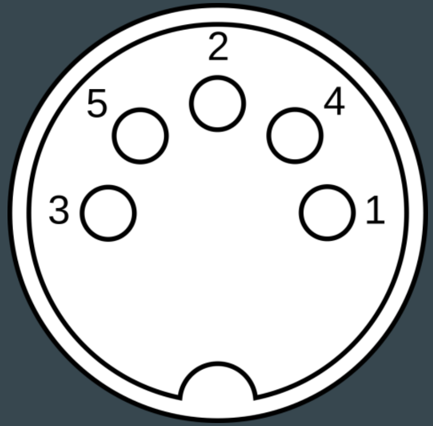
The DiGuitar

...

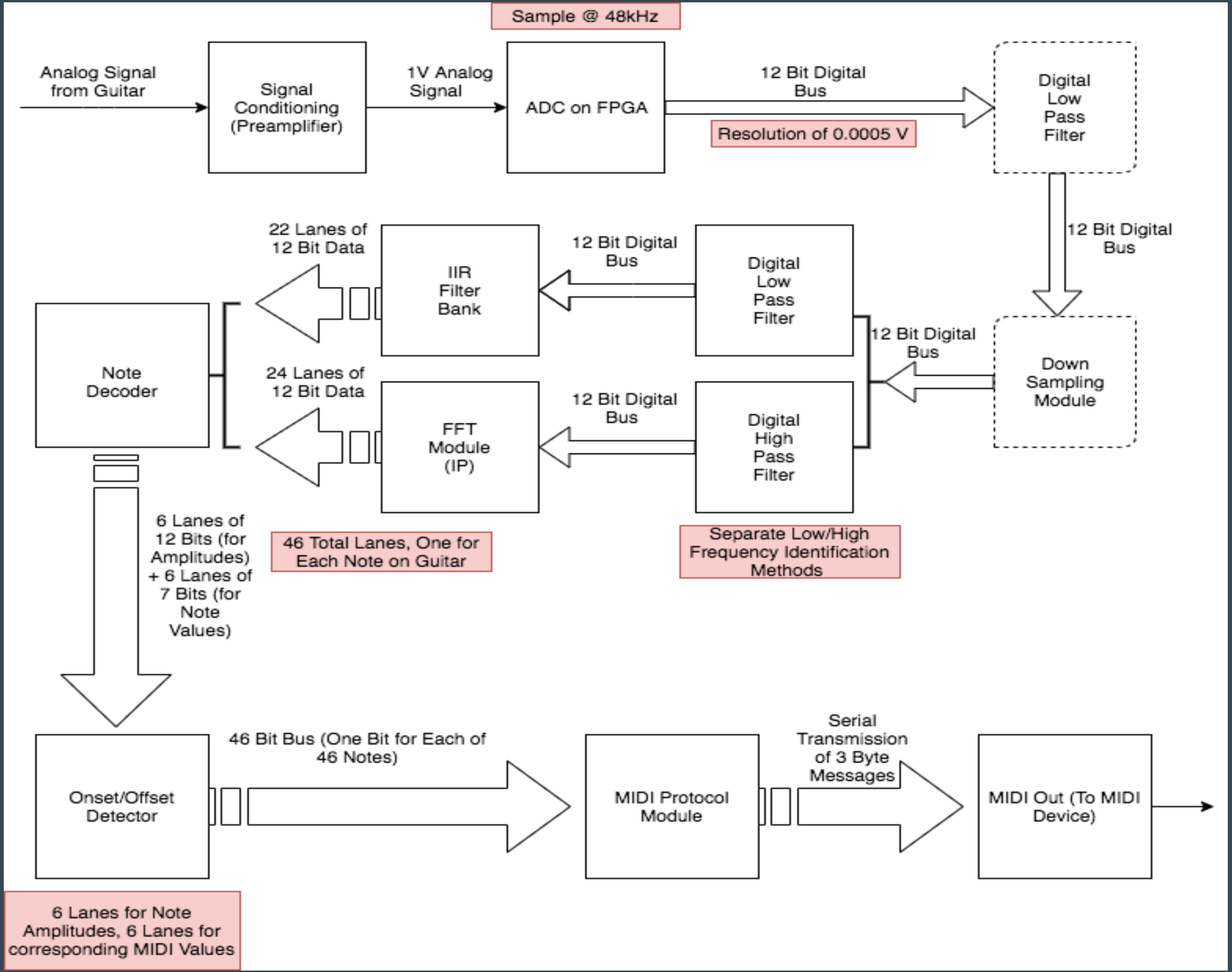
Ishaan Govindarajan and Eric Pence

Overview

TL;DR: take the **analog input** from a guitar and convert it into a **digital MIDI datastream** via **DSP Magic™* in real time**



*Not actually magic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Signal Conditioning (Preamplifier)
1V Analog Signal
ADC on FPGA
12 Bit Digital Bus
Resolution of 0.0005 V
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FFT Module (IP)
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46 Total Lanes, One for Each Note on Guitar
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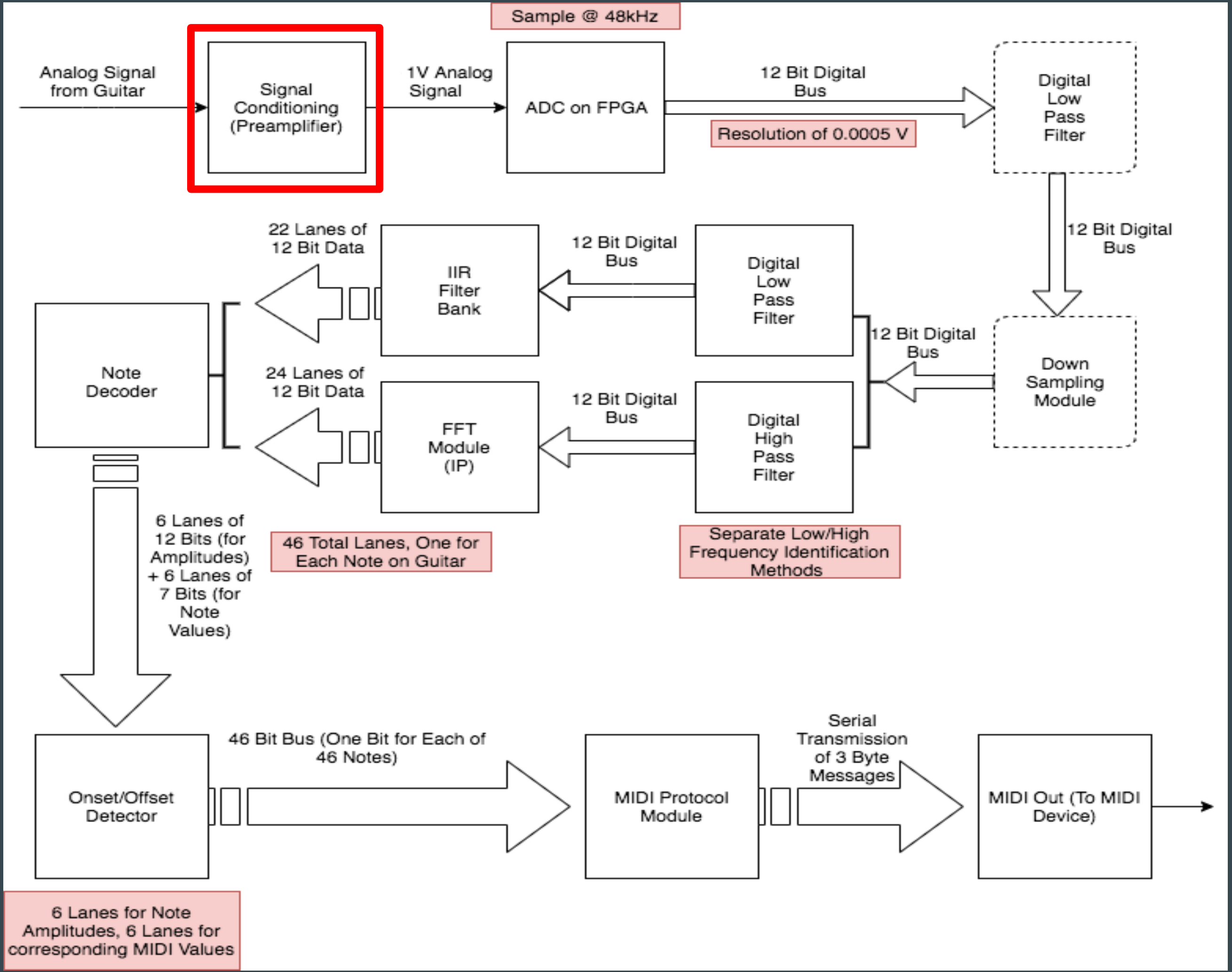
Serial Transmission of 3 Byte Messages
MIDI Out (To MIDI Device)
6 Lanes for Note Amplitudes, 6 Lanes for corresponding MIDI Values



