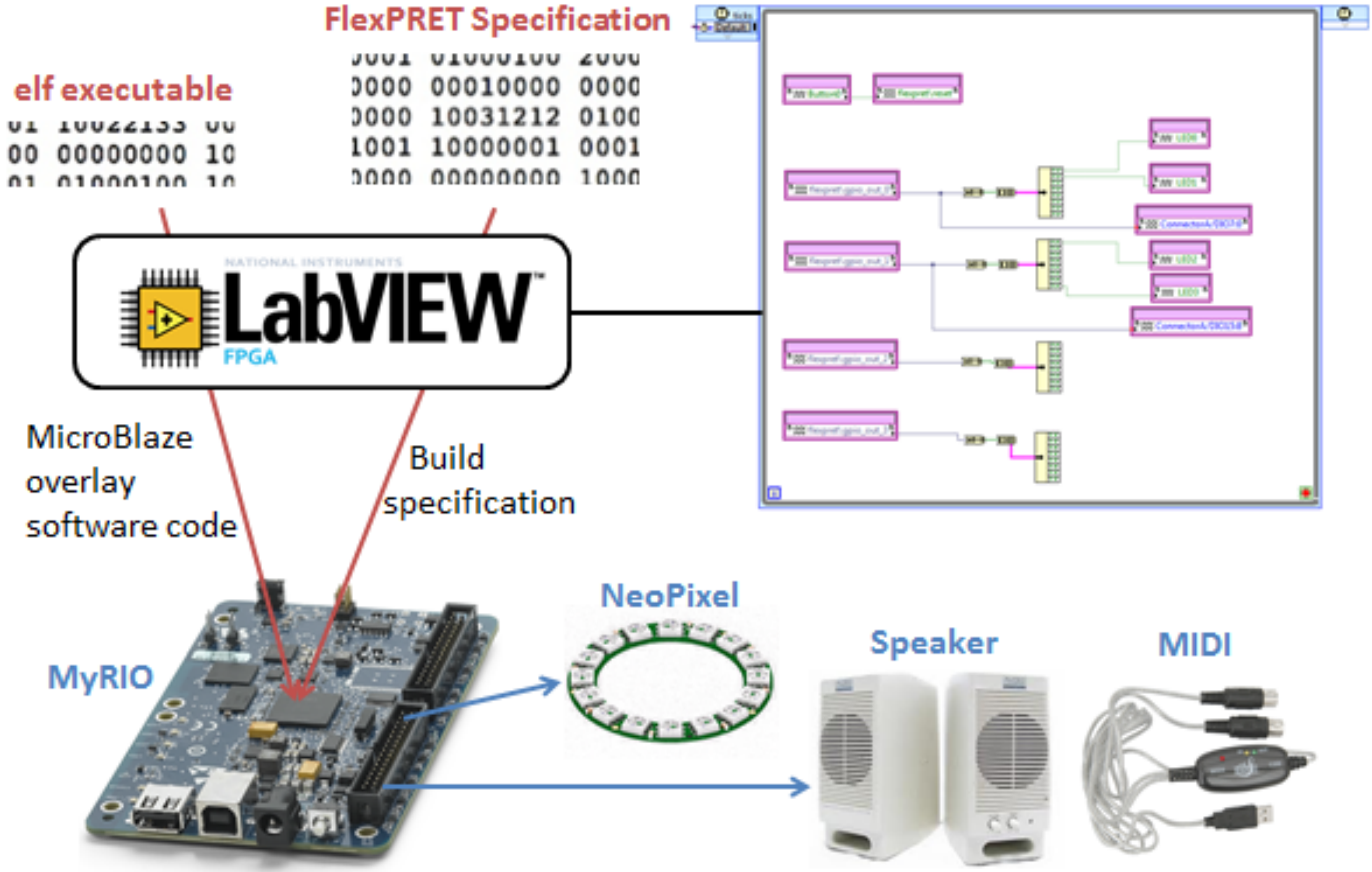
- RTU: FlexPRET
  - Efficient
  - Precise timing control
  - Multitasking



