ECE313 Music & Engineering
MIDI

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Outline

- MIDI Overview
- MIDI Spec
  - Hardware
  - Protocol
    - Commands
    - Controllers
    - Channel Modes
    - System Exclusive
- MIDI Files

MIDI Hardware

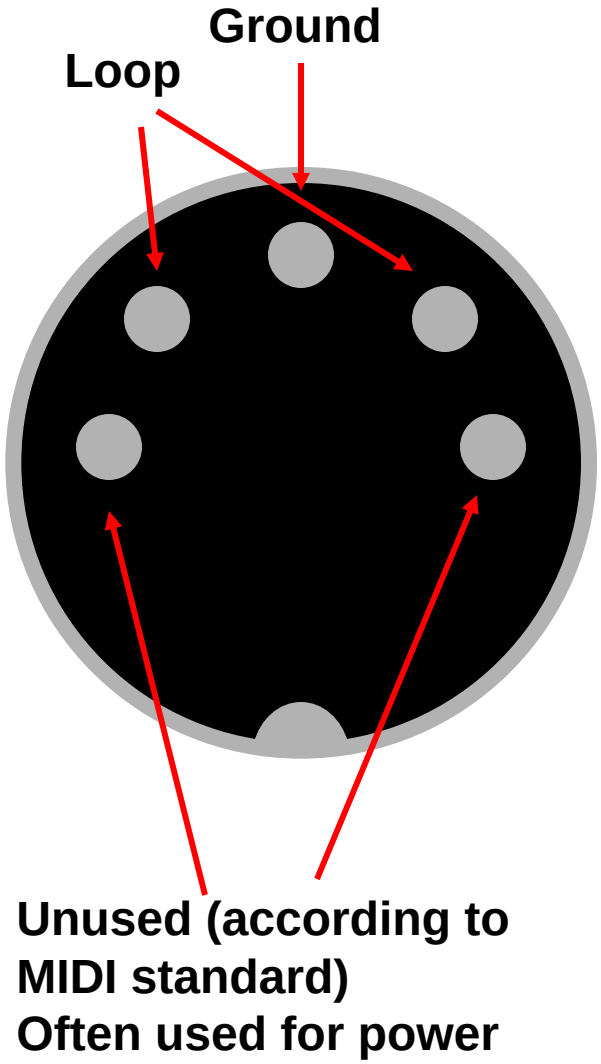
Pre-MIDI

- Since the early days of synthesizers, musicians have wanted to control multiple sound generators from one keyboard controller
- Before a digital interface was standardized, other things were attempted to send note information
  - CV & Gate
    - A control voltage was used to indicated the pitch (1 volt per octave – 83.33mV per semitone)
    - A control pulse (5 volts) was used to start the pitch
  - Problems
    - One voltage means the system is monophonic (single pitch only)
    - Voltage drops affects the pitch

MIDI

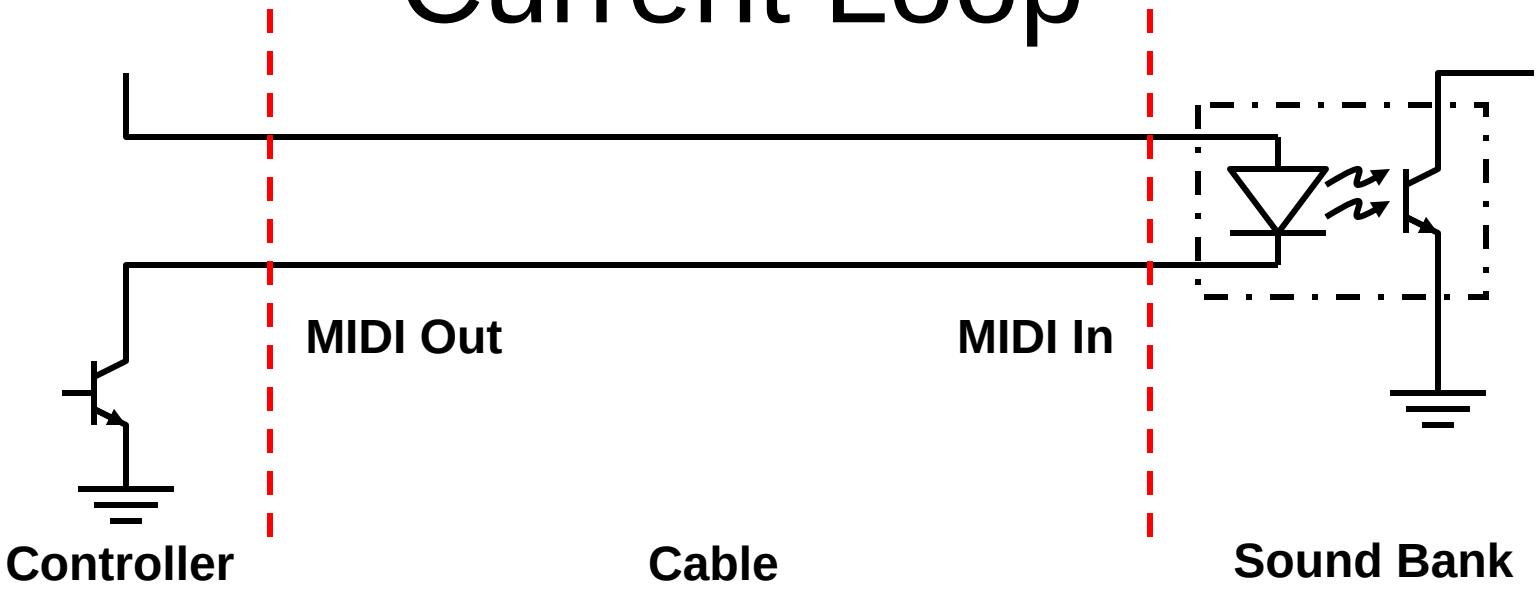
- MIDI = Musical Instrument Digital Interface
- A standardized way to connect instruments
  - synchronize two machines for live performance
  - Record musical performance information in a compact format (pre-hard disk recording)
    - Recording includes all performance information
      - Key pressed
      - Velocity
      - Pressure / After-touch
      - Foot Pedals / Controllers
  - Different Channels (up to 16 per cable) can separate different instruments.
- MIDI Spec
  - Mechanical / Electrical
  - Data Formatting

MIDI Cable



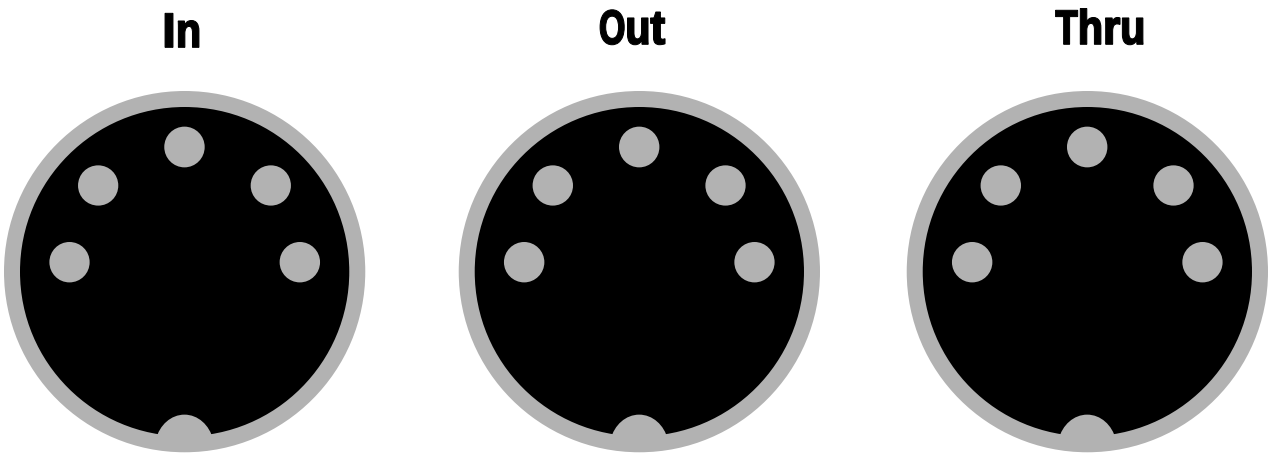
- Each MIDI cable is unidirectional.
  - It carries two conductors for uses a a current loop
  - Ground
  - Two unused pins
- Common Physical format
  - 5 pin 180^0 DIN
  - 15 meter limit

Current Loop



- Each MIDI cable includes
  - One current loop for transmitting data
    - Logical 0 is indicated by current on in the current loop
    - The current from the sending device drives the LED in the opto isolator in the receiving device.
  - Ground for shielding
    - Connected only to the transmitting controller
    - The ground is never connected to the receiving instrument.
    - No Ground Loops!
- Each Cable is good for one connection
- Active Devices are required to split MIDI signals or recombine them.