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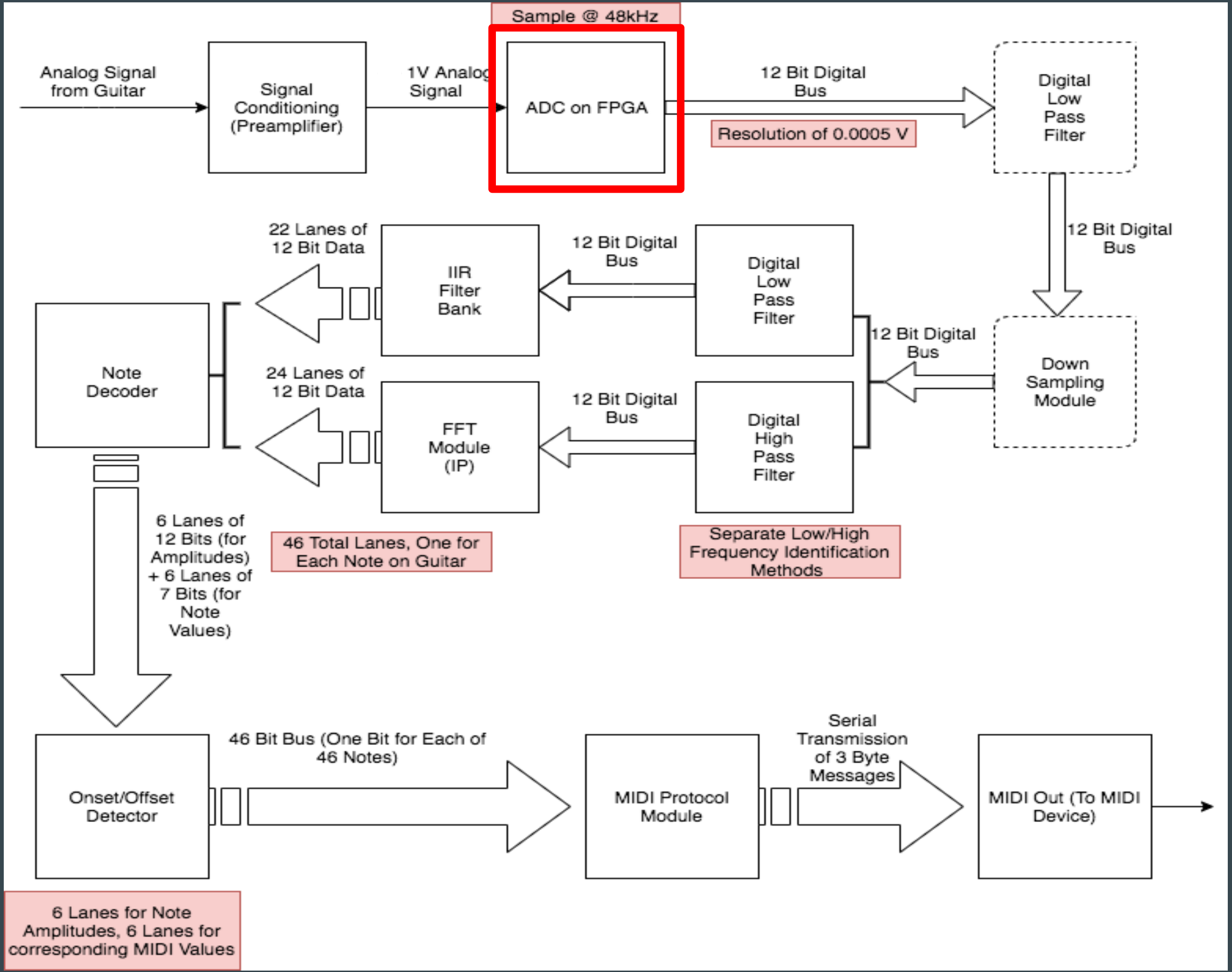

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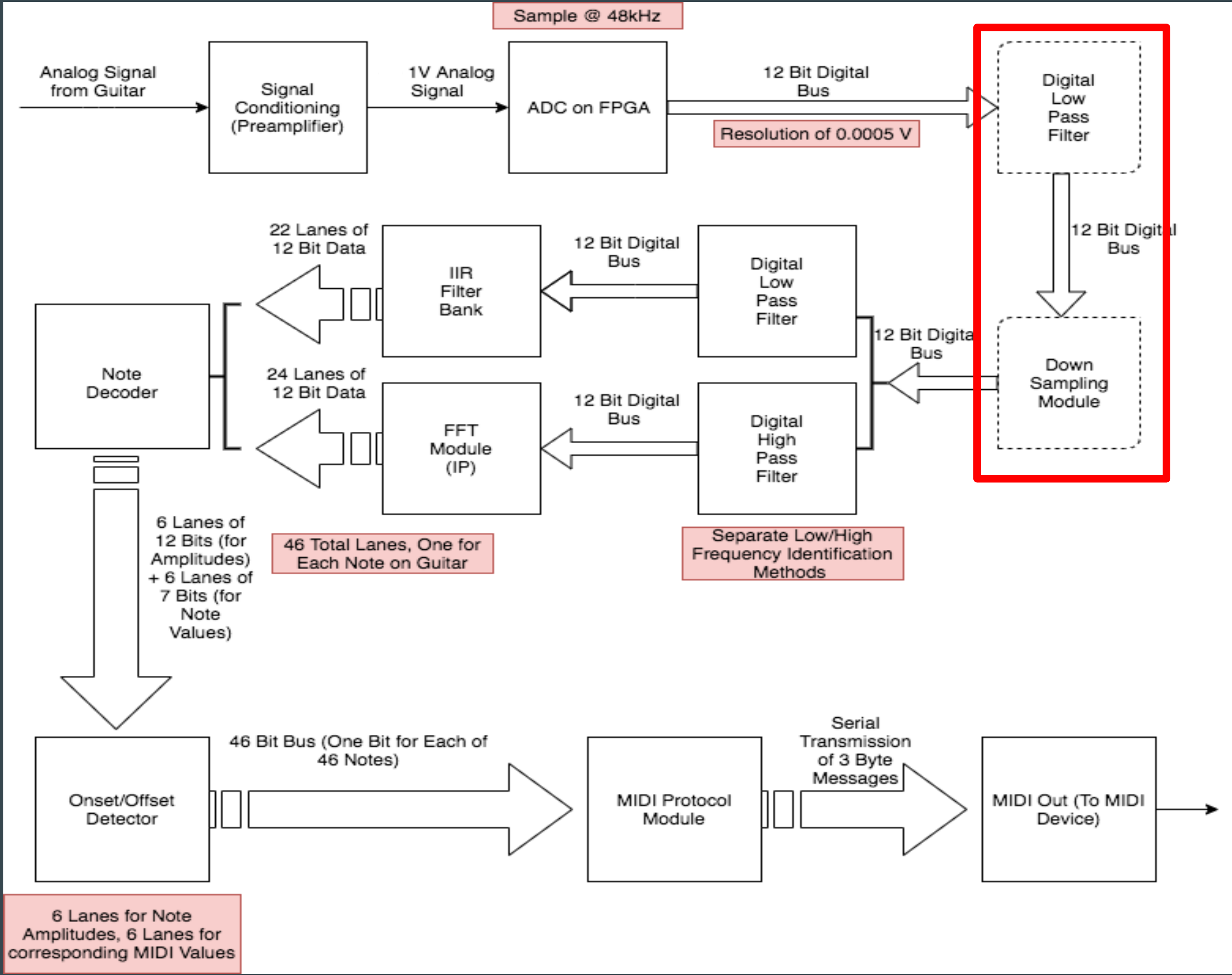
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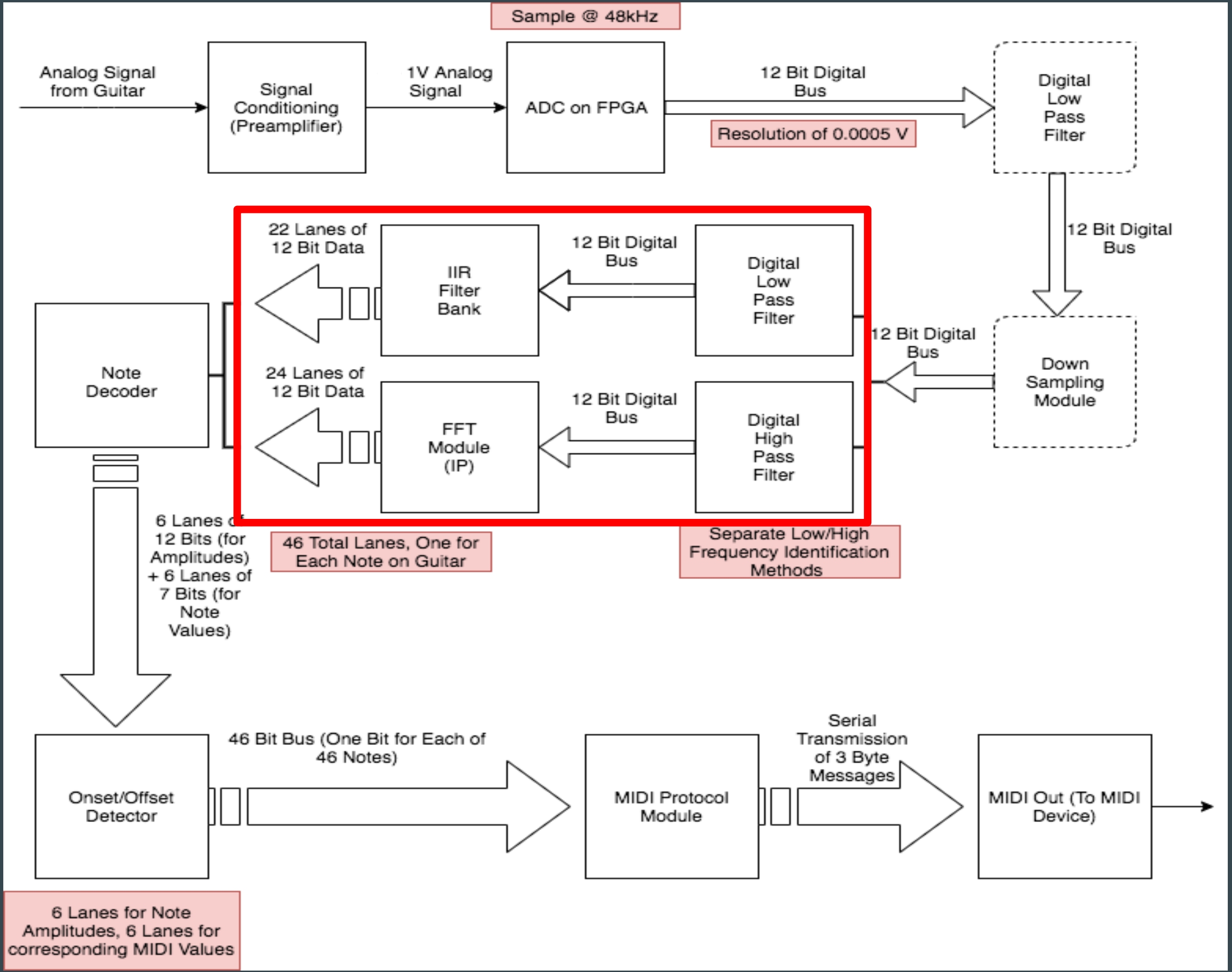

