



**Guidebook**

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## Introduction

Welcome to the world of XG! Yamaha has introduced this powerful new format—an extension of the existing **GM** and **GS** standards—in order to enable a new generation of synthesizers and tone generators to meet the demands of the coming multimedia age. XG provides capabilities far beyond that of GM and GS, permitting a much higher degree of musical expressiveness and sophistication while at the same time strictly adhering to all GM requirements.

This Guidebook is designed to supplement and expand upon the technical details provided in the XG Specifications. Its purpose is to act as a MIDI and General MIDI “primer,” as well as documenting the improvements to, and similarities between, the XG and GS formats. We hope you find the information here useful as you begin exploring the many exciting possibilities provided by XG.

*Note: All numeric values given in this Guidebook are in standard **decimal** unless indicated otherwise. Numbers followed by a small “h” are given in **hexadecimal**.*

### Why XG?

MIDI—the Musical Instrument Digital Interface—has forever changed the way we create and listen to music. Its initial adoption as an industry standard in 1983 solved many problems of incompatibility between different makes and models of electronic instruments, but, ironically, over the years led to a number of new incompatibility problems. These issues were exacerbated as sequencers became the de facto standard for music composition and the need arose to play back music files on instruments other than the one originally used for recording. For example, the same type of sound might be stored in one memory slot in one instrument and in a completely different slot in another instrument. Also, each manufacturer tended to use a proprietary mapping for drum kits—one might assign a snare drum to key number 40, for instance, while another might assign it to key number 46.

Many of these problems were addressed in 1991 with the adoption of a “recommended practice” called General MIDI (GM for short). Instruments that are GM-compatible follow a standardized set of rules for memory organization and drum mapping, as well as meeting a minimum set of requirements for the reception of selected MIDI messages. This makes it possible for a large variety of instruments made by different manufacturers to reproduce GM music files (that is, sequencer files that utilize the GM standard) with a good degree of accuracy. A summary of General MIDI features can be found in Yamaha’s “Introduction to XG” document. A more detailed description is provided in the “General MIDI System Level 1” document published by the MIDI Manufacturer’s Association.

Despite its widespread success, GM is limited to basic MIDI functions and is unable to support the advanced features provided by many of today’s multitimbral tone generators. For example, GM specifies the usage of only 128 different voices and offers no support for onboard effects. Also, even though MIDI messages can often be used to control GM instruments, the required data is device-dependent; models with similar functions often require very different control data.

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Conscious of these limitations, the Roland Corporation introduced their General Synthesis (“GS”) format in 1991 (almost simultaneously with the industry-wide announcement of GM). GS is a standardized set of specifications for Roland tone generators which, though upwardly compatible with GM, expands on a number of areas. Most notably, GS provides optional support for two onboard effects (reverb and chorus) and has provision for a number of additional voices beyond the 128-voice GM sound set. These additional voices (called “Variation Tones”) are accessed via MIDI Bank Select messages (control change #0 and, in rare circumstances, control change #32). The current GS spec describes a total of 98 “Variation Tones,” making for a total of 226 voices. Any device that is GS-compatible is designed to be able to reproduce “GS Music Data” (MIDI music files created under the GS format).

Like GM, GS has proven to be a commercial success, due largely to its usage by many producers of commercial sequencer files. This is not surprising, since GS dealt with many of the features found in the state-of-the-art synthesizers and tone generators of 1991. But the state of the art in electronic instruments changes very rapidly indeed, and GS has not kept pace. Today’s instruments typically provide many hundreds of factory presets, and most offer more than two onboard effects. Also, there have been a number of new MIDI messages adopted since 1991—none of which are included in the GS format. More significantly, the ever-increasing importance of multimedia—and the demands which multimedia imposes on today’s electronic instruments—is not addressed at all by GS.