MIDI Connectors



- Traditionally MIDI devices included three MIDI connectors.
  - In – used to control the device – i.e. controls the device as a sound generator
  - Out – used to control other devices – i.e. use the device as a controller for other MIDI devices (in stead of or in addition to itself
  - Thru – an isolation copy of the In Port. This is an active repeater that allows chaining a controller's signal through multiple devices
- Some times the Thru and Out functionality is combined into a single port that can be programmed for either use.

MIDI devices

- Because of the physical format, and splitting or combination of signals requires active devices
  - Switchers – connects controllers to sound sources
  - Merge – combines signals from multiple inputs
  - Patch Bays – reconfigurable
    - Merges, splits, switches, etc
    - Programmable via USB
    - Ex. MOTU micro express
      - 4 Inputs
      - 6 Outputs

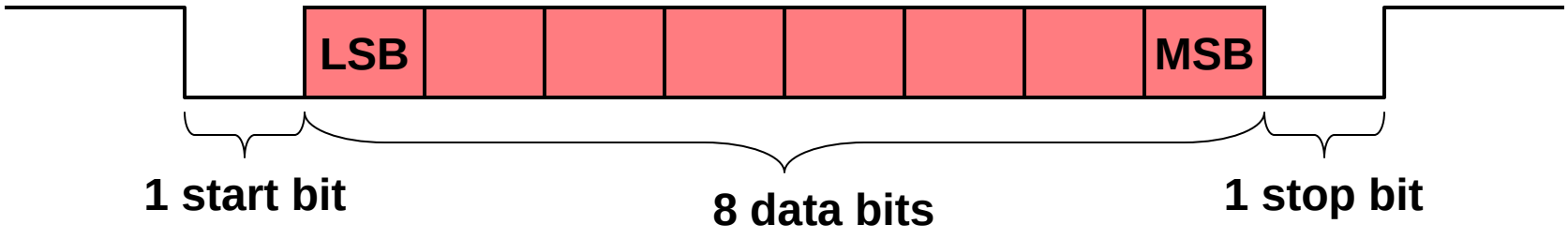
Wireless MIDI

- Available since the early 2000s
- Usually transmits in the 2.4 GHz band
  - Often uses Bluetooth
  - Available from m-audio, midiworks and others
- Likely proprietary
- Unfortunately debuted far after the peak of keytar usage, when they would have been most useful.

MIDI Data Format

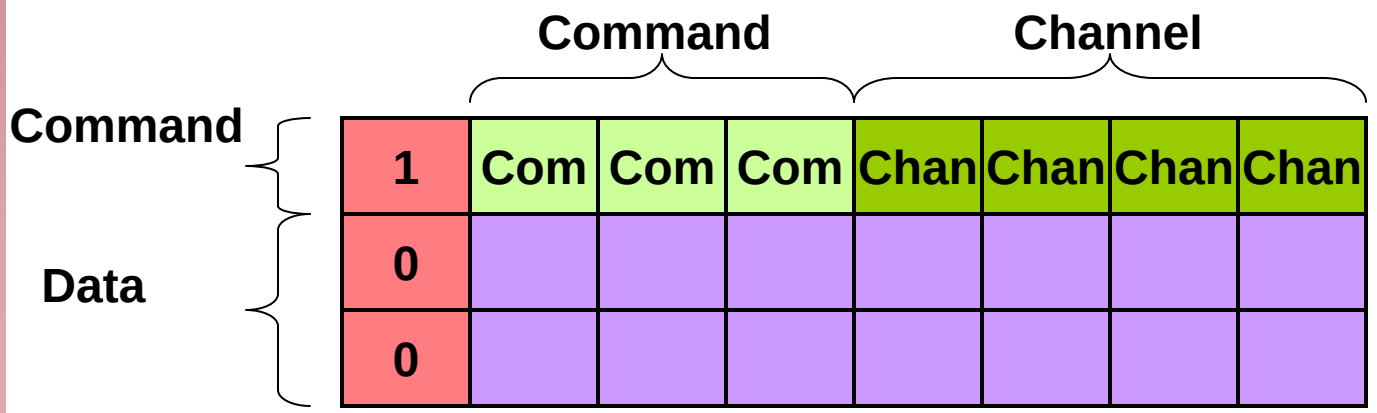
Serial Format

- The MIDI standard was defined in 19XX
- Originally designed to work with a common CDP 6402 Asynchronous UART controller by Harris
- Baud rate is 31,250
- 1 start bit, 8 data bits, 1 stop bit, no parity
- On the cable, the LSB is transmitted first.
  - (but for this presentation, we will display commands with MSB left)



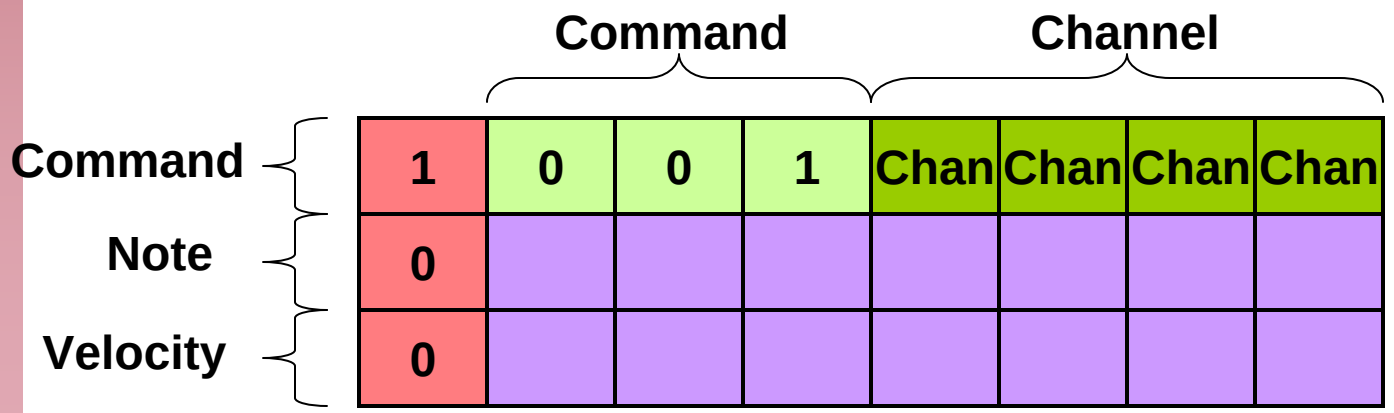
MIDI Protocol

- All commands are in groups of 2 or 3 bytes
  - Byte 1 is the Status or Command Byte
    - MSB = 1 (MSB=0 for data bytes)
    - Bits 6—4 determine the command
    - Bits 3—0 indicate the channel in use
  - Byte 2 is the first data byte
  - Byte 3 is the second data byte (if included – per command)



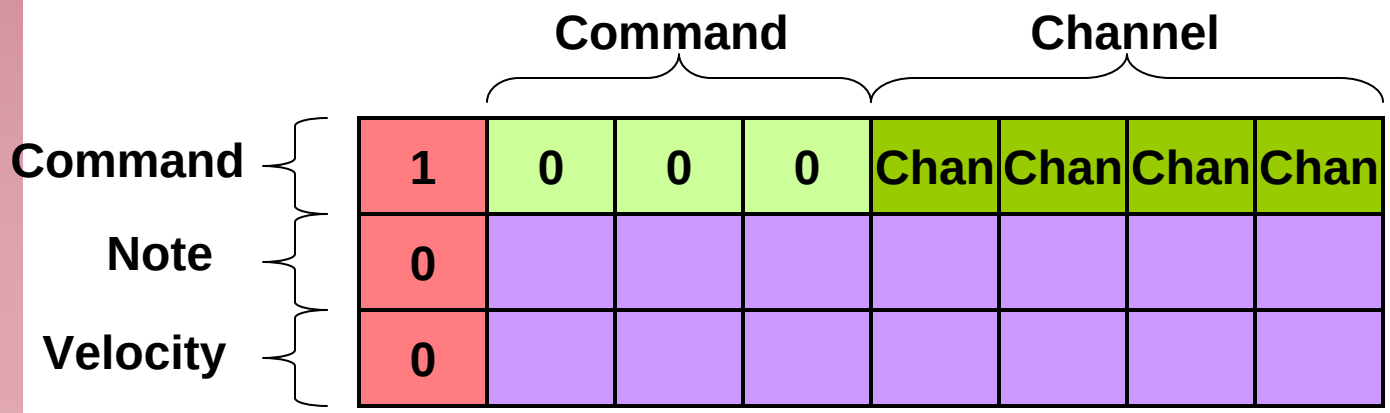
Note On

- The most common command is “Note On”
- This command initiates (or terminates) a note
- Includes 2 parameters
  - First data byte = Note Values (0-127)
  - Second data byte = Velocity (0-127)