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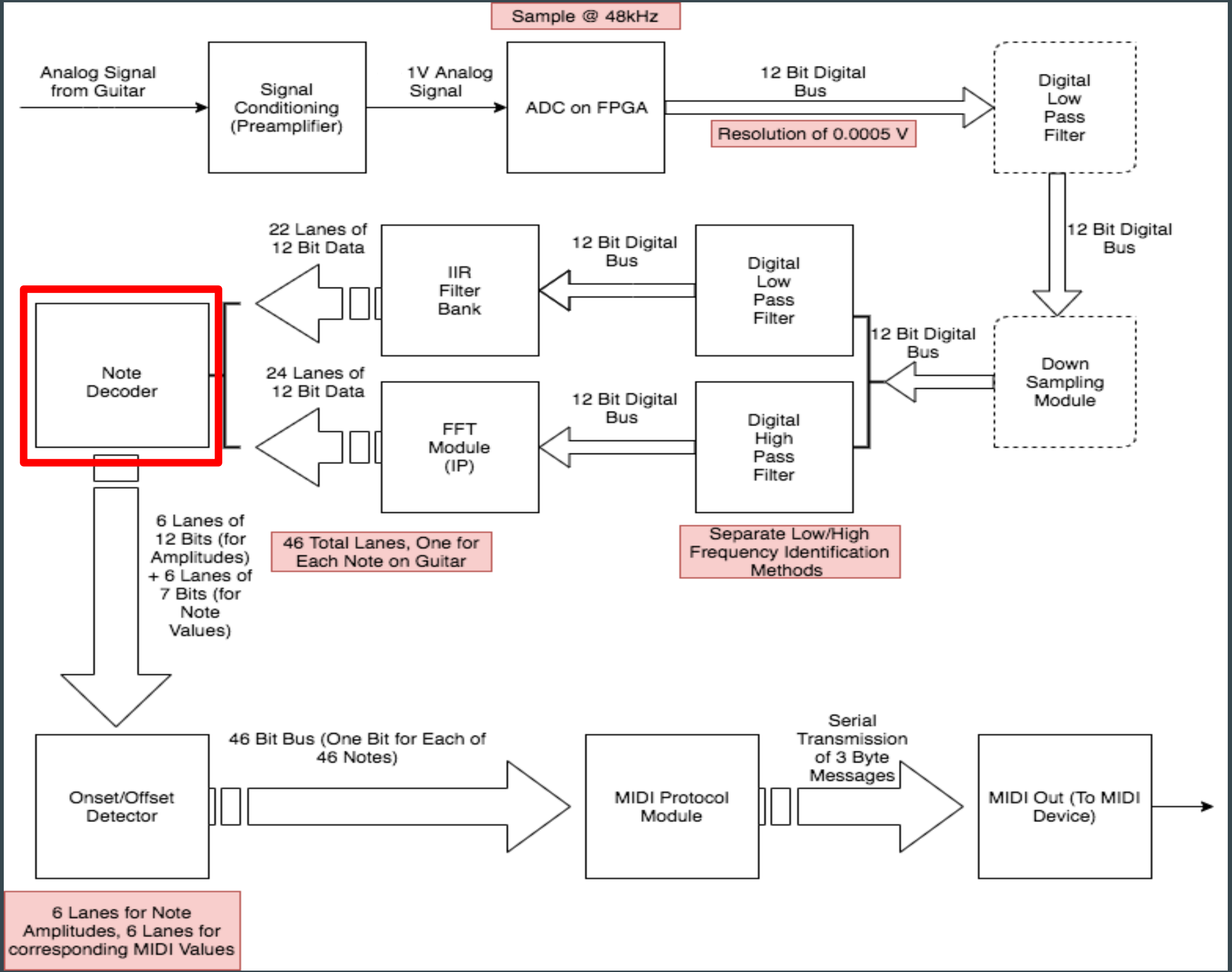
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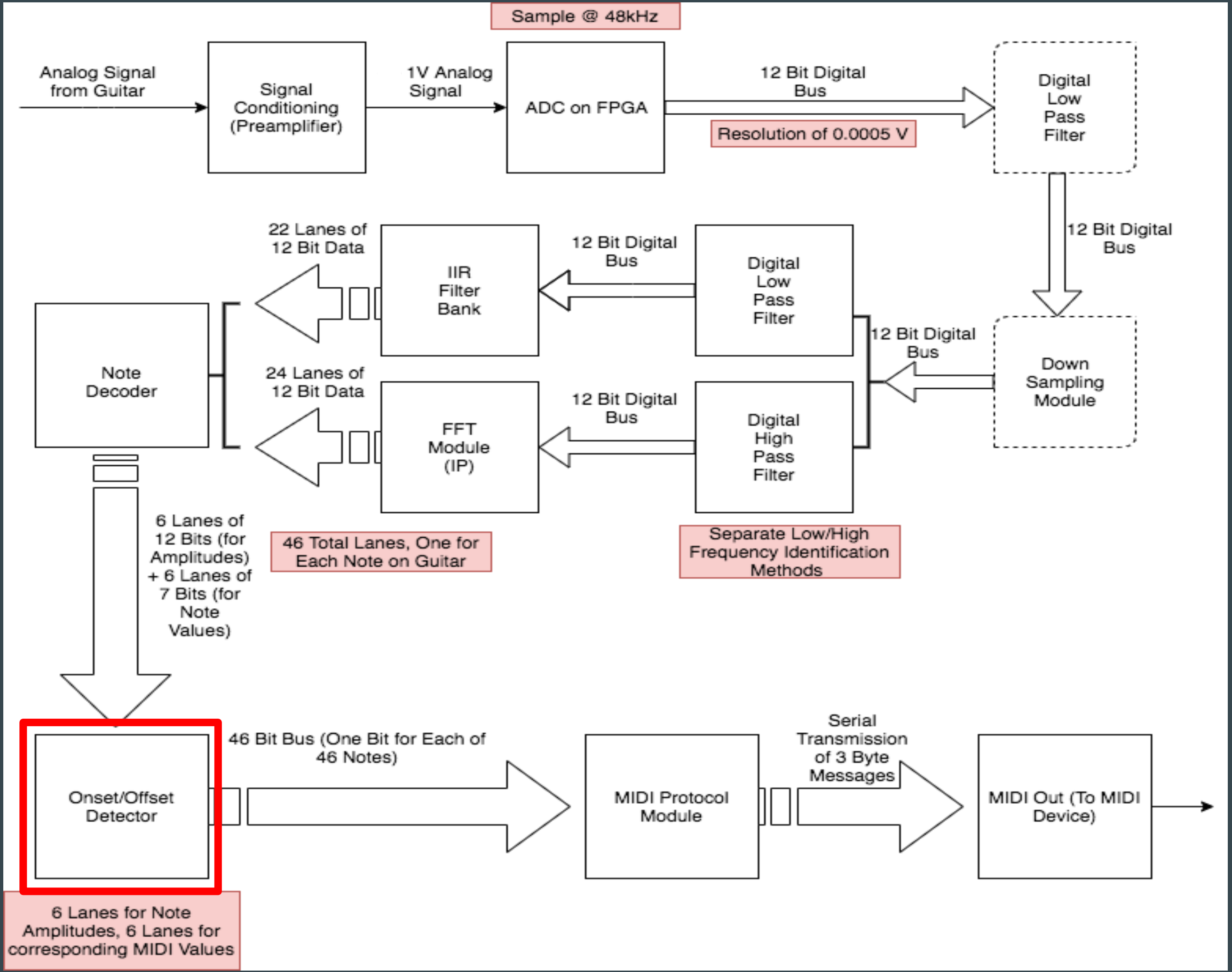

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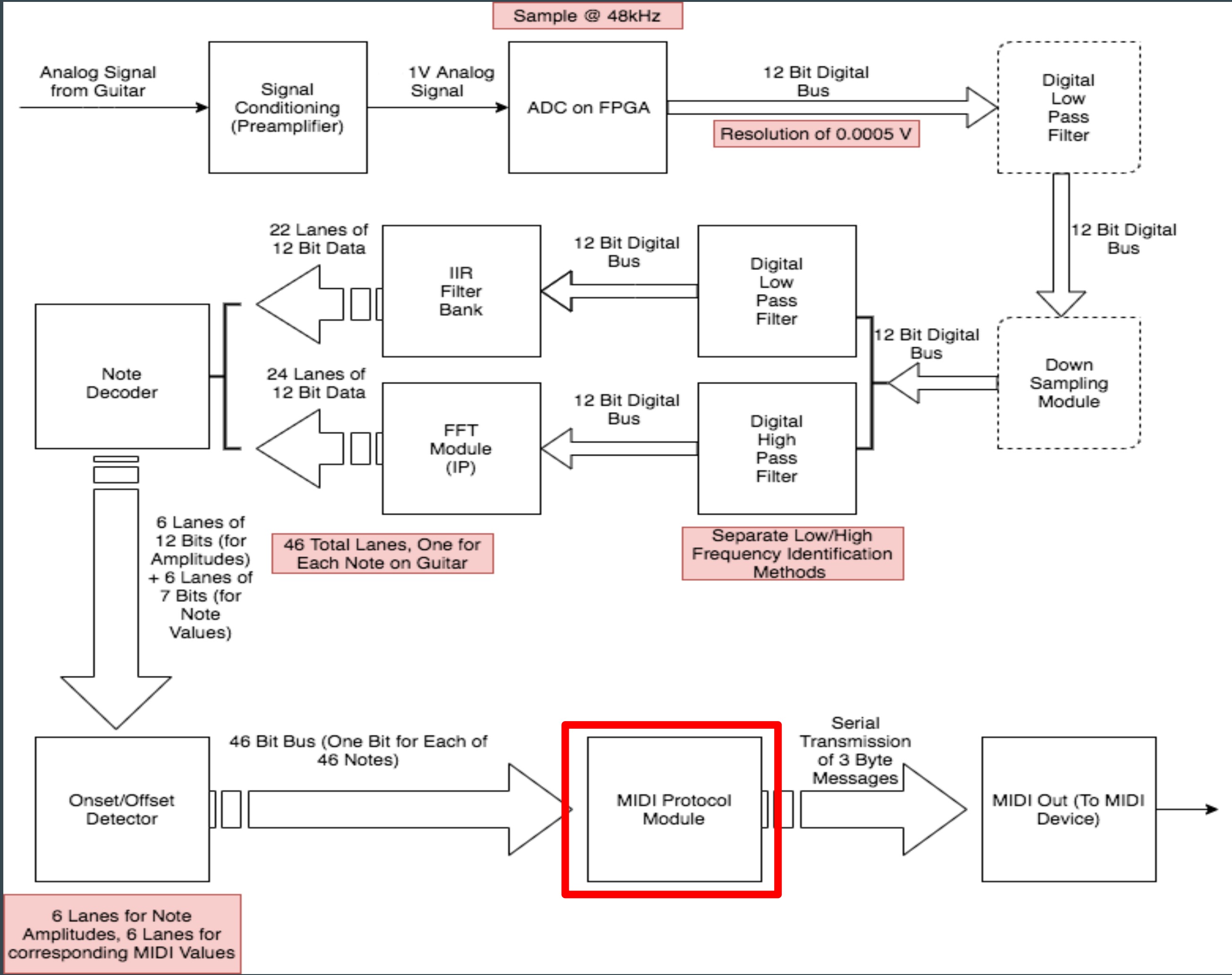