These are the reasons why Yamaha has introduced XG. In effect, XG is a “second-generation” GS, while still adhering to the basic foundation laid by the GM standard. XG instruments are able to access thousands of standardized voices via up to 32 MIDI channels, and they provide three or more onboard effects as well as one or more optional external audio channels—all under precise MIDI control. Standardized MIDI messages can be used to modify voices, enabling user customization to a degree far exceeding that of any previous instruments. Dozens of third-party manufacturers are currently creating commercial XG music files that take advantage of these new features, enabling XG instruments to play back full-blown music productions, complete with **realtime changes** of voice parameters and full-featured **automated mixdown**.

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The many enhancements that XG adds to both GM and GS are described in detail in the pages of this Guidebook. Suffice it to say that XG not only reflects the present state of the art in MIDI tone generators—it is also clearly the format of the future.



### Three Key Goals

Yamaha's development of the XG format has focused on the following three key goals:

- 1. Compatibility* - Any XG instrument, regardless of model or manufacturer, will provide faithful reproduction of XG music files. Because the XG format is 100% compatible with GM, XG instruments will also provide precise reproduction of GM music files. XG instruments can also play back GS music files when operating in GM mode (some GS music files may require a moderate degree of editing to achieve complete compatibility).
- 2. Scalability* - The XG format has been designed from the ground up to be scalable, so that each XG instrument can display its unique character while rendering accurate playback of XG music files in accordance with its level of sophistication. For example, if a particular instrument doesn't support a Variation voice, it will automatically substitute the corresponding basic GM voice. If a model includes a **graphic equalizer**, it can generate pre-programmed frequency curves to further enhance the music; if not, the music will simply be played back with a flat frequency curve. The goal is to achieve a practical level of compatibility that can nonetheless accommodate diverse instrumentation.
- 3. Expandability* - The XG format employs an "open" architecture that will allow it to be expanded and enhanced as future technological developments warrant. The goal is to create a format that will always be in step with the state of the art.

### Overview of XG Features

- *Polyphony* - XG instruments must have a minimum total polyphony of 32 notes (in contrast to the 24-note polyphony required by GM and GS).
- *Number of MIDI channels* - XG instruments support up to 32 MIDI channels, enabling up to 32-way multitimbral operation.
- *Channel assignments* - Like GM and GS, XG instruments normally reserve MIDI channel 10 as a “rhythm channel” (as well as channel 26, if the instrument supports 32 MIDI channels), playing drum and percussion parts. However, the XG format enables additional rhythm channels to be specified in real time, enabling the composer to create complex percussive parts and also simplifying the process of crossfades between songs.
- *Number of voices* - XG supports literally thousands of voices, accessed by using MIDI Bank Select messages (control change #0 and #32), followed by Program Change messages.
- *Voice organization* - XG “Melody” voices (that is, melodic sounds mapped over the entire keyboard) are organized into 128 banks, with each bank containing up to 128 voices. Bank 0 contains the standard GM Sound Set, with other banks organized according to musical characteristics, making it easy to locate alternate “Variation” sounds. In addition, there is a bank of SFX (Special Effects) voices, a bank of rhythm kits (percussive sounds, mapped one to a key), and a bank of SFX kits (SFX sounds, mapped one to a key).

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- *Voice modification* - The XG format provides standardized means for altering voices in real time (even individual sounds within a rhythm kit!), using MIDI control change messages and NRPNs (Non-Registered Parameter Numbers).\* The composer of XG music files can therefore provide a high level of musical expressiveness by altering the level, pan position, filter cutoff frequency and/or resonance, envelope attack, decay and release rates, and effects send levels of each voice independently.
- *Effects* - XG instruments must provide at least three different internal effects and may optionally contain additional ones such as a master graphic equalizer. The XG format allows for high-level control over these effects, using MIDI control change or system exclusive messages to select effects types, set signal routings and send and return levels, and even alter effects parameters themselves in order to create customized signal processing.
- *External audio input* - One of the most exciting new XG features is optional support for one or more channels of external audio data. This data is input from any microphone or line-level source and is then routed to the XG instrument's analog-to-digital ("A/D") converter. In this way, the external signal can be processed and mixed right along with the tone generator signal, under direct realtime MIDI control. One application for this feature is in karaoke, where the composer of an XG music file can specify the precise type and amount of effects processing required for a microphone input. Multimedia authors can also use this feature to create customized settings for interactive audience participation.

