

A MIDI Primer For Computer Scientists

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Abstract. This is the first in a series of technical reports dealing with the use of sound by programs. In this report, some of the important features of MIDI (Musical Instrument Digital Interface) are described. This is in no way a complete reference to MIDI. Instead, this technical report provides a brief introduction to MIDI devices for computer scientists who want to use these devices to produce sound from programs.

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1 Introduction

MIDI stands for Musical Instrument Digital Interface. The MIDI standard dates back to the 1980s and is still evolving. Manufacturers of MIDI equipment have extended the standard in different ways. Since we are not interested in making music, but rather in generating notes with a MIDI synthesizer, we will restrict our attention to the basics. More detailed information can be found in [1]. Almost nothing in this report is exactly correct. All of the concepts have been oversimplified so that they can be easily described. This simplified view is sufficient for most uses we have in mind.

A MIDI synthesizer is a device for creating sounds. The synthesizers we are interested in can generate many sounds at once. A sound is specified by giving its pitch, its volume, and its timber. The pitch determines which note is played. The timber corresponds to the instrument which is playing the note. Typically a synthesizer has several channels; 16 is common. Each channel can be set to simulate the sound of one instrument chosen from hundreds that are preprogrammed into the device. We will concentrate on the 128 instruments and the drum kit that make up General MIDI and should be available on all MIDI synthesizers.

First the device is initialized. This includes specifying which instrument to use for some of the channels. After that commands can be sent to play notes. The simplest command is to start a note corresponding to a given channel with a given pitch and volume. The note is played and will continue until another command stops the note. If several start commands are given before the corresponding stop commands, the notes can be played at the same time.

2 Channels and Instruments

The MIDI literature usually refers to 16 channels numbered 1 through 16. However, when commands are sent to MIDI devices these channels are represented by 4 bits, so at the hardware level the channel numbers are in the range from 0 to 15. We will always refer to channels using this range. To set a particular channel to correspond to a particular instrument, you must send a three-byte message to the device. The first byte contains 0xc in the high nibble and the channel number in the low nibble. The second byte is 0, and the third byte is an instrument number. The table at the end of the report gives the correspondence between numbers and instruments the General MIDI interface. This set is supported by almost all devices and is sufficient for our needs. The instruments include a number of different pianos, organs, string instruments, wind instruments and a few sound effects such as a telephone, birds, a helicopter, and a gun shot. You would set up a channel from a C program with a function which might look like:

```
send_three_bytes(0xc0+channel,0,instrument);
```

In addition to the standard instruments, General MIDI also specifies a drum kit. This is a collection of drum and other percussion-like sounds which are grouped together as one instrument. Often a synthesizer's default setup will assign one channel, channel 9, to the drum kit and all others to the first MIDI instrument, a piano. With a drum kit each pitch corresponds to a different type of drum instrument. For example, a pitch value of 60 on most instruments corresponds to a C note. In the General MIDI drum kit, this corresponds to hitting a Bongo.

In the MIDI terminology, what we have called instruments are called *programs* and the commands to associate programs with channels are called *program change messages*.

Usually program numbers are given in the range from 1 to 128, rather than the range 0 to 127 which we have used. We have chosen to count starting at 0 because this is how the hardware interface works. The table at the end of this report gives a complete list of the General MIDI instruments available on a particular synthesizer, the Korg X5DR [2]. The following table gives a list of the instrument types and the corresponding numbers.

Numbers	Family
0 to 7	Piano
8 to 15	Chromatic Percussion
16 to 23	Organ
24 to 31	Guitar
32 to 39	Bass
40 to 47	Strings
48 to 55	Ensemble
56 to 63	Brass
64 to 71	Reeds
72 to 79	Pipes
80 to 95	Synth lead
96 to 103	Synth effects
104 to 111	Ethnic
112 to 119	Percussive
120 to 127	Sound effects

3 Starting and Stopping Notes

You start a note by giving the channel, the pitch, and the volume. The channel determines the instrument and the pitch determines the note. The pitch and volume are each in the range 0 to 127. A volume of 0 represents no sound. A pitch of zero corresponds to a very low C (21 notes below the lowest note on a piano) and a pitch of 127 corresponds to a very high G (7 notes above the highest note on a piano). A start note command is three bytes. The first

byte contains 0x90 in the high nibble and the channel number in the low nibble. The second byte is the pitch and the third byte is the velocity. You can send such a command from a C program with

```
send_three_bytes(0x90+channel,pitch,volume);
```

After you start a note in continues playing until you stop it. You can stop the note by sending three bytes.

```
send_three_bytes(0x80_channel,pitch,volume);
```

Different instruments behave differently between the starting and the stopping of a note. When you strike a key on a piano, the note is loud at first and then starts to die out slowly, even while you hold down the note. Releasing the note causes the sound to die out more quickly. An organ behaves differently. As long as you hold down the note, you get a sound with almost constant volume. The sound dies out quickly when the note is released. For other instruments the note dies out so quickly after it is started that the time between the start and stop commands makes little difference in the perceived sound. I have classified each instrument as to my perception of how the sound behaves after a start command, and this is listed in the table at the end of this report.