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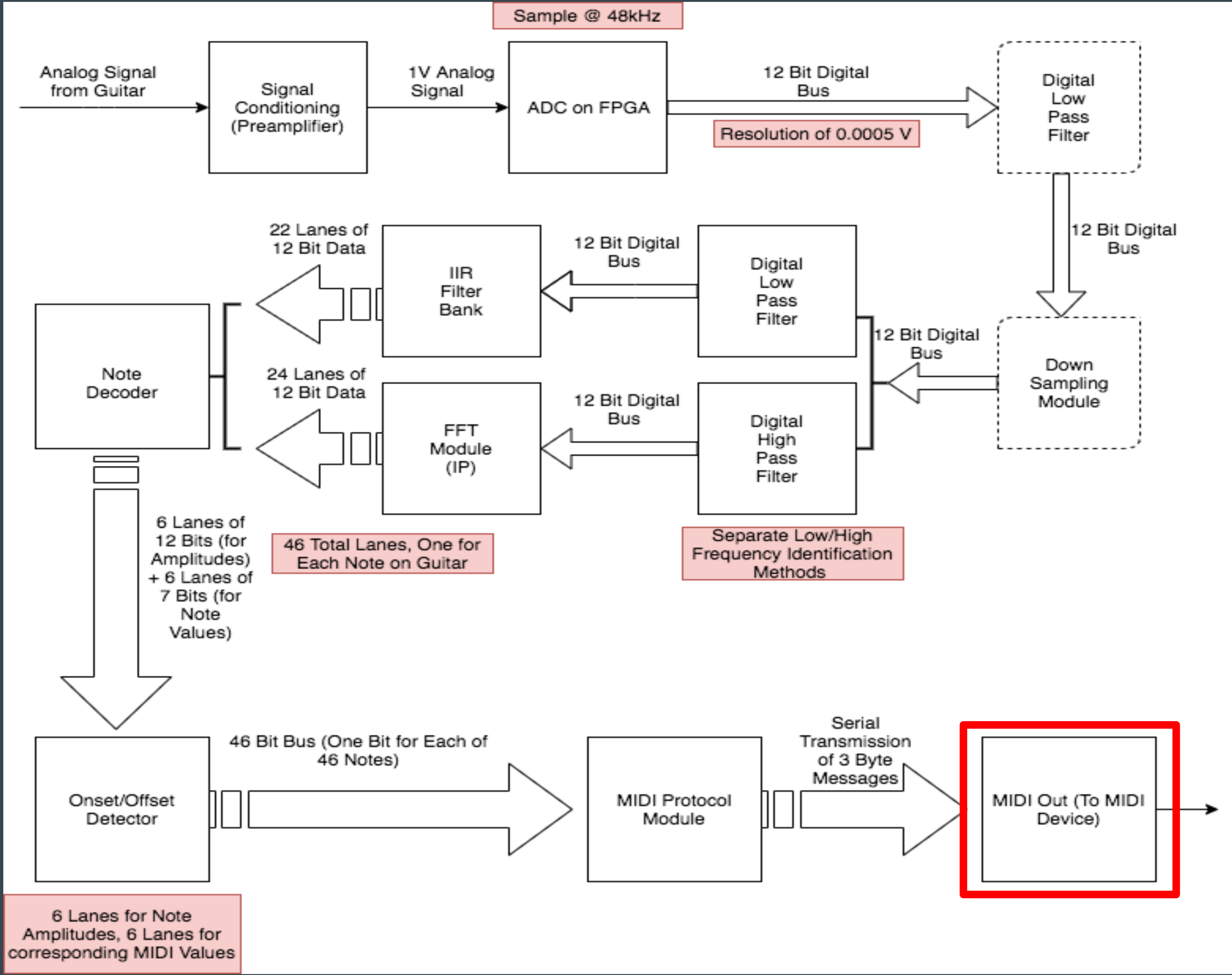

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The "DSP Magic"

When u need to do some digital signal processing and have no idea what to do

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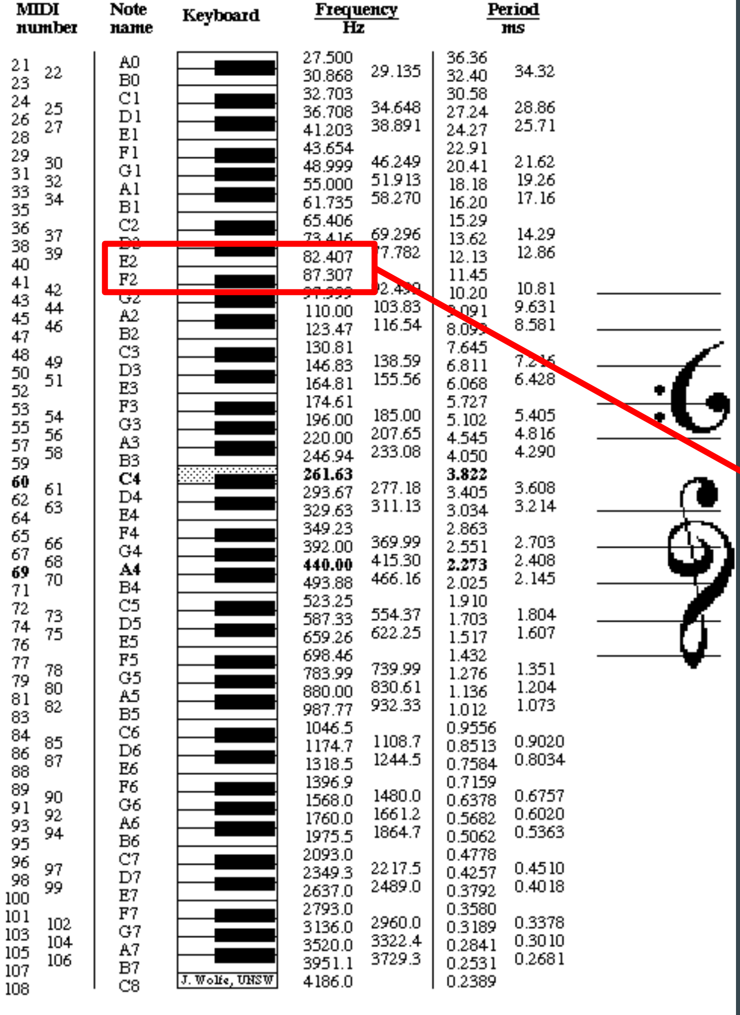
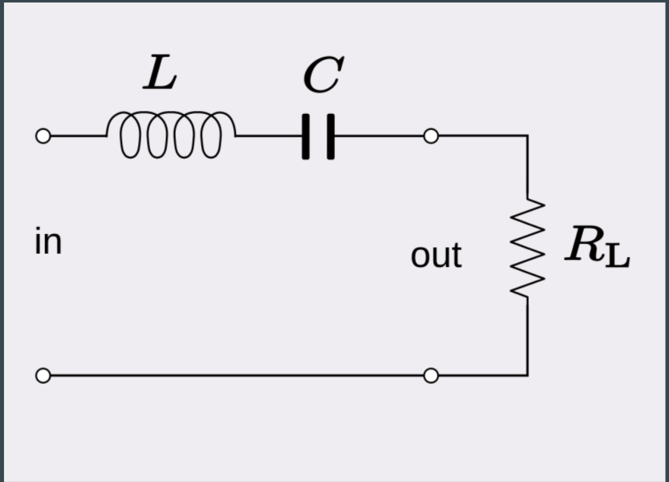
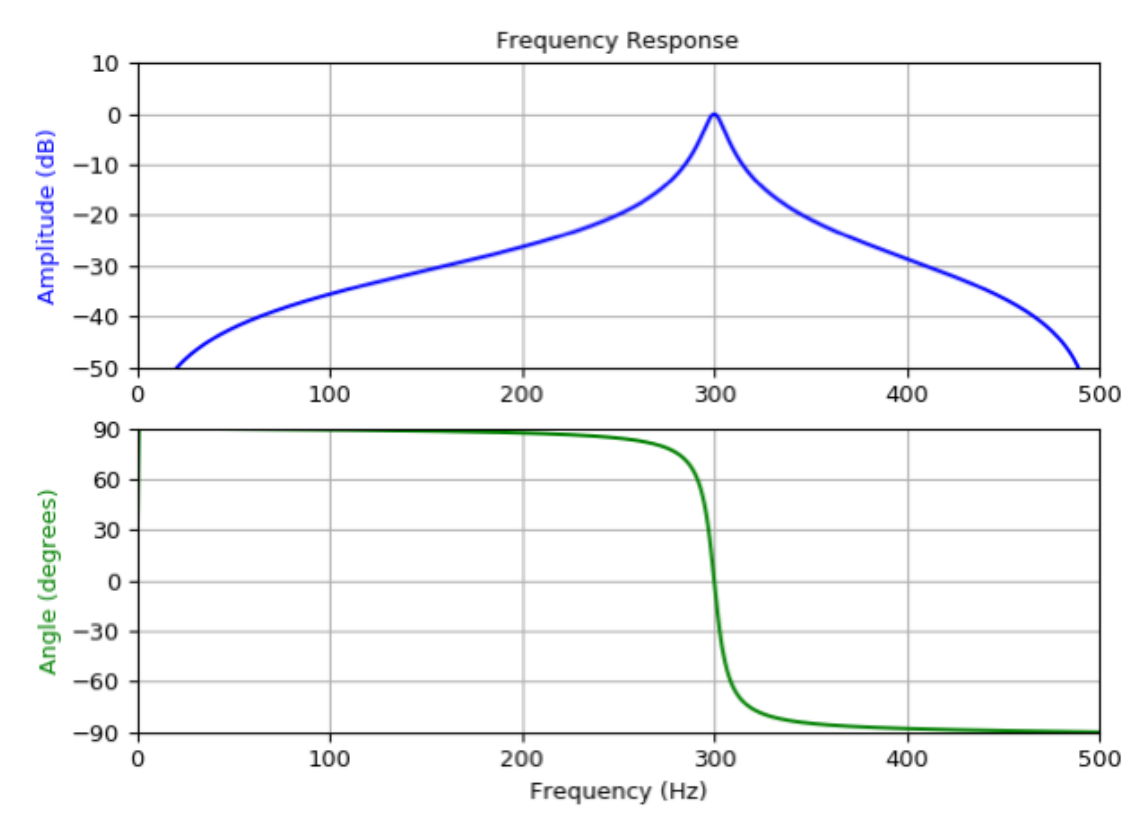