\* *System exclusive messages can also be used for non-realtime parameter change.*

### Channels and Polyphony

MIDI is a **serial interface** that enables multiple channels of data to be transmitted down a single wire. This is somewhat analogous to cable television, where numerous TV channels are transmitted over a single cable. The original MIDI Specification called for the “simultaneous” transmission of 16 channels of musical information, which seemed like a lot back in the early 1980s, when few if any instruments had multitimbral capability. Today, a single instrument can often reproduce 16 timbres simultaneously, responding to all 16 channels of incoming MIDI data. However, due largely to limitations of transmission and processing speed, the MIDI Specification has never been amended to include more than 16 channels.

The MIDI Specification defines technical details such as transmission speed, word length, and general syntax of standardized digital messages, but it is important to understand that it does not address the issue of how a tone generator will handle incoming MIDI data. For example, the number of channels that can be received, the types and numbers of voices per channel, and the methods of key assignment are all unspecified, as is the total polyphony of the tone generator.

### *GM*

GM-compatible instruments are by definition multitimbral tone generators which must be able to play at least 16 timbres simultaneously in response to all 16 MIDI channels. MIDI channel 10 is used exclusively as a “rhythm channel,” playing a standardized “GM Percussion Map,” with a different percussive sound assigned to each note.

These instruments must have the ability to play different sounds on each channel, with each channel polyphonic. They must have a total polyphony of at least 24 **dynamically allocated** voices for both melodic and percussive sounds, or 16 dynamically allocated melody voices plus 8 percussion voices. This is to ensure that any unused voice will be available to play a newly requested note regardless of channel. However, GM does not define how processing is to take place if there are no more unused voices available.

### *GS*

GS-compatible instruments comply with all GM guidelines as stated above and add the ability to specify multiple rhythm channels through the use of a system exclusive message called “Use For Rhythm Part.” However, this message cannot be used for realtime change of channel assignment.

Voice allocation occurs with channel 10 (the rhythm channel) taking highest priority, followed by channels 1 -> 2 ... 9 -> 11 -> 12 ... 16. Thus, GS recommends that the most important musical parts be assigned to lower MIDI channels. System exclusive messages can be used to reserve minimum numbers of voices per channel or to change the dynamic allocation routine for any channel, including channel 10.



XG-compatible instruments comply with all GM guidelines as stated above and, like GS, add the ability to specify multiple rhythm channels. However, here this is accomplished through the use of a control change message (cc #0 = 7Fh) instead of system exclusive messages, allowing the assignment to be made in real time during playback of a music file. As in GM, MIDI channel 10 is normally used as a rhythm channel—this is the default setting. However, if required, channel 10 can easily be designated as a sixteenth melody channel through the use of a realtime control change message (cc #0 = 00h). For more information on the use of these messages, see the section in this Guidebook entitled “[Voice Organization and Selection](#).”

In addition, XG expands on GM and GS by increasing the minimum polyphony—all XG-compatible instruments are capable of playing 32 notes simultaneously (as opposed to 24). There is also provision for the reception of up to 32 MIDI channels, and XG instruments which are able to receive 32 MIDI channels have 32-way multitimbral capability. Furthermore, there is optional provision for the addition of one or more external audio input channels, where the incoming audio signal is A/D converted and the resulting signal’s volume, pan, and effect processing can be placed under direct realtime MIDI control, just as with other channels.

As with GS, voice allocation occurs with channel 10 (the rhythm channel) taking highest priority, followed by channels 1 -> 2 ... 9 -> 11 -> 12 ... 16. If the XG instrument is capable of receiving 32 MIDI channels, processing moves to the second set of 16 channels (channels 17 - 32) after the first set (channels 1 - 16) has been processed, and here too, the rhythm channel (channel 26) takes priority.