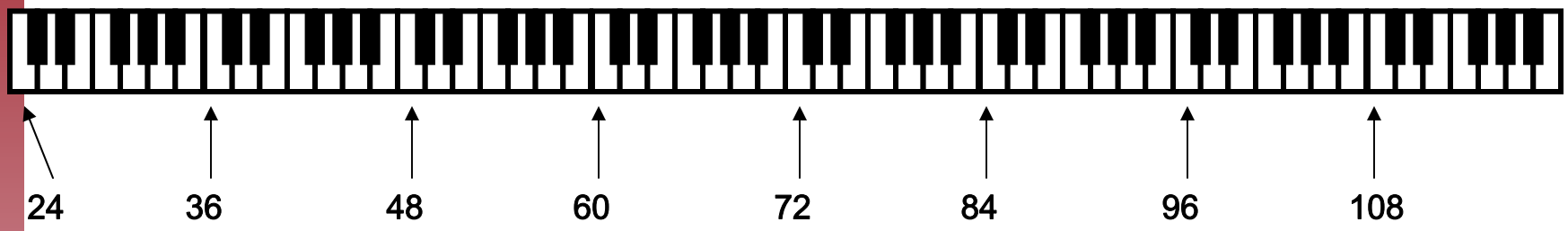


Note Off

- The companion to “Note On” is “Note Off”
- This command terminates a note
- Includes 2 parameters
  - First data byte = Note Values (0-127)
  - Second data byte = Velocity (0-127)
    - Used to indicate the release velocity
- An alternative to the Note Off command is to send a “Note On” command with Velocity = 0

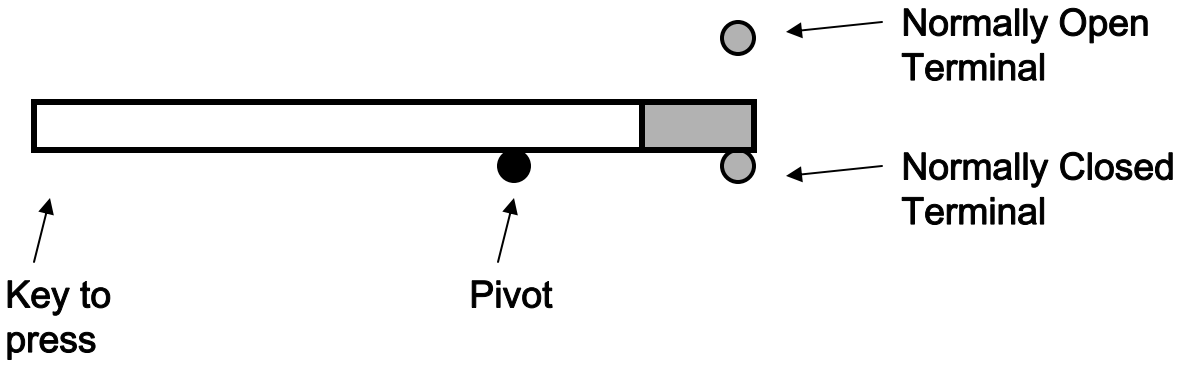


MIDI Note Numbers



- MIDI notes are defined for the Piano keyboard plus roughly 2 octaves above and below
- Middle C = 60 (decimal)
- Only defined for equal temperament – enharmonics are equal

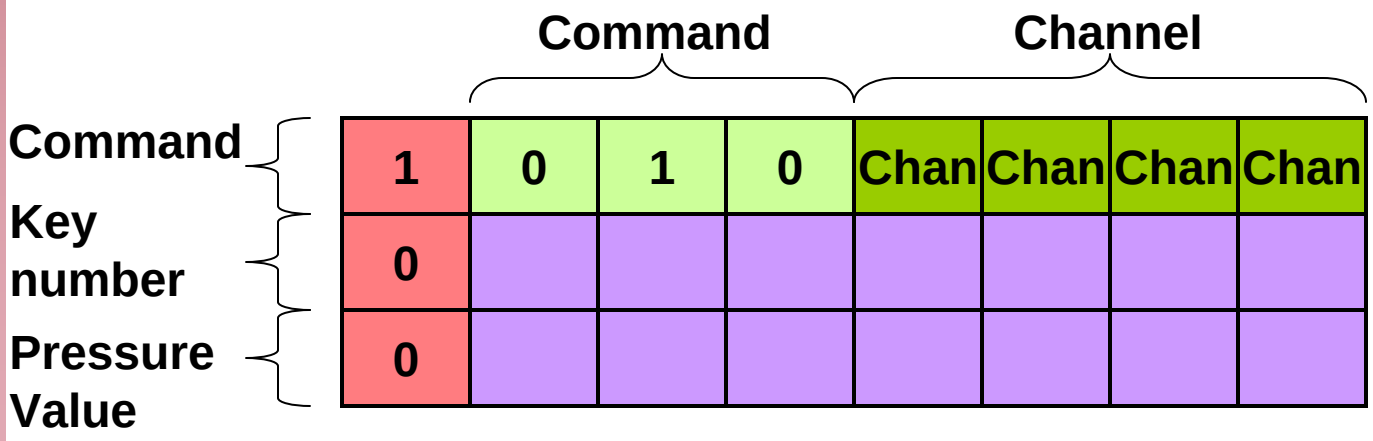
Velocity



- The Velocity data byte gives a measure of how hard the key is initially pressed
- The velocity is measured as the time the end of the takes to move from the normally closed terminal to the normally open terminal
- Values range from 0 to 127
  - 0 is reserved to be the same as Note Off

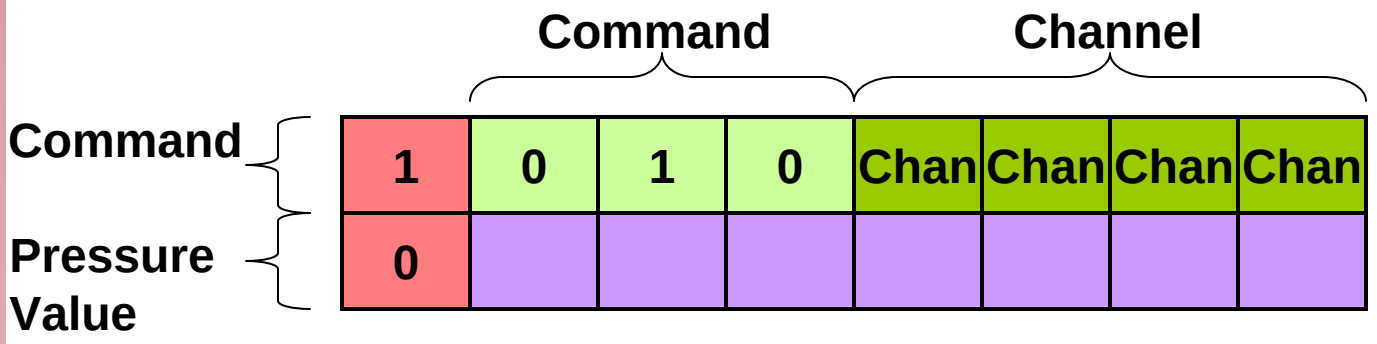
Polyphonic Key After-touch

- Some controllers include after touch for conveying information after the key has been pressed.
- After touch measures pressure
- Only available in some controllers
- Useful for simulating wind instruments
- Applies to a specific key



Channel After-touch

- In addition to after touch on specific keys, there is also a channel after touch.
- One pressure command given as a average of all keys
  - Requires less data throughput (which is good since MIDI is extremely limited)