MIDI number		Note name	Frequency Hz		Period ms	
21	22	A0	27.500	29.135	36.36	34.32
23		B0	30.868		32.40	
24	25	C1	32.703	34.648	30.58	28.86
26	27	D1	36.708	38.891	27.24	25.71
28		E1	41.203		24.27	
29	30	F1	43.654	46.249	22.91	21.62
31	32	G1	48.999	51.913	20.41	19.26
33	34	A1	55.000	58.270	18.18	17.16
35		B1	61.735		16.20	
36	37	C2	65.406	69.296	15.29	14.29
38	39	D2	73.416	77.782	13.62	12.86
40		E2	82.407		12.13	
41	42	F2	87.307	92.499	11.45	10.81
43	44	G2	97.999	103.83	10.20	9.631
45	46	A2	110.00	116.54	9.091	8.581
47		B2	123.47		8.099	
48	49	C3	130.81	138.59	7.645	7.216
50	51	D3	146.83	155.56	6.811	6.428
52		E3	164.81		6.068	
53	54	F3	174.61	185.00	5.727	5.405
55	56	G3	196.00	207.65	5.102	4.816
57	58	A3	220.00	233.08	4.545	4.290
59		B3	246.94		4.050	
60	61	**C4**	**261.63**	277.18	**3.822**	3.608
62	63	D4	293.67	311.13	3.405	3.214
64		E4	329.63		3.034	
65	66	F4	349.23	369.99	2.863	2.703
67	68	G4	392.00	415.30	2.551	2.408
69	70	**A4**	**440.00**	466.16	**2.273**	2.145
71		B4	493.88		2.025	
72	73	C5	523.25	554.37	1.910	1.804
74	75	D5	587.33	622.25	1.703	1.607
76		E5	659.26		1.517	
77	78	F5	698.46	739.99	1.432	1.351
79	80	G5	783.99	830.61	1.276	1.204
81	82	A5	880.00	932.33	1.136	1.073
83		B5	987.77		1.012	
84	85	C6	1046.5	1108.7	0.9556	0.9020
86	87	D6	1174.7	1244.5	0.8513	0.8034
88		E6	1318.5		0.7584	
89	90	F6	1396.9	1480.0	0.7159	0.6757
91	92	G6	1568.0	1661.2	0.6378	0.6020
93	94	A6	1760.0	1864.7	0.5682	0.5363
95		B6	1975.5		0.5062	
96	97	C7	2093.0	2217.5	0.4778	0.4510
98	99	D7	2349.3	2489.0	0.4257	0.4018
100		E7	2637.0		0.3792	
101	102	F7	2793.0	2960.0	0.3580	0.3378
103	104	G7	3136.0	3322.4	0.3189	0.3010
105	106	A7	3520.0	3729.3	0.2841	0.2681
107		B7	3951.1		0.2531	
108		C8	4186.0		0.2389	

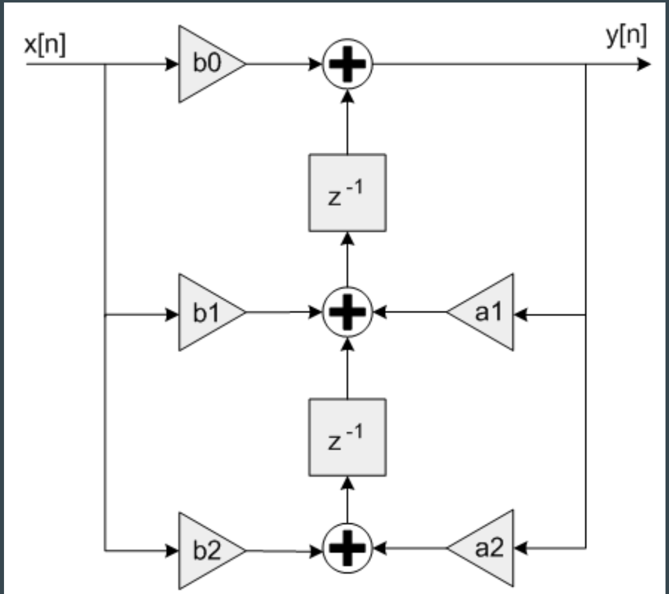
Two lowest notes a guitar in standard tuning can play:

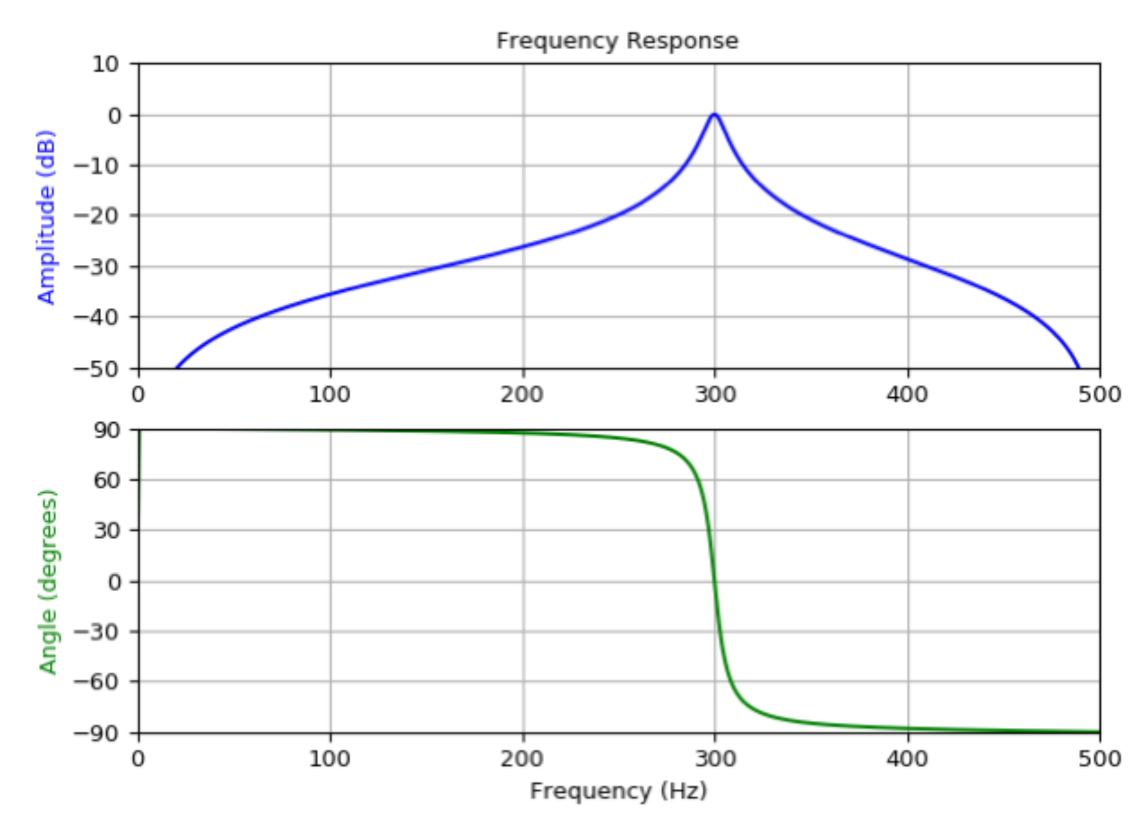
5Hz Resolution = 200ms long DFT!
AKA 200ms latency!