### Note Messages

The most basic kind of MIDI *channel message* (that is, a MIDI message “flagged” with a particular channel number) is the Note On message. This corresponds to the action of playing a key on the keyboard. The Note On message is actually a three-part message: The first part, called the *status byte*, announces the kind of message it is. The second and third parts, called *data bytes*, contain information describing the note number that was played and the velocity with which the note was struck (this is a measurement of the downward speed of the key as it was depressed). There are two ways that MIDI can describe the action of releasing a key on a keyboard. The most common is to use a Note On message with a velocity value of 0; this is interpreted by virtually all tone generators as having the meaning, “stop playing the specified note.” Alternatively, a Note Off message can be used. This is similar to a Note On message in that it too contains three parts—a status byte (containing a different value than the Note On message), followed by data bytes describing the note number being released and, optionally, the velocity with which it was released (this last parameter—called “release velocity”—is rarely recognized by MIDI instruments).

It is more efficient to use a Note On message with a velocity of 0 to describe the release of a note because of a MIDI feature called *running status*. This is a rule that allows the status byte to be omitted when several messages of the same kind are transmitted in succession. The advantage of using running status is that it economizes on the amount of data transmitted—particularly important when sending a dense stream of data to a multitimbral tone generator.

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It's important to realize that a note will not necessarily stop sounding when a Note Off (or Note On with velocity of 0) message is received, due to the action of the instrument's internal *envelope generators*. These are devices which enable a sound to change volume, timbre, and sometimes pitch, throughout its duration. When a Note Off (or Note On with velocity of 0) message is received, the envelope generators for that note jump immediately to their release segment. A parameter called *release rate* (or *release time*) then determines how long it takes for the envelopes to return to zero; when the envelope controlling volume reaches its zero point, the sound is no longer heard.

It is not required of all MIDI instruments that they respond to velocity, and even if they do, the MIDI Specification does not give any guidelines as to how they will respond, although most instruments increase the loudness (as well as, in many cases, the brilliance) of a note as higher velocity values are received. The MIDI Spec suggests the application of an exponential curve when applying velocity to volume; however, manufacturers may substitute different curves.

MIDI specifies 128 note numbers (from 0 - 127) which correspond to the musical notes C2 - G8, with middle C defined as being note number 60. However, MIDI instruments do not have to necessarily cover the full range of note numbers, and there is no direction as to how notes that fall outside of the range of an instrument are to be processed. Additionally, there is no requirement that pitches be equal tempered, nor is there a defined frequency for the pitch of each key.



### ***GM***

GM specifies that all voices (including percussion voices played over the rhythm channel), must respond to Note On velocity messages, but need not respond to release velocity. There is a direction that the rhythm channel should ignore Note Off messages, using Note On with velocity of 0 instead.

GM also stipulates that note number 69 (middle A) have a frequency of 440 Hz. In the case of melodic sounds, the scale must be equal tempered. Note numbers 36 - 96 must sound correctly, with each voice playable in the highest and lowest octaves of the key range determined for that instrument type. Pitch and **temperament** are not defined for percussion voices played over the rhythm channel, but note numbers 60 - 72 must play with appropriate timbre and pitch.

### ***GS***

In addition to the GM guidelines stated above, GS instruments use System exclusive messages to set Scale Tuning and to enable various percussive voices to respond to Note Off.



XG instruments comply with all GM guidelines as stated above and add a number of new specifications:

- The **velocity curve** is defined by the formula  $20 \times \log(\text{velocity}^2)/127$ . Release velocity is not supported.
- Although in general XG instruments do not respond to Note Off messages, certain percussive voices (including brush-type drums, whistle and guiro sounds) respond to Note Off by default. System exclusive messages can be used to set other percussive voices to respond to Note Off.
- As with GS, the scale temperament of XG instruments is set by the internal parameter Scale Tune (the default is equal temperament), and can be modified with system exclusive messages.