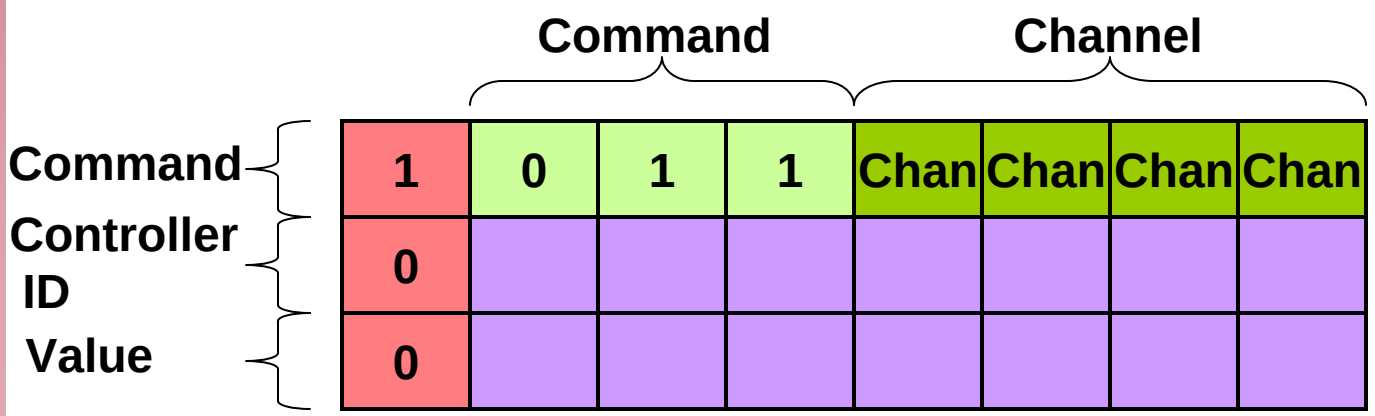


Controllers

- In addition to note information, MIDI also specifies controllers
- Controllers are used to control “expressivity”
  - e.g. sustain or damper pedal on a piano
  - Volume or modulation
- Affects all notes on the channel.

Controller Command

- The Controller command includes 3 bytes
  - The command byte that specifies the channel
  - The Controller ID that specifies the Controller
  - The Value field that gives the 7 bit MSB or LSB
- Many Controllers have 2 bytes, LSB & MSB
  - The LSB is located 0x20 above the MSB
    - E.g. Mod wheel MSB is 0x01 & Mod Wheel LSB is 0x21
    - Allows for 16384 gradations.
- Some controllers (originally 64—69 decimal), were binary only
  - For binary controllers 0x00 – 0x3F = off
  - 0x40 – 0x7F = on

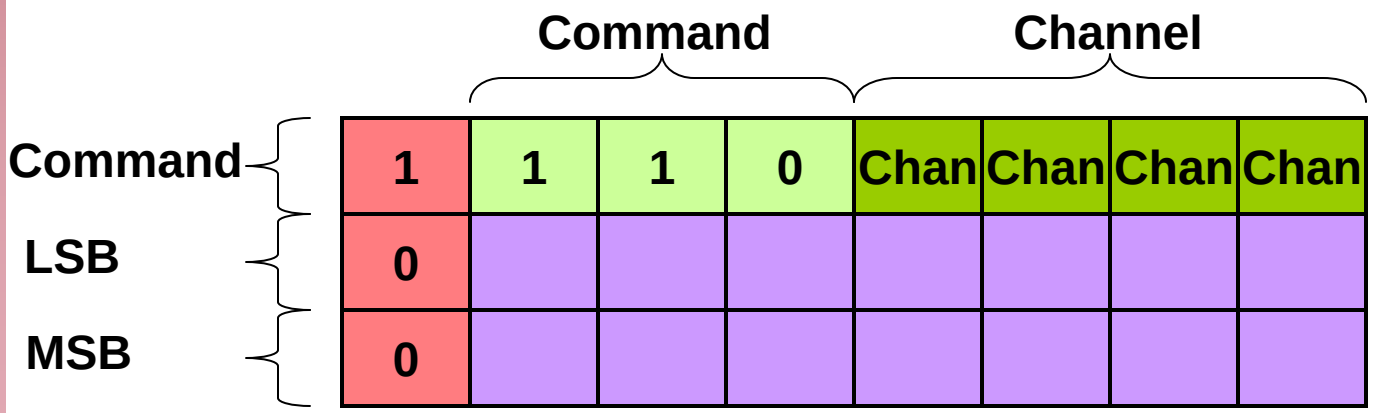


Common Controllers

Controller Number	Controller Name
0	Bank Select MSB
1	Modulation wheel
2	Breath controller
4	Foot controller
5	Portamento time
6	Data entry
7	Main Volume
64	Damper Pedal (sustain)
65	Portamento on/off

Pitch Bend

- One controller is so common, it gets its own special command
- The Pitch Bend command include the MSB and LSB
  - Gives a possible 16384 gradations
  - Many older keyboards only use MSB
    - For +/- 1 whole step bends, 128 gradations gives about 1/5 of a semi-tone.



Aside: How Much Pitch Bend?

- The question remains, how much Pitch Bend is in the pitch bend stick?
- To answer this, we look at Registered and Non-Registered Parameter Numbers
  - Registered Parameter Numbers are defined in the MIDI standard with standard addresses
  - Non-Registered Parameter Numbers are device specific and must be called out in the users manual
- Constructed as a series of Controller commands
  - Controllers 98 & 99 are used to specify the address for NRPNs
  - Controllers 100 & 101 are used to specify the address for RPNs
  - Controller 6 is used to program the MSB data
  - Controller 38 is used to program the LSB data
  - Controller 96 and 97 can be used for increment and decrement (respectively)

Example: Programming Pitch Bend

Command	1	0	1	1	Chan	Chan	Chan	Chan	
NRPN MSB	0	1	1	0	0	1	0	0	RPN 0/0 is pitch bend range
MSB Val	0	0	0	0	0	0	0	0	
Command	1	0	1	1	Chan	Chan	Chan	Chan	
NRPN LSB	0	1	1	0	0	1	0	1	
LSB Val	0	0	0	0	0	0	0	0	
Command	1	0	1	1	Chan	Chan	Chan	Chan	
Value MSB	0	0	0	0	0	1	1	0	
MSB Val	0	0	0	0	0	0	1	0	2 semitones
Command	1	0	1	1	Chan	Chan	Chan	Chan	
Value LSB	0	0	1	0	0	1	1	0	
LSB Val	0	0	0	0	0	0	0	0	0 1/100ths of a semitone

Running Status

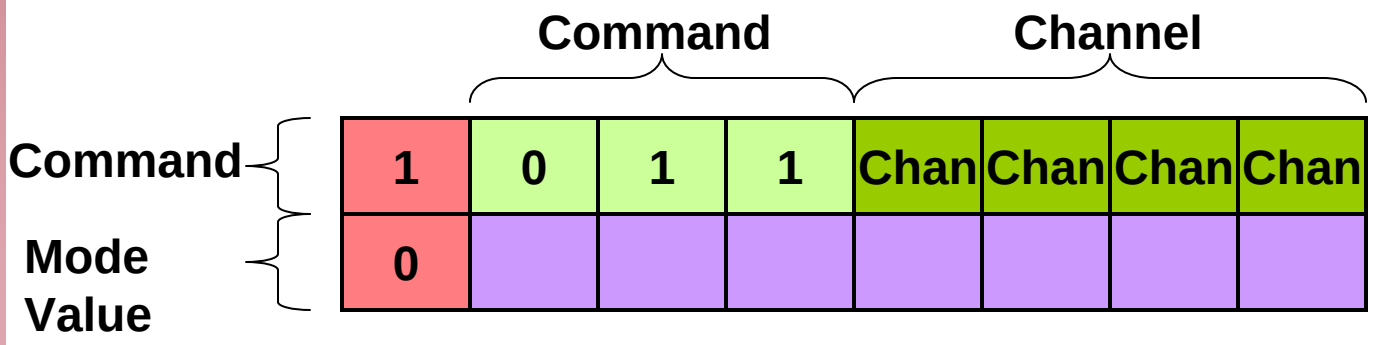
- When the same command is repeated, there is an option in the MIDI standard to use what is called “Running Status”
- Remember that the first byte is called the status or command byte
- This is especially useful for long strings of fast notes
  - Only the note value and velocity need to be given.
  - Remember Velocity = 0 is the same as Note off.