Results

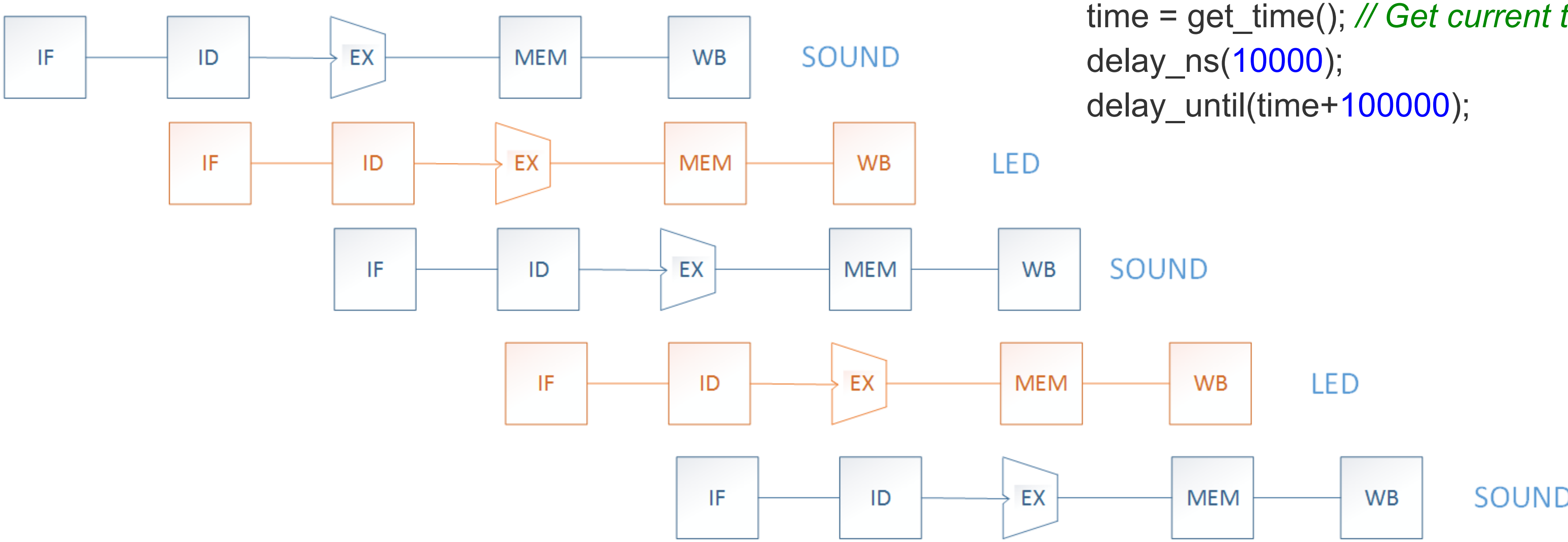


WorkFlow


FlexPRET Specification
elf executable
LabVIEW
FPGA
MicroBlaze
overlay
software code
Build
specification
NeoPixel
Speaker
MIDI
MyRIO

FlexPRET

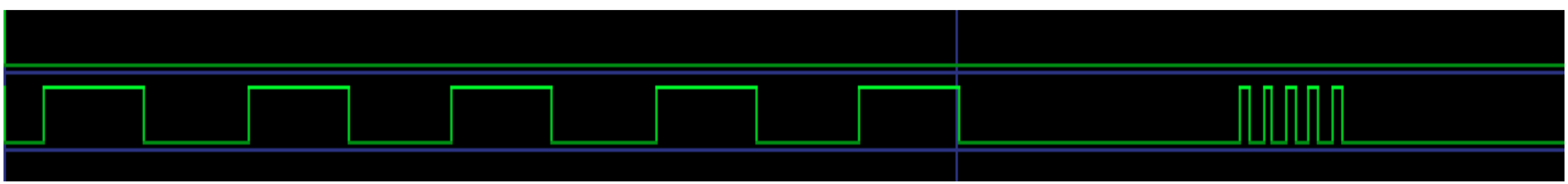
- Timing control is not an easy task on conventional processors
  - Using timed interrupt as well as other complex mechanisms
- FlexPRET - Better timing control enabled from the architecture level
  - Exploiting cycle-level accuracy (~10ns on 100MHz FlexPRET)
  - Better isolation between different threads
  - More user-friendly programming interfaces




```
time = get_time(); // Get current time
delay_ns(10000);
delay_until(time+100000);
```

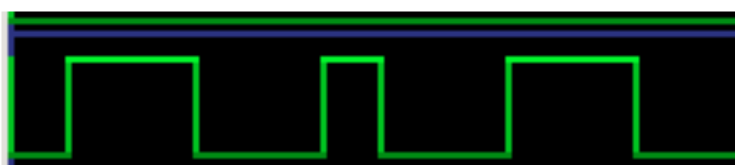
Sound Generation

- Method 1: Generate sound with square wave
  - toggling GPIO pin with certain frequencies for different notes
  - using arrays for period and duration of each note