The value that I have called volume is referred to as velocity in the MIDI terminology. It corresponds to how fast the note is hit, or how fast pressure is applied to the note. For most instruments this directly corresponds to the volume of the note. The velocity for the stop note command refers to the speed at which the note is released. The differences here are usually not noticeable to the untrained ear, and so the velocity value for the stop note command is not critical.

4 The Hardware Interface

The MIDI standard defines a set of DIN connectors, voltage levels and a bit rate. Communication is asynchronous serial at 31250 bits per second. The serial communication uses a 5 milliamp current loop. It takes 3 bytes to start a note. With the serial overhead of one start bit and one stop bit it takes 10 bits to send a byte so the 30 bits in the command to start a note can be sent in less than a millisecond. The MIDI interface is not compatible with the standard RS232-C serial interface on most computers and so a computer needs a MIDI port to hook it directly to a MIDI device. Most PC sound cards include such a port. Workstations typically do not have a MIDI port but serial-to-MIDI adapters are available from Keytronics [3] for about \$100. Some synthesizers are now being made with built-in serial ports allowing them to be connected directly to a standard serial port of a PC or workstation. One such device and a library for interfacing to it is described in [2].

5 The Table

The table given on the next page lists the correspondence between numeric values and the things they can represent. For each number in the range 0 to 127, 5 values are given. The first is the instrument that is represented by the number when the number is used in a channel initialization command. Next is my perception of how the volume of the note behaves while the note is on. This is called the envelope of the note and is in the column labeled L. I have used three classifications. F means that the note dies out fast. S means that the note dies out slowly. C means that the volume is constant as long as the note is on so that it does not die out until it is stopped. The third entry is the Drum Kit sound that the number corresponds to if it is used as the pitch for a note on channel 9. Only notes 28-87 represent valid Drum Kit sounds. Next is my perception of the envelope of that Drum Kit sound. Last is the note that the number represents when used as the pitch of a start note or stop note command.

I have picked out a few of the instruments and Drum Kit sounds as being an interesting subset to examine when determining what to use for an auralization. These are listed in boldface. The serious user will want to listen to all of the MIDI instruments and drum sounds.

References

- [1] C. Braut, "The Musicians's Guide to MIDI," SYBEX Inc, Alameda, CA, 1992.
- [2] S. Robbins, "Controlling the Korg X5DR Synthesizer from a UNIX Program," UTSA Division of Computer Science Technical Report, CS-95-12.
- [3] Keytronics, Inc. xxx