Example: Programming w/ Running Status

Command	1	0	1	1	Chan	Chan	Chan	Chan
NRPN MSB	0	1	1	0	0	1	0	0
MSB Val	0	0	0	0	0	0	0	0
NRPN LSB	0	1	1	0	0	1	0	1
LSB Val	0	0	0	0	0	0	0	0
Value MSB	0	0	0	0	0	1	1	0
MSB Val	0	0	0	0	0	0	0	1
Value LSB	0	0	1	0	0	1	1	0
LSB Val	0	0	0	0	0	0	0	0

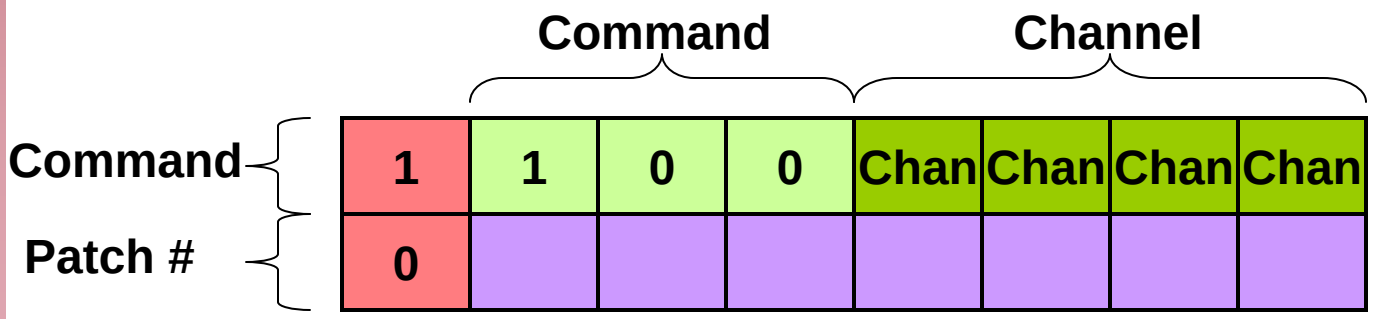
Channel Modes

- In MIDI instruments, there are a number of channel modes.
  - Omni – the instrument responds to commands on any channel
  - Polyphonic – the instrument can create more than one pitch at a time. (up to some internal limit)
  - Monophonic – the instrument should only create one pitch at a time.
- These indicate how the instrument is to respond to input
  - Omni On – 0xBn 0x7D
  - Omni Off – 0xBn 0x7C
  - Poly On – 0xBn 0x7F
  - Mono On – 0xBn 0x7E
  - All notes off – 0xBn 0x7B
  - All sounds off – 0xBn 0x78



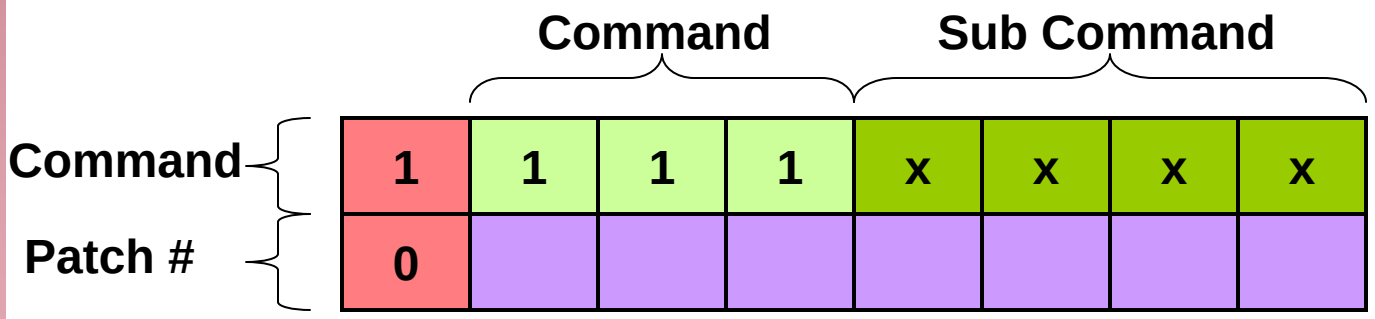
Patch Change

- Patch Changes tell the instrument to change settings.
- Typically this means instrument sounds, but it could also included effects settings.
  - Some rack mount guitar or vocal effects processors use patch changes to control banks of effects, even though they don't respond to MIDI note commands
- The lower ground of patches has been standardized as "General MIDI"
  - This makes it easier to control instruments remotely.
  - Grand Piano is Patch 0



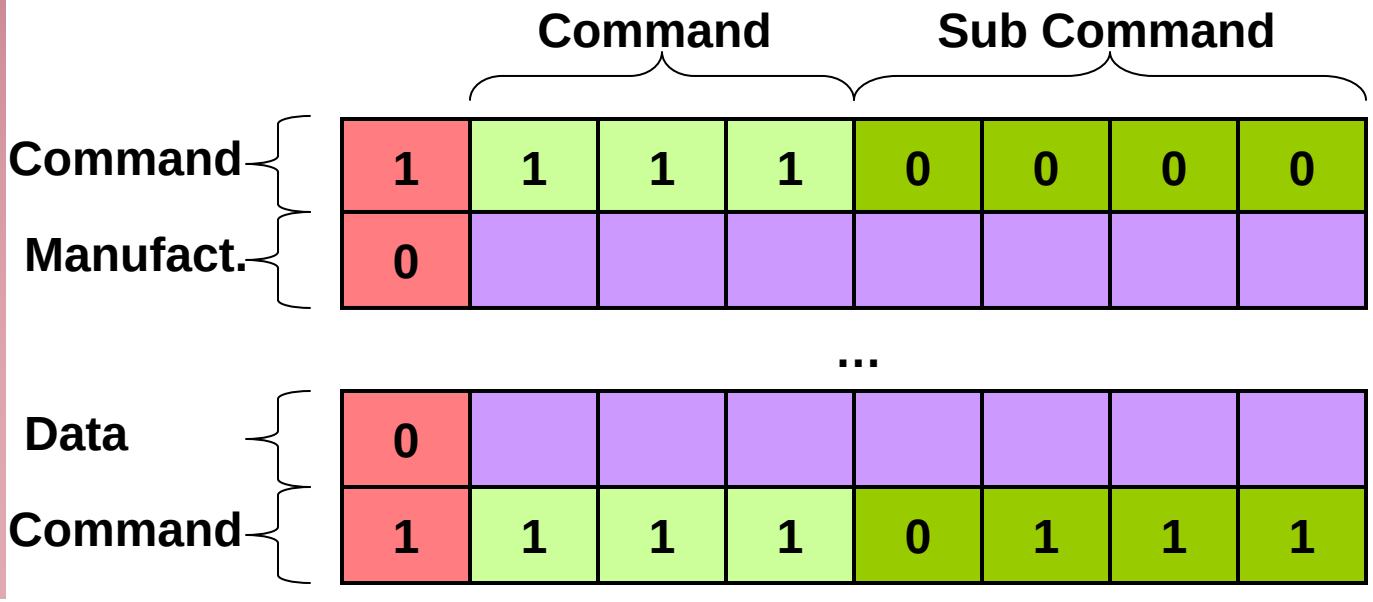
System Commands

- Certain commands take no channel information
- These are the system level commands
- Example
  - F1 used in MIDI Time Code
  - F2 Song Position Pointer
  - F3 Song Select



System Exclusive

- In addition to the standard System Level commands, there is also a facility for proprietary commands
- The System Exclusive commands begins with an 0xF0 command and doesn't end until a 0xF7 command is received
- What comes between the start and stop is up to the manufacturer
- The first byte after the initial system exclusive command is the Manufacturer ID – must be obtained from MIDI STD Organization



Standard System Exclusive

- As System Exclusive became more popular, standard system exclusive manufacturer IDs were added
  - 0x7E – Non Real Time parameters
  - 0x7F – Real Time Parameters
- Example
  - Consider the following Command String:
    - 0xF0 0x7E 0xNN 0x06 0x01 0xF7
      - Where
        - » NN is the channel number
      - This is the device query command
  - A possible response is the following:
    - 0xF0 0x7E 0xNN 0x06 0x02 0xID 0xLF 0xMF 0xLM 0xMM 0xRV 0xRV 0xRV 0xF7
      - Where
        - » NN is the channle number
        - » ID is the Manufacturer ID
        - » LF is the LSB of the Family Code
        - » MF is the MSB of the Family Code
        - » LM is the LSB of the Member Code
        - » MM is the MSB of the Member Code
        - » RV specifies the Version Revision

System Exclusive

- System Exclusive messages can be used to program patch settings, which can be called later via the Patch Change command
- SysEx messages are often used for
  - File Dumps
  - Sample Dumps
    - Very very slow at MIDI rates

Sequencing

- While hard disk recording is relatively new, MIDI sequencing has been common for decades
- Use a device to record & playback MIDI commands
  - Previously common stand alone, now usually a PC
  - Can change key or tempo later
- Ports
  - In – used for recording
  - Out – acts as a Thru during recording, acts as an output for playback
- Controls
  - Typically styled after tape machines
- Integration
  - Now, usually integrated with hard disk recording software
    - Pro Tools – HD recording with sequencing added
    - CuBASE – sequencing with HD recording added
- Visual Formatting
  - Piano Roll
  - Conventional Music
  - Text Event List
- Quantization
  - Align notes to a grid