Sound Generation

- Method 2: Generate sound on computer using MIDI
  - send bytes according to MIDI protocol
    - asynchronous serial interface
    - fixed to 31.25 kbit/sec bitrate
    - currently using MIDI channel 3
    - send least significant bit first
  - sequence of 3 bytes for note on/off
    - note on/off + MIDI channel (e.g. 0x93)
    - note pitch (e.g. 0x40)
    - velocity 0-126 (can be translated into volume)



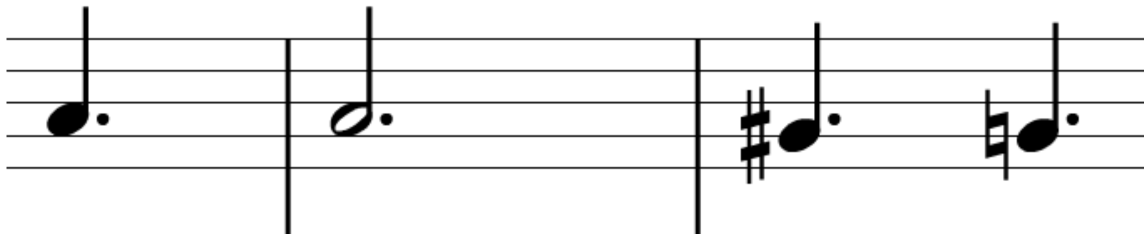
```
Note on for channel 3:
0x93 -> 1001 0011
actual sequence:  0 1100 1001 1
```

Song Pattern Generation

- Songs are represented as sequence of notes and durations (in second)
- Using a python script, we convert the pattern into several arrays where each contains information for duration and notes in different format (e.g. number of cycles, period in nanoseconds, MIDI pitch representation)

```
A4 0.70
Mute 0.05
A4 1.5
G4# 0.75
G4 0.75
```

```
unsigned int note[SONG_LENGTH] = {1136363, 50000000, 1136363,
1203948, 1275510};
unsigned int duration[SONG_LENGTH] = {154, 1, 330, 155, 147};
unsigned int duration_ns[SONG_LENGTH] = {349999958, 50000000,
749999910, 373224035, 374999940};
char note_byte[SONG_LENGTH] = {0x45, 0, 0x45, 0x44, 0x43};
```



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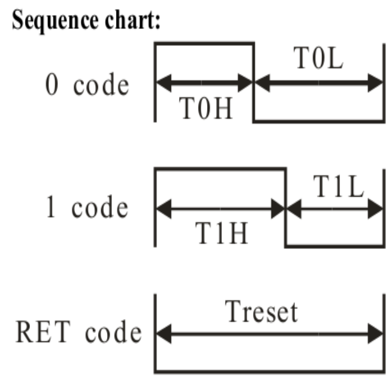
NeoPixel Spec

Data transfer time(TH+TL=1.25μs±600ns)

T0H	0 code ,high voltage time	0.35us	±150ns
T1H	1 code ,high voltage time	0.7us	±150ns
T0L	0 code , low voltage time	0.8us	±150ns
T1L	1 code ,low voltage time	0.6us	±150ns
RES	low voltage time	Above 50μs	