Num	Instrument	L	Drum	L	Note	Num	Instrument	L	Drum	L	Note
0	G01 Piano	M			C -2	64	G65 Soprano Sax	C	Open Conga	F	E 3
1	G02 Brite Piano	M			C# -2	65	G66 Alto Sax	C	Hi Timbal	F	F 3
2	G03 Hammer Piano	M			D -2	66	G67 Tenor Sax	C	Lo Timbal	F	F# 3
3	G04 Honky Tonk	M			D# -2	67	G68 Baritone Sax	C	Agogo	F	G 3
4	G05 New Timesh	M			E -2	68	G69 Sweet Oboe	C	Agogo	F	G# 3
5	G06 Digi Piano	M			F -2	69	G70 English Horn	C	Cabasa	F	A 3
6	G07 Harpssichord	M			F# -2	70	G71 Bassoon Oboe	C	Maracas	F	A# 3
7	G08 Clavichord	M			G -2	71	G72 Clarinet	C	Whistle S	F	B 3
8	G09 Celesta	M			G# -2	72	G73 Piccolo	C	Whistle L	M	C 4
9	G10 Glocken	M			A -2	73	G74 Flute	C	Guiro S	F	C# 4
10	G11 Music Box	M			A# -2	74	G75 Recorder	C	Guiro L	M	D 4
11	G12 Vibes	M			B -2	75	G76 Pan Flute	C	Claves	F	D# 4
12	G13 Marimba	M			C -1	76	G77 Bottle	C	WoodBlock2	F	E 4
13	G14 Xylophone	M			C# -1	77	G78 Shakuhachi	C	WoodBlock3	F	F 4
14	G15 Tubular	M			D -1	78	G79 Whistle	C	Mute Cuica	F	F# 4
15	G16 Santur	M			D# -1	79	G80 Ocarina	C	Open Cuica	F	G 4
16	G17 Full Organ	C			E -1	80	G81 Square Wave	C	MuteTriang	F	G# 4
17	G18 Perc Organ	C			F -1	81	G82 Saw Wave	C	OpenTriang	F	A 4
18	G19 BX - 3 Organ	C			F# -1	82	G83 Syn Caliope	C	Cabasa	F	A# 4
19	G20 Church Pipe	C			G -1	83	G84 Syn Chiff	C	JingleBell	M	B 4
20	G21 Positive	C			G# -1	84	G85 Charang	M	Bell Tree	F	C 5
21	G22 Musette	C			A -1	85	G86 Air Chorus	C	Castanet	F	C# 5
22	G23 Harmonica	C			A# -1	86	G87 Rezzo 4ths	C	Side Kick	F	D 5
23	G24 Tango	C			B -1	87	G88 Bass & Lead	C	Taiko Lo	F	D# 5
24	G25 Classic Guitar	M			C -0	88	G89 Fantaasio	C			E 5
25	G26 Acoustic Guitar	M			C# -0	89	G90 Warm Pad	C			F 5
26	G27 Jazz Guitar	M			D -0	90	G91 Poly Pad	C			F# 5
27	G28 Clean Guitar	M			D# -0	91	G92 Hhost Pad	C			G 5
28	G29 Mute Guitar	M	Rock Kick	F	E -0	92	G93 Bowed Glass	C			G# 5
29	G30 Over Drive	M	Snare 3	F	F -0	93	G94 Metal Pad	C			A 5
30	G31 Dist Guitar	M	Open HH	F	F# -0	94	G95 Halo Pad	C			A# 5
31	G32 Rock Monics	C	Fat Kick	F	G -0	95	G96 Sweep	C			B 5
32	G33 Jass Bass	M	Timbales	F	G# 0	96	G97 Ice Rain	M			C 6
33	G34 Deep Bass	M	Snare 1	F	A 0	97	G98 Sound Track	C			C# 6
34	G35 Pick Bass	M	RollSnare1	M	A# 0	98	G99 Crystal	M			D 6
35	G36 Fretless	M	Real Kick	F	B 0	99	G100 Atmosphere	C			D# 6
36	G37 Slap Bass 1	M	ProcesKick	F	C 1	100	G101 Brightness	C			E 6
37	G38 Slap Bass 2	M	Side Kick	F	C# 1	101	G102 Goblin	C			F 6
38	G39 Synth Bass 1	M	Rock Snare	F	D 1	102	G103 Echo Drop	C			F# 6
39	G40 Synth Bass 2	C	Hand Claps	F	D# 1	103	G104 Star Theme	C			G 6
40	G41 Violin	C	LightSnare	F	E 1	104	G105 Sitar	M			G# 6
41	G42 Viola	C	Tom Lo	F	F 1	105	G106 Banjo	M			A 6
42	G43 Cello	C	Tite HH	F	F# 1	106	G107 Shamisen	M			A# 6
43	G44 Contra Bass	C	Tom Lo	F	G 1	107	G108 Koto	M			B 6
44	G45 Tremolo Strings	C	Pedal HH	F	G# 1	108	G109 Kalimba	M			C 7
45	G46 Pizzicato	F	Tom Lo	F	A 1	109	G110 Scotland	C			C# 7
46	G47 Harp	M	Open HH	F	A# 1	110	G111 Fiddle	C			D 7
47	G48 Timpani	C	Tom Hi	F	B 1	111	G112 Shanai	C			D# 7
48	G49 Marcato	C	Tom Hi	F	C 2	112	G113 Metal Bell	M			E 7
49	G50 Slow String	C	Crash Cym	M	C# 2	113	G114 Agogo	M			F 7
50	G51 Annalog Pad	C	Tom Hi	F	D 2	114	G115 Steel Drums	M			F# 7
51	G52 String Pad	C	Ride Edge	F	D# 2	115	G116 Wood Block	M			G 7
52	G53 Choir	C	China Cym	M	E 2	116	G117 Taiko	M			G# 7
53	G54 Doo Voice	C	Ride Cup	F	F 2	117	G118 Tom	M			A 7
54	G55 Voices	C	Tambourine	F	F# 2	118	G119 Synth Tom	M			A# 7
55	G56 Orch Hot	F	Splash Cym	M	G 2	119	G120 Rev Cymbol	M			B 7
56	G57 Trumpet	C	Cowbell	F	G# 2	120	G121 Fret Noise	M			C 8
57	G58 Trombone	C	Crash Cym	F	A 2	121	G122 Noise Cliff	M			C# 8
58	G59 Tuba	C	Vibraslap	M	A# 2	122	G123 Seashore	M			D 8
59	G60 Muted Trumpet	C	Ride Cym 1	M	B 2	123	G124 Birds	C			D# 8
60	G61 French Horn	C	Hi Bongo	F	C 3	124	G125 Telephone	C			E 8
61	G62 Brass	C	Lo Bongo	F	C# 3	125	G126 Helicopter	C			F 8
62	G63 Syn Brass 1	C	Mute Conga	F	D 3	126	G127 Stadium	C			F# 8
63	G64 Syn Brass 2	C	Open Conga	F	D# 3	127	G128 Gun Shot	M			G 8