MIDI Files

MIDI Files

- Midi files typically carry the .MID extension
- They make use of the MIDI standard including possibly using
  - Running Status
  - SysEx messages
- There are 3 types of MIDI files
  - 0 = One Multi Channel Track (always 1 track)
  - 1 = One or More Simultaneous tracks (where each track is linear and should be combined with the others – this is the most common type)
  - 2 = One or More sequences of independent tracks

MIDI file chunks

- All data is sent in chunks
  - First part of the chunk is a four byte ASCII Description
    - MThd = header chunk
    - MTrk = track chunk
  - Next in the chunk is a four byte length
  - The remainder of the Chunk is data
- Header
  - [MThd -4 bytes] [Length -4 bytes] [file format – 2 bytes] [# of tracks – 2 bytes] [pulses per quarternote (ppq) – 2 bytes]
    - Pulses per quarter not is used in the track information to determine the number of clock ticks in a quarter note
- Track Information
  - Typically the first track includes information about the music
  - All tracks are simply a time stamp followed by a MIDI command
  - [MTrk – 4 bytes] [Length – 4 bytes] [delta time since last event – variable] [event – 2 or 3 bytes]

Non-MIDI events (meta events)

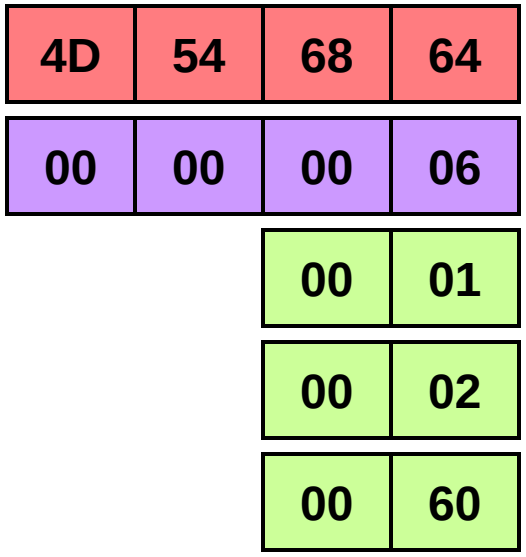
- Additional non-MIDI events are embedded in the file with FF command
- Format
  - FF [type_#] [length] [fields]
  - Types
    - 00 = sequence number
    - 01 = ASCII text message (lyric)
    - 02 = copyright notice
    - 03 = sequence / track name
    - 04 = instrument name
    - 05 = lyric
    - 06 = song marker
    - 07 = cue point
    - 20 01 cc = MIDI channel reference for SysEx or meta events
    - 2F 00 = end of track
    - 51 03 tt tt tt = temp in (us/ppqn)
    - 54 05 hh mm ss ff sf = SMTPE offset
    - 58 04 NN DD CC BB
      - NN = numerator of the time signature
      - DD = denominator of the time signature (as a power of two – ex. 4/4 -> DD=2)
      - CC = the number of MIDI clicks per metronome beat
      - BB – the number of notated 32nd notes per quarter note
    - 59 02 SF KK
      - SF = Number of sharps (positive numbers) or number of flats (negative)
      - KK = Key (0 for major, 1 for minor)
    - 7F length data – sequencer specific

Extended Lengths

- As mentioned above, in MTrk chunks, the format is a length followed by a MIDI command
- How long is the length?
  - Can be as short as one byte
  - Can be longer
- Encoding
  - The last byte of the length has bit 7 = 0
  - All other bytes should have bit 7 = 1
  - The total length is computed from only the 7 least significant bits of the byte
  - Ex. 0x83 0x00
    - = 1 000 0011 0 000 0000
    - Eliminated in the 7th bit from each
      - gives 0000011 000000
      - This equals 384
        - » Given PPQ = 96 this is a whole note

Example File

- From Music Technology Reference Book
- Segments within the chunk drawn for clarity



MThd

Length = 6 bytes

MIDI File Format = 1
(Multi Track Synchronous)

2 tracks total

96 ppqn

Example File (cont)

4D	54	72	6B				
00	00	00	1A				
00	FF	58	04	04	02	18	08
00	FF	51	03	07	A1	20	
00	C0	05					
00	91	3C	64				
60	91	3C	00				
00	FF	2F					

MTrk

Length = 26 bytes

Time Signature = 4/4,
24 clicks per metronome beat,
8 32nd note beats in a quarter note

500,000 uSec per ppq = 120 BPM

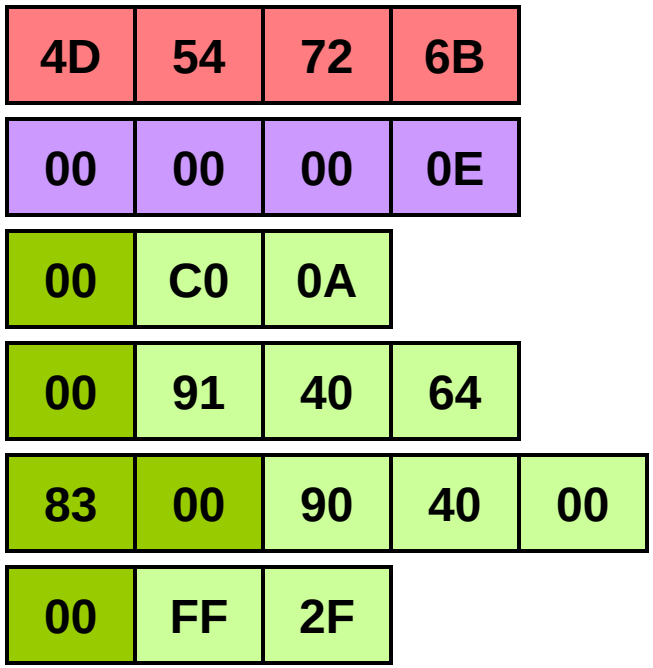
Change to path 5 @ time zero

Note On = C3 Velocity = 100

Note On = C3 Velocity = 0
(note off ¼ note later

End of Track

Example File (cont)



MTrk

Length = 26 bytes

Change to path 10 @ time zero

Note On = E3 Velocity = 100

Note Off = E3 Velocity = 0
note off one whole note later

End of Track

Example File A

- Can you name that tune?

```
4D 54 68 64 00 00 00 06 00 01 00 04 00 F0 4D 54
72 6B 00 00 00 13 00 FF 58 04 04 02 18 08 00 FF
51 03 09 27 C0 00 FF 2F 00 4D 54 72 6B 00 00 00
D6 00 FF 03 05 76 6F 63 61 6C 00 C0 34 00 90 3C
50 81 40 80 3C 40 30 90 3C 50 81 40 80 3C 40 30
90 3C 50 81 10 80 3C 40 24 90 3E 50 30 80 3E 40
0C 90 40 50 81 40 80 40 40 30 90 40 50 81 10 80
40 40 24 90 3E 50 30 80 3E 40 0C 90 40 50 81 10
80 40 40 24 90 41 50 30 80 41 40 0C 90 43 50 83
00 80 43 40 60 90 48 50 81 10 80 48 40 24 90 48
50 30 80 48 40 0C 90 43 50 81 10 80 43 40 24 90
43 50 30 80 43 40 0C 90 40 50 81 10 80 40 40 24
90 40 50 30 80 40 40 0C 90 3C 50 81 10 80 3C 40
24 90 3C 50 30 80 3C 40 0C 90 43 50 81 10 80 43
40 24 90 41 50 30 80 41 40 0C 90 40 50 81 10 80
40 40 24 90 3E 50 30 80 3E 40 0C 90 3C 50 83 00
80 3C 40 00 FF 2F 00 4D 54 72 6B 00 00 00 6F 00
C1 00 83 60 91 43 50 00 91 40 50 00 91 3C 50 83
00 81 3C 40 00 81 40 40 00 81 43 40 84 40 91 3C
50 00 91 40 50 00 91 43 50 83 00 81 43 40 00 81
40 40 00 81 3C 40 84 40 91 3C 50 00 91 40 50 00
91 43 50 83 00 81 43 40 00 81 40 40 00 81 3C 40
84 40 91 3C 50 00 91 40 50 00 91 43 50 83 00 81
43 40 00 81 40 40 00 81 3C 40 00 FF 2F 00 4D 54
72 6B 00 00 00 6B 00 91 37 50 00 91 34 50 00 91
30 50 86 00 81 30 40 00 81 34 40 00 81 37 40 81
40 91 30 50 00 91 34 50 00 91 37 50 86 00 81 37
40 00 81 34 40 00 81 30 40 81 40 91 30 50 00 91
34 50 00 91 37 50 86 00 81 37 40 00 81 34 40 00
81 30 40 81 40 91 30 50 00 91 34 50 00 91 37 50
86 00 81 37 40 00 81 34 40 00 81 30 40 00 FF 2F
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
```