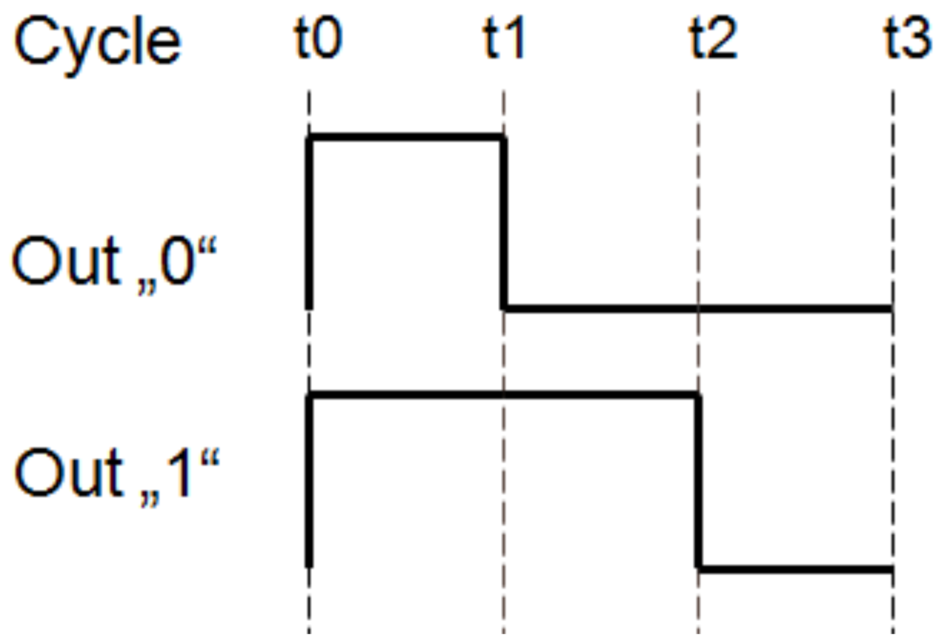
Source: WS2812 Datasheet

	Timing WS2812B	Timing WS2812	WS2812 Cycles
T_{HI_IN} "0"	62.5 ns - 563 ns	62.5 ns - 500 ns	<3
T_{HI_IN} "1"	≥ 625 ns	≥ 563 ns	>3
T_{PERIOD_IN}	≥ 1063 ns	≥ 875 ns	>5
$T_{DELAY\_IN\_OUT}$	~ 208 ns	~ 166 ns	1
T_{HI_OUT} "0"	~ 416 ns	~ 333 ns	2
T_{HI_OUT} "1"	~ 832 ns	~ 666 ns	4
T_{RESET}	> 9 μs	> 10.8 μs	-

Source: Tim's Blog
https://cpldcpu.wordpress.com/2014/01/14/light_ws2812-library-v2-0-part-i-understanding-the-ws2812/

Real tolerance: +/- ~215 ns

Neopixel Timing



Neopixel Timing

How many times can we set LEDs between notes?

~30us per LED

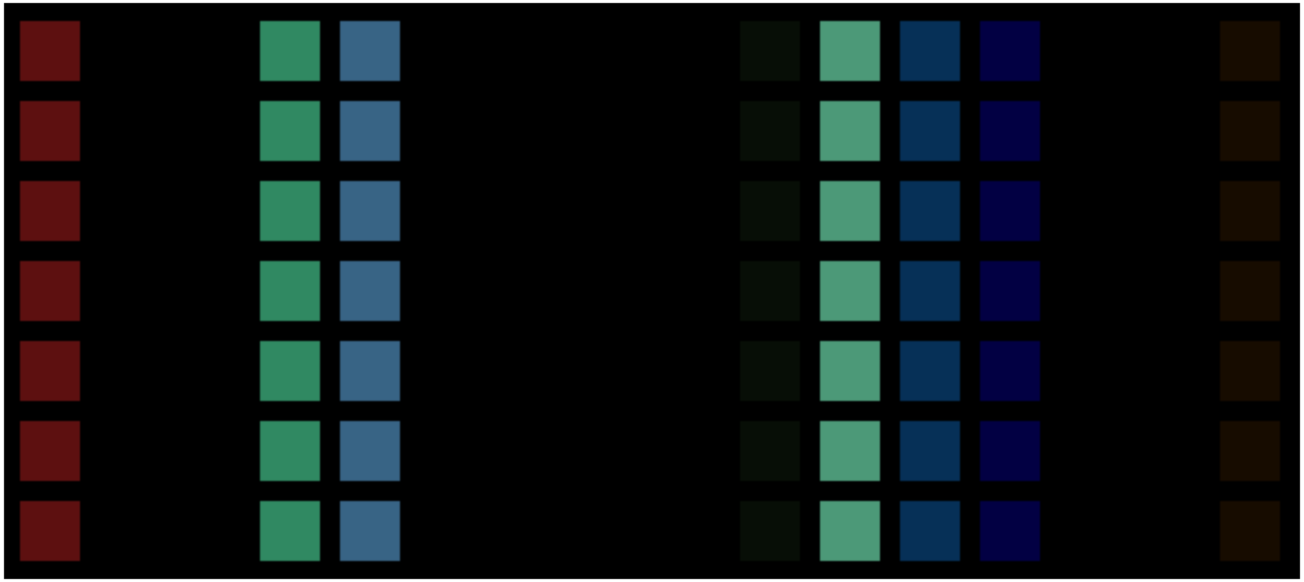
17*6 = 102 LEDS

102 * 30 = 3060 us = ~3ms per update

~100ms per note so about **33 updates**

Using updated timing, we can send signals 7 times faster, so we can 33*7 = **231 updates**

Simulator



Neopixel Driver

Acknowledgement

Sincere appreciation towards our Professors, GSIs, and especially our nice mentor - Michael Zimmer.

Thank you for listening. Go Bears!