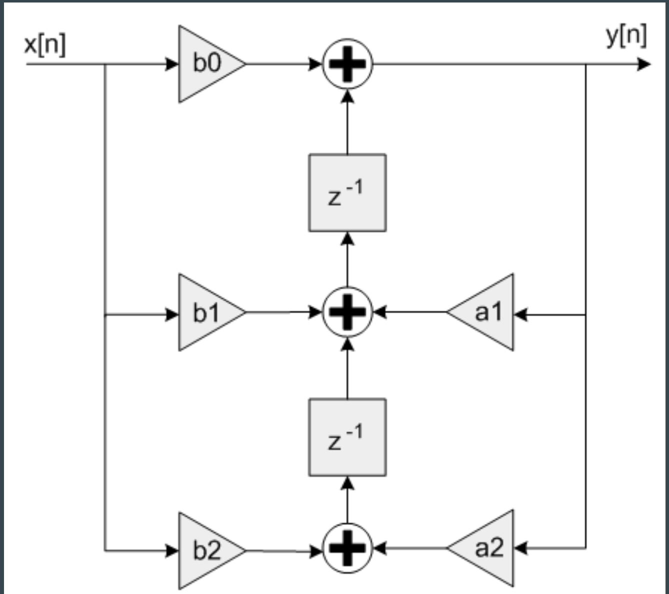


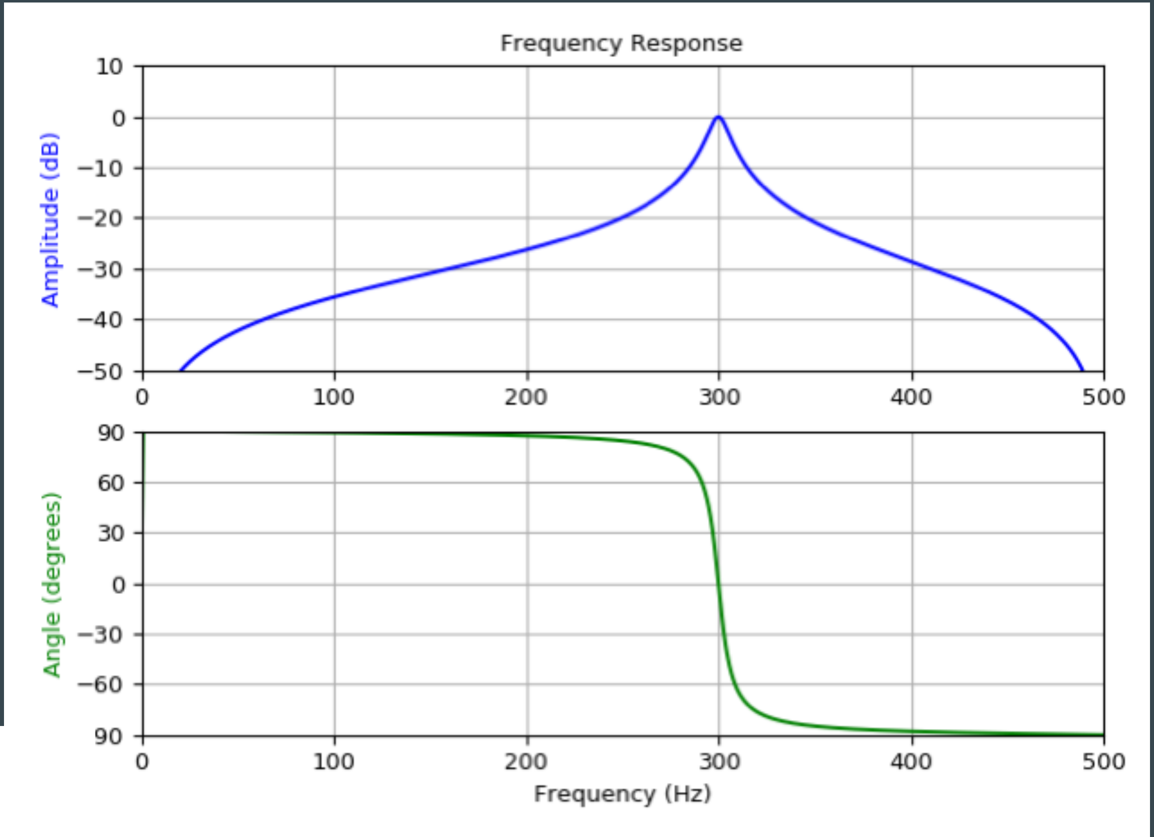
RLC Band-pass Filter





IIR Biquad Filter



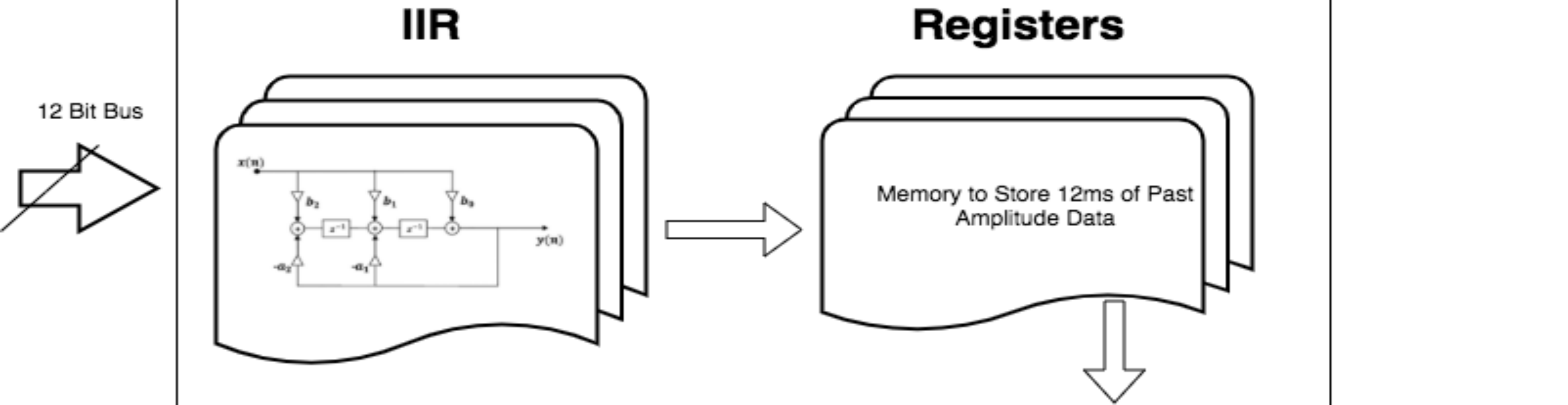


scipy.signal.iirpeak

scipy.signal.iirpeak(*w0, Q, fs=2.0***)**

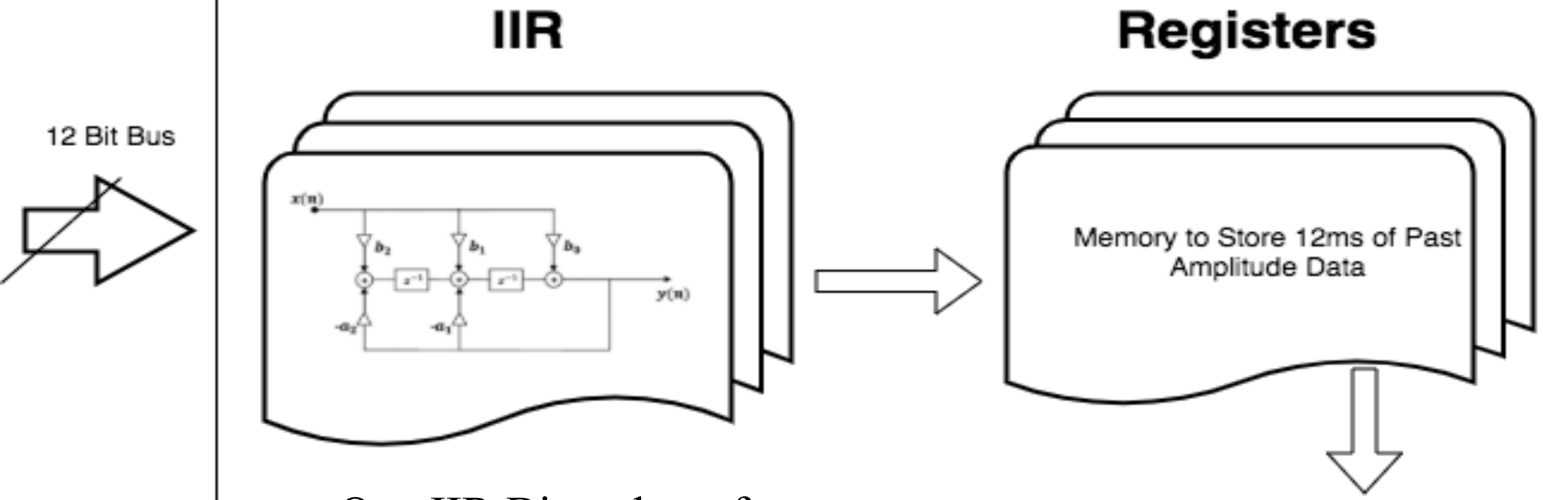
Design second-order IIR peak (resonant) digital filter.

The ideal frequency decoder...

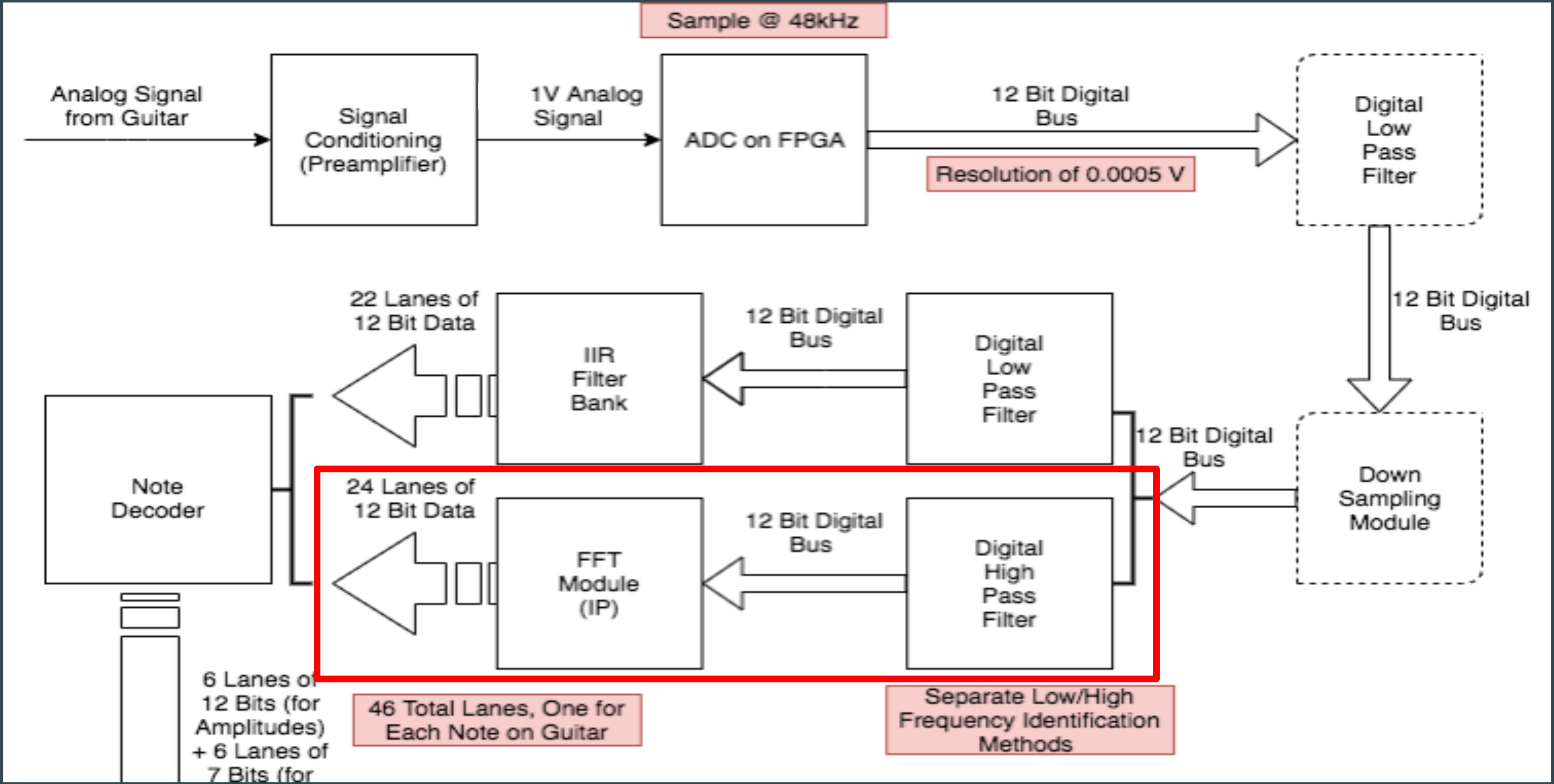


- One IIR Biquad per frequency
- Can capture a frequency in 12ms <u>max</u>

The ideal frequency decoder...