Example A Decode

4D 54 68 64 -> M T h d - Start of the header chunk
00 00 00 06 -> header hunk length
00 01 -> MIDI file format 1
00 04 -> Number of tracks
00 F0 -> 240 ppqn

4D 54 72 6B -> M T r k
00 00 00 13 -> length = 19 bytes
00 FF 58 04 04 02 18 08 - > @ time zero - FF 58 04 is the time sig - 04 02 means 4/4 -
18 = number of MIDI clicks per metronome beat - 08 32nd beats per quarter
00 FF 51 03 09 27 C0 -> @ time zero - FF 51 03 is the temp - 09 27 C0 = 600,000 uSec per quarter note =
60/tttttt = 100 bpm
00 FF 2F 00 -> FF 2F 00 is the mandatory end of track
^^ length field

SPOILER NOTES (conventions used in this file – determined by evalutation)

divide 240 by 5 = 48.
This is the time of a "breath" - remainder of beat for note
for a 16th note, the total is 64 pulses - 48 for note and 12 for "breath"
dotted eighth would be 180 - 144 for note or 36 for breath
1/2 note = 384 / 96
1/4 note = 192 / 4

Example A Decode (cont)

4D 54 72 6B -> M T r k
00 00 00 D6 -> length = 214 bytes
00 FF 03 05 76 6F 63 61 6C -> FF 03 = Track name = "vocal"
00 C0 34 -> @ time zero - patch change to 52 - Choir Aahs
00 90 3C 50 -> note on channel 1 C3 - Middle C - Velocity = 80 (1st beat of Measure 1)
81 40 80 3C 40 -> note off channel 1 C3 Velocity = 64, 192 pulses later - 1/4 note
30 90 3C 50 -> note on channle 1 C3 Vel=80, 48 pulses later (2nd beat of Measure 1)
81 40 80 3C 40 -> note off chan 1 C3 vel=64, 192 pulses later - 1/4 note
30 90 3C 50 -> note on chan1 C3 vel=80, 48 pulses later (3rd beat of Measure 1)
81 10 80 3C 40 -> note off chan 1 C3 vel=64 - 144 pulses later - dotted 1/8 note
24 90 3E 50 -> note on chan 1 D3 vel=80 - 36 pulses later (180 pulses after the beat - on the Ah 16th note)
30 80 3E 40 -> note off chan 1 D3 vel=64 - 48 pulses later (228 pulses after the beat) - 16th note
0C 90 40 50 -> note on chan 1 E3 vel=80 - 12 pulses later (4th beat of Measure 1)
81 40 80 40 40 -> note off chan 1 E3 vel=64 - 192 pulses later - 1/4 note
30 90 40 50 -> note on chan 1 E3 vel=80 - 48 pulses later (1st beat of Measure 2)
81 10 80 40 40 -> note off chan 1 E3 verl=64 - 144 pulses later - dotted 1/8 note
24 90 3E 50 -> note on chan1 D3 vel=80 - 36 pulses later (180 pulses after last beat - Ah 16th note)
30 80 3E 40 -> note off chan1 D3 vel=64 - 48 pulses later - 16th note
0C 90 40 50 -> note on chan1 E3 vel=80 - 12 pulses later (2nd beat of Measure 2)
81 10 80 40 40 -> note off chan1 E3 vel=64 - 144 pulses - dotted 1/8 note
24 90 41 50 -> note on F3 - 36 pulses - (Ah 16th note)
30 80 41 40 -> note off F3 - 48 pulses later - 16th note
0C 90 43 50 -> note on G3 - 12 pulses later (3rd beat of Measure 2)
83 00 80 43 40 -> note off G3 - 384 pulse later - 1/2 note
60 90 48 50 -> note on C4 - 96 pulses later (1st beat of Measure 2)

Example A Decode(cont)

81 10 80 48 40 -> C4 off - 144 p - dotted 1/8
24 90 48 50 -> C4 on - 36 p
30 80 48 40 -> C4 off - 48 p - 16th
0C 90 43 50 -> G3 on - 12 p (2nd beat of Measure 3)
81 10 80 43 40 -> G3 off - 144 p - dotted 1/8
24 90 43 50 -> G3 on - 36p
30 80 43 40 -> G3 off - 48p - 16th note
0C 90 40 50 -> E3 on - 12p (3rd beat of measure 3)
81 10 80 40 40 -> E3 off - 144p - dotted 1/8
24 90 40 50 -> E3 on - 36p
30 80 40 40 -> E3 off - 48p - 16th note
0C 90 3C 50 -> C3 on - 12p - (4th beat of measure 3)
81 10 80 3C 40 -> C3 off - 144p - dotted 8th
24 90 3C 50 -> C3 on - 36p
30 80 3C 40 -> C3 off - 48p - 16th note
0C 90 43 50 -> G3 on - 12p - (1st beat of measure 4)
81 10 80 43 40 -> G3 off - 144p - dotted 1/8
24 90 41 50 -> F3 on - 36p
30 80 41 40 -> F3 off - 48p - 1/16
0C 90 40 50 -> E3 on - 12p (2nd beat of measure 4)
81 10 80 40 40 -> E3 off - 144p - dotted 1/8
24 90 3E 50 -> D3 on - 36p -
30 80 3E 40 -> D3 off - 48p - 1/16
0C 90 3C 50 -> C3 on - (3rd beat of measure 4)
83 00 80 3C 40 -> C3 off - 384 p - 1/2 note
00 FF 2F 00 -> FF 2F 00 is the mandatory end of track