- One IIR Biquad per frequency
- Can capture a frequency in 12ms <u>max</u>
- First time using IIR filters, so will be a stretch goal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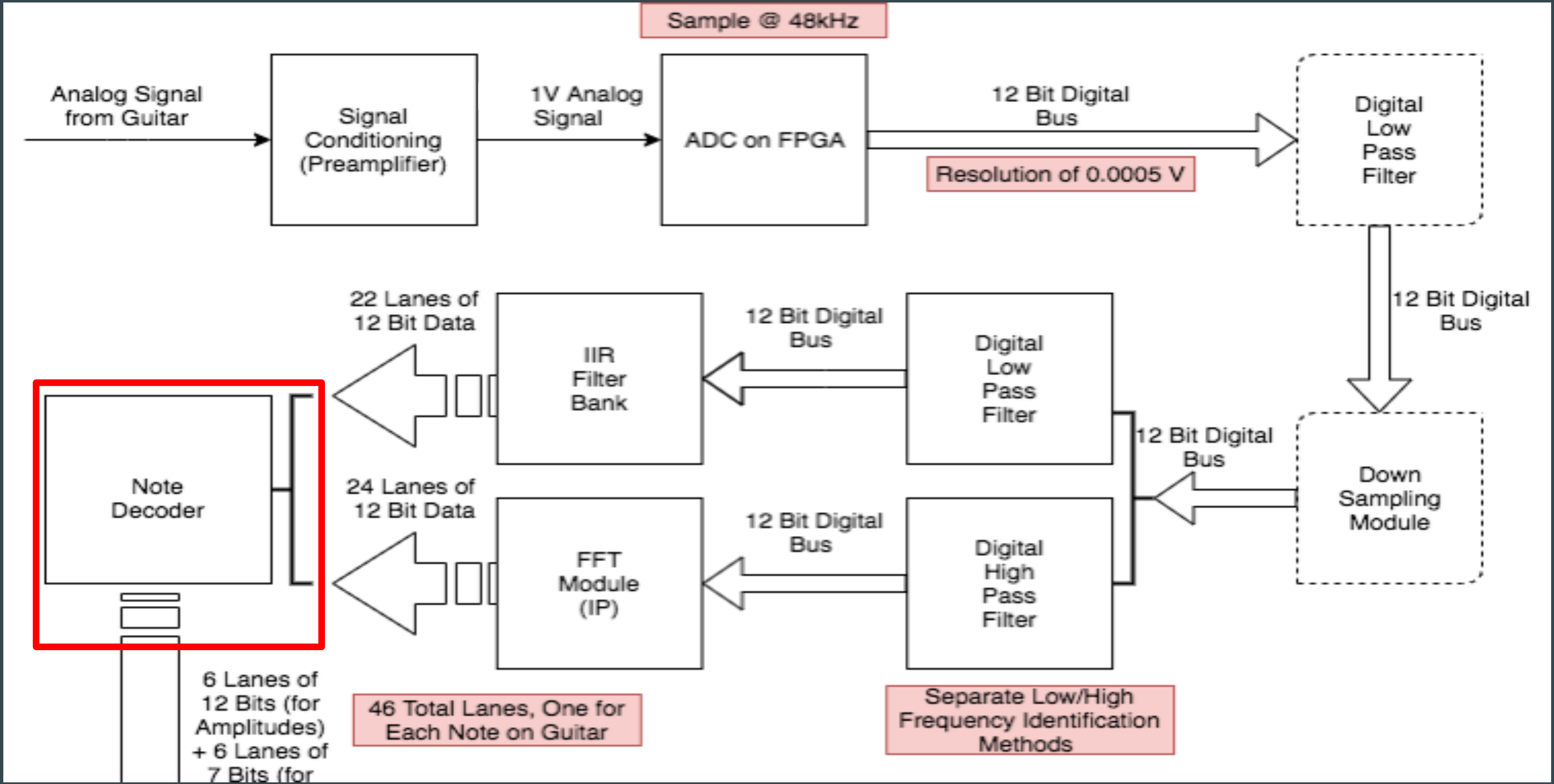
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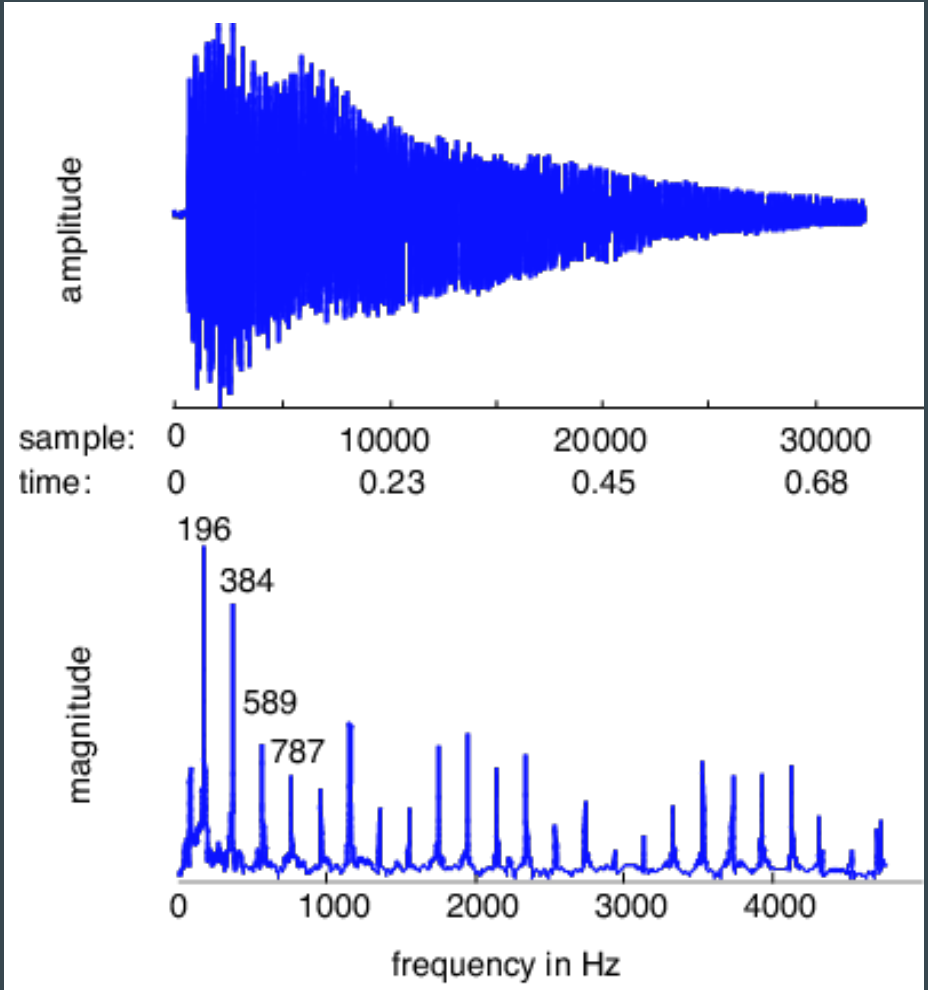
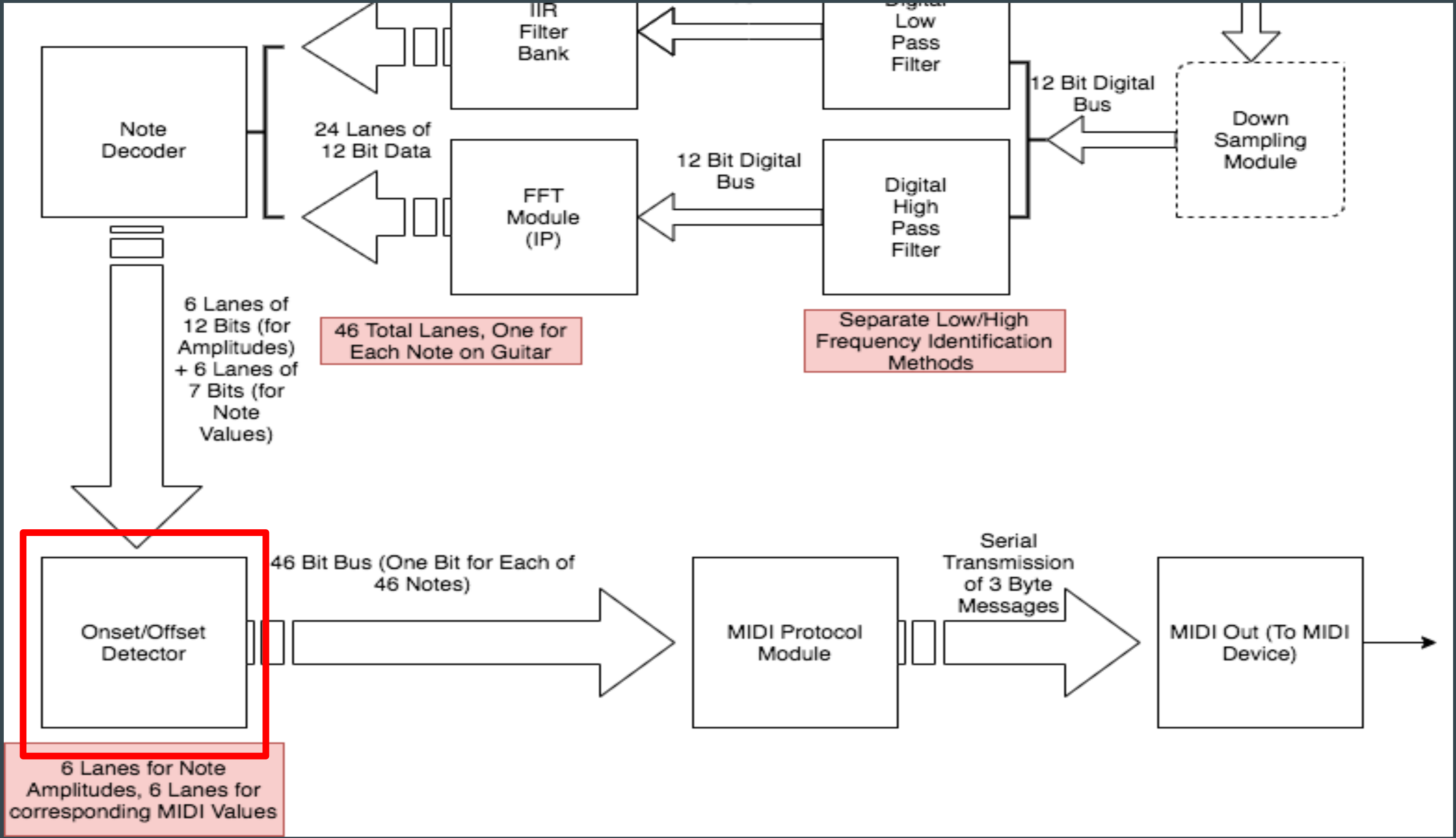
Note Decoder