Example B

4D 54 68 64 00 00 00 06 00 01 00 03 01 E0 4D 54
72 6B 00 00 00 13 00 FF 58 04 04 02 18 08 00 FF
51 03 09 57 94 00 FF 2F 00 4D 54 72 6B 00 00 01
BD 00 FF 03 06 4D 65 6C 6F 64 79 00 B0 00 00 00
C0 47 00 B0 07 6C 00 B0 07 6C 24 90 41 3C 82 47
80 41 40 81 08 90 41 42 82 5A 80 41 40 76 90 48
4E 82 5A 80 48 40 81 18 90 48 4E 82 6D 80 48 40
5E 90 4A 4E 82 2E 80 4A 40 81 1F 90 4A 50 82 06
80 4A 40 81 6E 90 48 4E 83 22 80 48 40 84 1E 90
46 42 82 6D 80 46 40 81 0C 90 46 44 82 63 80 46
40 73 90 45 4C 82 35 80 45 40 81 38 90 45 4E 82
35 80 45 40 81 2C 90 43 46 82 2B 80 43 40 81 32
90 43 4C 82 37 80 43 40 81 32 90 41 40 84 46 80
41 40 82 40 90 48 3A 82 19 80 48 40 81 77 90 48
46 82 2E 80 48 40 81 36 90 46 42 81 7A 80 46 40
81 78 90 46 3F 82 35 80 46 40 81 2C 90 45 42 82
08 80 45 40 81 50 90 45 50 82 14 80 45 40 81 3A
90 43 3F 84 5D 80 43 40 82 22 90 48 3E 82 47 80
48 40 81 42 90 48 46 82 0D 80 48 40 81 64 90 46
3E 81 74 80 46 40 81 77 90 46 44 82 29 80 46 40
81 3F 90 45 4E 82 19 80 45 40 81 5E 90 45 52 82
23 80 45 40 81 3A 90 43 3A 84 5F 80 43 40 82 1F
90 41 3A 82 4A 80 41 40 81 41 90 41 42 82 10 80
41 40 81 65 90 48 4A 82 04 80 48 40 81 4B 90 48
48 82 24 80 48 40 81 52 90 4A 50 81 70 80 4A 40
81 6A 90 4A 50 81 7F 80 4A 40 81 62 90 48 42 85
0F 80 48 40 82 1B 90 46 40 82 21 80 46 40 81 48
90 46 48 82 29 80 46 40 81 45 90 45 4C 82 09 80
45 40 81 51 90 45 4E 82 07 80 45 40 81 70 90 43
3D 82 11 80 43 40 81 50 90 43 50 81 72 80 43 40
81 56 90 41 44 86 7F 80 41 40 00 FF 2F 00 4D 54
72 6B 00 00 05 0F 00 FF 03 05 50 69 61 6E 6F 00
B1 00 00 00 C1 00 00 B1 07 60 00 B1 07 60 00 B1
07 60 00 B1 07 60 00 B1 07 60 00 B1 07 60 00 B1
07 60 00 B1 07 60 00 B1 07 60 00 B1 07 60 00 B1
07 60 00 B1 07 60 00 B1 07 60 00 B1 07 60 00 B1
07 60 00 B1 07 60 00 B1 07 60 00 B1 07 60 00 B1
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07 60 00 B1 07 60 00 B1 07 60 00 B1 07 60 00 B1
07 60 00 B1 07 60 00 B1 07 60 00 B1 07 60 00 B1
07 60 00 B1 07 60 00 B1 07 60 00 B1 07 60 00 B1
07 60 19 91 41 57 20 91 35 48 82 11 81 35 40 0A
81 41 40 81 1F 91 41 50 12 91 35 52 81 4C 91 40
2B 04 91 37 50 2C 81 35 40 07 81 41 40 81 38 81
37 40 01 91 39 4C 07 81 40 40 10 91 41 55 81 42
91 37 4A 2A 81 39 40 81 4E 91 3C 5D 04 91 39 52
29 81 37 40 07 81 41 40 81 20 91 35 3A 10 81 39
40 81 63 81 35 40 0F 91 3E 52 1A 91 3A 4E 0C 81
3C 40 81 2F 91 3C 55 20 81 3E 40 81 5F 81 3A 40
08 91 3E 5D 2D 91 3A 66 0E 81 3C 40 81 3C 91 40
52 12 81 3E 40 81 08 81 40 40 5F 91 41 59 01 81
3A 40 17 91 39 59 83 4E 91 35 55 1E 81 39 40 28
81 41 40 82 70 81 35 40 34 91 3C 59 0A 91 37 59
83 03 81 3C 40 55 91 30 55 03 81 37 40 01 91 3C
64 83 17 91 3A 40 29 81 3C 40 0B 81 3A 40 02 91
39 4A 12 81 30 40 1A 91 35 52 81 43 91 37 52 02
91 3A 55 1D 81 35 40 26 81 39 40 81 29 91 3C 59
0A 91 39 52 32 81 37 40 12 81 3A 40 81 02 81 39
40 01 91 39 55 0E 91 35 42 33 81 3C 40 81 42 91
3A 62 18 91 2E 52 1C 81 39 40 08 81 35 40 82 5A
81 2E 40 54 91 37 5D 0F 91 30 50 05 81 3A 40 82
4B 81 30 40 49 81 37 40 41 91 39 66 1A 91 29 5F
86 04 81 39 40 22 81 29 40 81 25 91 39 57 0D 91
41 4E 81 42 91 37 42 1D 81 39 40 09 91 45 57 45
81 41 40 81 16 91 39 48 10 91 48 55 0D 81 37 40
22 81 45 40 81 1E 81 39 40 0A 91 35 48 15 91 45
46 36 81 48 40 26 81 45 40 7A 81 35 40 09 91 37
52 31 91 3C 42 81 3B 91 35 48 0D 91 43 52 18 81
37 40 81 46 91 37 52 14 91 46 46 0E 81 35 40 0C
81 3C 40 05 81 43 40 81 36 91 43 4C 14 91 34 3E
05 81 37 40 11 81 46 40 81 37 81 34 40 20 91 35
37 06 91 3C 55 1C 81 43 40 81 44 91 41 50 0B 91
37 42 1E 81 3C 40 1D 81 35 40 81 39 91 45 57 06
91 39 57 0A 81 37 40 27 81 41 40 81 27 91 41 55
00 91 35 4A 03 81 45 40 47 81 39 40 81 2D 91 37
57 03 91 40 5B 17 81 35 40 04 81 41 40 83 2E 91
3C 52 1E 91 30 52 0E 81 37 40 0A 81 40 40 81 44
81 3C 40 81 33 81 30 40 72 91 2D 55 02 91 41 59
82 2A 81 41 40 27 81 2D 40 7C 91 45 48 02 91 2D
55 81 3D 91 2E 44 25 91 48 52 16 81 2D 40 81 31
81 2E 40 0F 91 30 40 24 91 40 57 1E 81 45 40 07
81 48 40 81 1C 91 2D 4A 0C 81 30 40 49 81 40 40
81 20 91 2B 52 12 91 43 46 09 81 2D 40 81 6F 91
46 4E 81 07 81 2B 40 5F 81 43 40 01 81 46 40 06
91 29 52 16 91 3C 55 81 27 91 2B 44 44 81 29 40
67 81 3C 40 3F 81 2B 40 13 91 2D 4C 2C 91 41 5B
81 58 91 29 57 06 91 45 50 01 81 2D 40 56 81 41
40 6D 81 29 40 41 91 40 66 0B 91 30 5B 01 81 45
40 84 47 81 30 40 54 81 40 40 82 03 91 41 5B 2A
91 35 57 81 48 91 37 40 28 81 35 40 72 81 37 40
13 81 41 40 46 91 35 52 08 91 45 5D 81 26 81 45
40 2F 91 43 62 01 91 33 50 42 81 35 40 81 2F 91
32 59 09 91 41 5B 0D 81 33 40 2E 81 43 40 82 35
81 32 40 81 02 91 32 52 09 81 41 40 01 91 41 5B
81 57 91 30 46 04 81 32 40 81 72 91 2E 42 0B 91
46 57 0F 81 30 40 28 81 41 40 81 35 91 30 44 24
81 2E 40 7D 81 46 40 56 91 46 57 07 91 32 59 24
81 30 40 81 1D 91 34 52 0B 91 43 59 25 81 32 40
01 81 46 40 46 81 34 40 81 0E 91 35 55 06 91 45
62 34 81 43 40 81 30 91 46 4E 3F 81 45 40 81 44
81 35 40 06 91 48 5D 00 91 29 4E 07 81 46 40 82
49 81 29 40 7E 91 2E 4A 04 81 48 40 2D 91 43 64
82 44 81 2E 40 29 81 43 40 54 91 2E 52 02 91 43
62 81 44 91 2B 4E 13 91 40 55 16 81 2E 40 11 81
43 40 60 81 2B 40 5E 91 29 39 0F 91 41 5B 25 81
40 40 81 3A 91 2B 52 47 81 29 40 73 81 41 40 3C
91 41 5F 02 91 2D 55 39 81 2B 40 81 17 81 2D 40
01 91 29 59 18 91 45 57 41 81 41 40 4A 81 29 40
6D 91 30 4C 08 91 3C 57 29 81 45 40 81 2B 81 3C
40 81 23 81 30 40 7E 91 3E 62 0D 91 30 5B 81 4A
91 40 55 27 81 3E 40 43 81 30 40 81 28 91 29 52
06 91 41 59 01 81 40 40 84 05 81 41 40 48 81 29
40 00 FF 2F 00 00 00 00 00 00 00 00 00 00 00 00

Example B Decode

4D 54 68 64 - MThd
00 00 00 06 - length = 6
00 01 - MIDI file type
00 03 - 3 Track
01 E0 - 480 pulses per quarter note

4D 54 72 6B - MTrk
00 00 00 13 - length = 19
00 FF 58 04 04 02 18 08 - 4/4 time everything else std
00 FF 51 03 09 57 94 - tttttt = 612244 = 98 bpm
00 FF 2F 00 -> end of track

Example B Decode (cont)

4D 54 68 64 - MThd
00 00 00 06 - length = 6
00 01 - MIDI file type
00 03 - 3 Track
01 E0 - 480 pulses per quarter note

4D 54 72 6B - MTrk
00 00 00 13 - length = 19
00 FF 58 04 04 02 18 08 - 4/4 time everything else std
00 FF 51 03 09 57 94 - tttttt = 612244 = 98 bpm
00 FF 2F 00 -> end of track

Example B Decode (cont)

4D 54 72 6B - MTrk
00 00 01 BD - 445 bytes
00 FF 03 06 4D 65 6C 6F 64 79 - Track Name - Melody

00 B0 00 00 - bank select MSB
00 C0 47 - change to patch 71 - bassoon
00 B0 07 6C - Volume controller = 108
00 B0 07 6C
24 90 41 3C - Note on F3 - 36 p in
82 47 80 41 40 - note off F3 - 327p
81 08 90 41 42 - note on F3 - 136p (close to beat 2 of meas 1 - 463 instead of 480)
82 5A 80 41 40 - note off F3 - 346p
76 90 48 4E - note on C4 - 118p
82 5A 80 48 40 - note off C4 - 346p
81 18 90 48 4E
82 6D 80 48 40

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