- Every note is made of a fundamental and overtones

- We only care about the fundamentals (i.e. get rid of the overtones)

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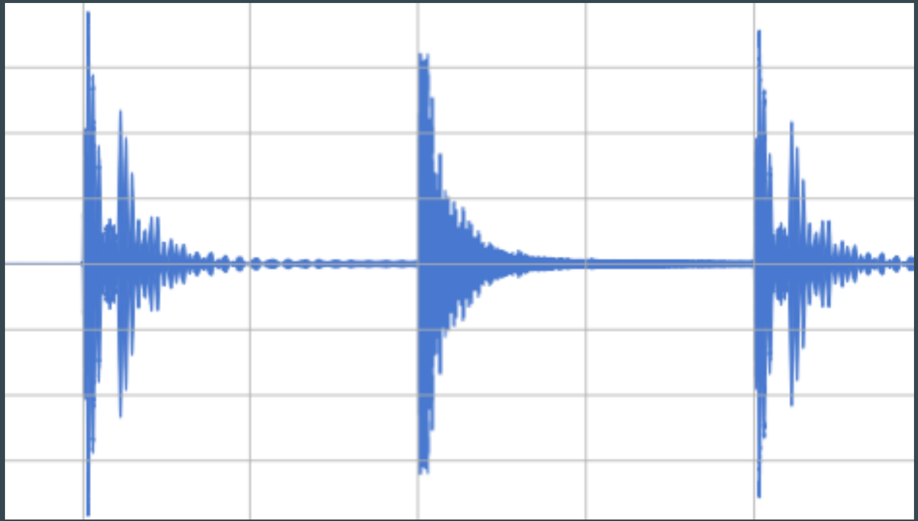
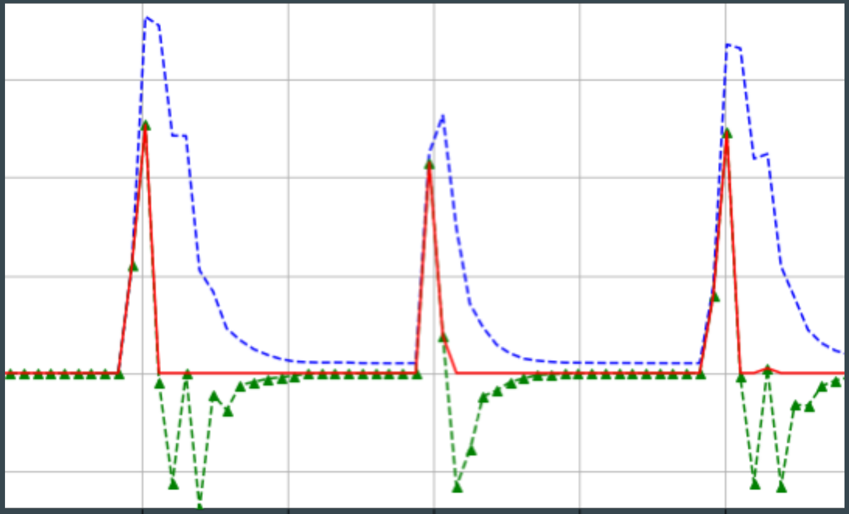
Onset/Offset Detector

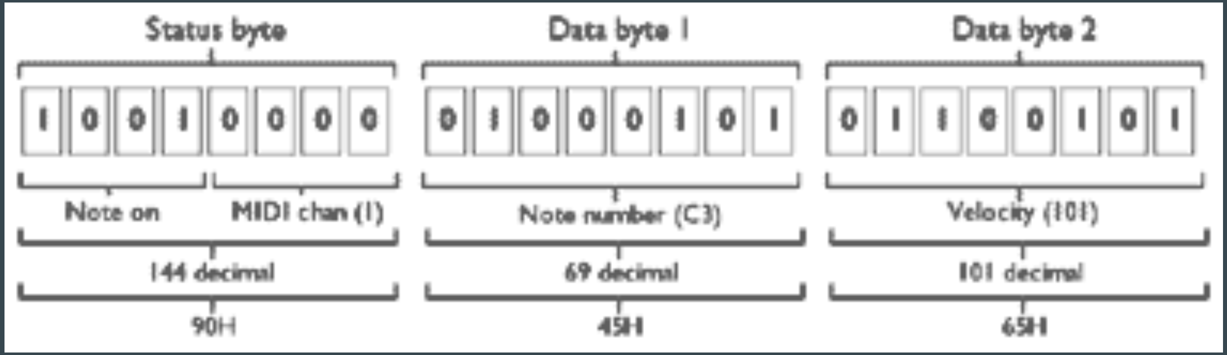
- Want to figure out when a note is played and not played
  - Detect **onsets** with spectral novelty function (as of now)
  - Detect **offsets** if amplitude crosses below certain threshold

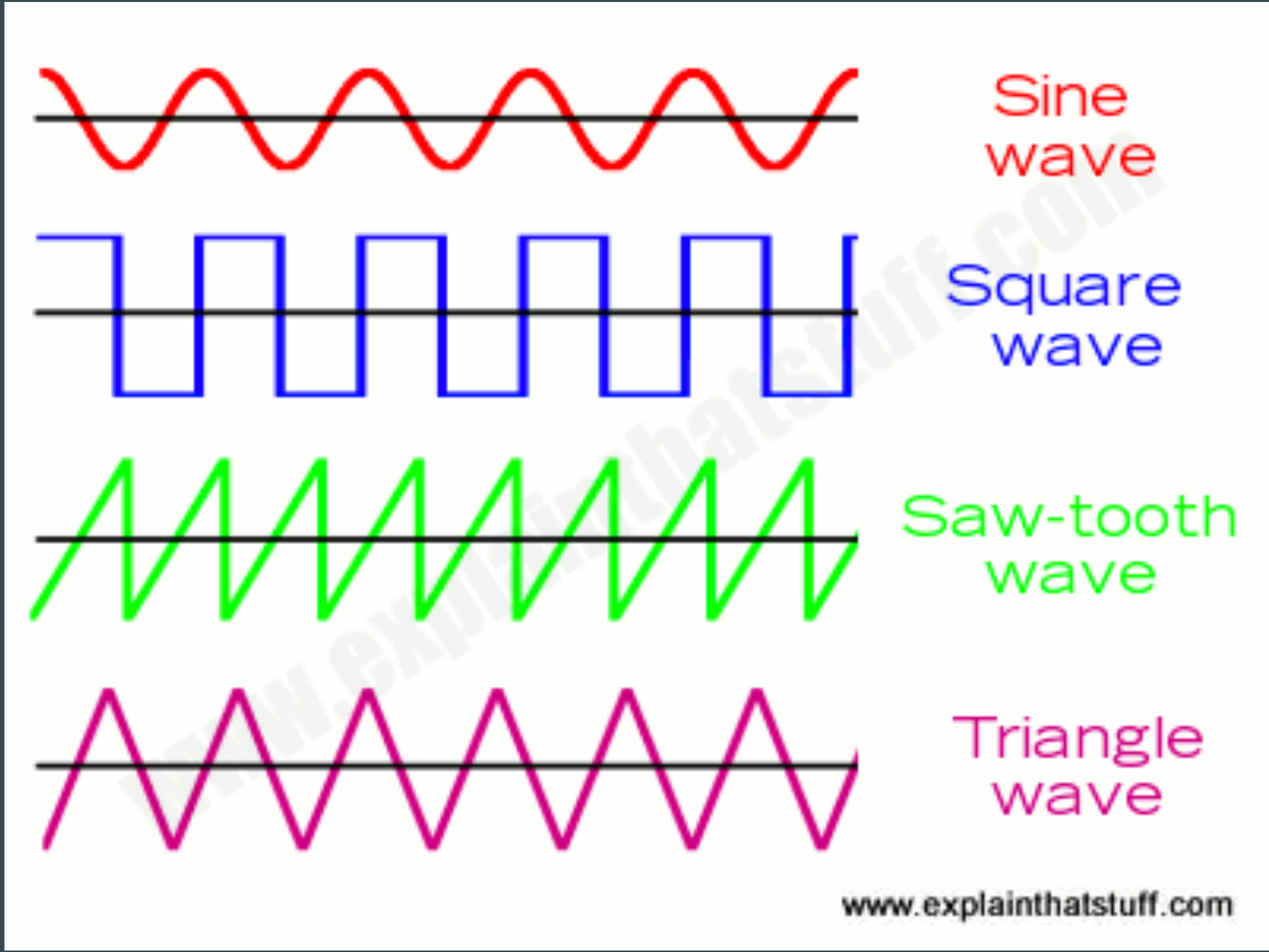




MIDI Module

- 31250 Baud
- 3 Byte Messages: 1 Status, 2 Data
  - Command: Note On/Off (128-255)
  - Data: Pitch, Loudness (0-127)




Sine wave
Square wave
Saw-tooth wave
Triangle wave
www.explainthatstuff.com

Timeline

- **Week 11/4-11/10:** Get Parts, Record guitar audio snippets, Python prototyping of DSP techniques
- **Week 11/11-11/17:** Analog input and sampling, MIDI verilog writing and testing, finish DSP prototyping
- **Week 11/18-11/24:** Downsampling verilog, port DSP modules into verilog
- **Week 11/25-12/1:** Integrate/Debug, Experiment with MIDI Output
- **Week 12/1-12/8:** Touch Up

Questions?