### Voice Organization and Selection

The MIDI Specification does not include any definition of how voices are to be organized in an instrument's ROM or RAM memory. The original version of the MIDI Spec provides for the use of specialized channel messages called *program change* (“pc”) messages, which enable the remote selection of 128 different voices (numbered 0 - 127, though some instruments may use alternate numbering schemes). This program change message points only to a voice *number*—it does not in any way “identify” a sound. Bear in mind that the current operational mode (e.g., “Performance mode,” “Tone mode,” etc.) of an instrument can also have an effect upon how a received program change message is interpreted. It is also worth noting that, upon receipt of a program change message, many older instruments turn off any held notes being produced by that channel. However, most modern multitimbral instruments allow currently-sounding notes to continue, and apply the newly received program change value to the next-played note.

The MIDI instruments of the mid- and late-1980s rarely had enough memory capacity to store more than 128 voices at a time, but the instruments of today can store many hundreds—if not thousands—of voices. For this reason, a later revision of the MIDI Specification included the concept of “banks.” Each MIDI bank is a collection of up to 128 voices. Remote selection of particular voices within a bank is made, as usual, with program change messages. However, remote selection of banks is made using one or two special *control change* (“cc”) messages called Bank Select. These messages, which may be used separately or in conjunction with one another, are assigned to control #0 and #32. Control #0 is said to carry the Bank Select “Most Significant Bit,” or “MSB,” while control #32 is said to carry the Bank Select “Least Significant Bit,” or “LSB.” Each message on its own has 8 usable bits of data, enabling up to 128 different values to be designated. Together, the two messages yield 14 usable bits of data, enabling up to 16,384 different values to be designated. Thus, a MIDI instrument which utilizes both Bank Select messages can theoretically be directed to select any of up to 2,097,152 voices—16,384 banks of 128 voices each!

The data of a received Bank Select message is preserved until the next received Bank Select message. For this reason, it is not necessary to re-transmit a Bank Select message before each program change message if you wish to access a different voice within the currently selected bank.

### **GM**

In order to ensure that different tone generators play back music data in a compatible way, it is necessary that program change messages select equivalent sounds on any system. GM specifies the organization of 128 melody voices into 16 groupings of 8 voices each, accessed by standard program change messages. Collectively, these are known as the *GM Sound Set*:

- |                                       |                                  |
|---------------------------------------|----------------------------------|
| a. Piano (pc # 1 - 8)                 | i. Reed (pc # 65 - 72)           |
| b. Chromatic Percussion (pc # 9 - 16) | j. Pipe (pc # 73 - 80)           |
| c. Organ (pc # 17 - 24)               | k. Synth Lead (pc # 81 - 88)     |
| d. Guitar (pc # 25 - 32)              | l. Synth Pad (pc # 89 - 96)      |
| e. Bass (pc # 33 - 40)                | m. Synth Effects (pc # 97 - 104) |
| f. Strings (pc # 41 - 48)             | n. Ethnic (pc # 105 - 112)       |
| g. Ensemble (pc # 49 - 56)            | o. Percussive (pc # 113 - 120)   |
| h. Brass (pc # 57 - 64)               | p. SFX (pc # 121 - 128)          |

There is no requirement that precise names be used for the voices themselves (in fact, there is some variation in the names of the voices included by different instruments in their GM Sound Set), and, in some cases (usually in lower-priced computer sound cards), the same voice may be used for two or more program numbers. More importantly, there is no stipulation as to the type of process to be used for sound generation. This means that the quality of these 128 voices can vary greatly from manufacturer to manufacturer or from model to model. In other words, two makes and models of GM-compatible instruments receiving the same program change message will not necessarily play identical sounds; however, the two sounds should, at least in theory, be similar.

GM specifies that when a program change message is received while a note is playing, the currently-sounding note will continue and the newly received program change value will be applied to the next played note.

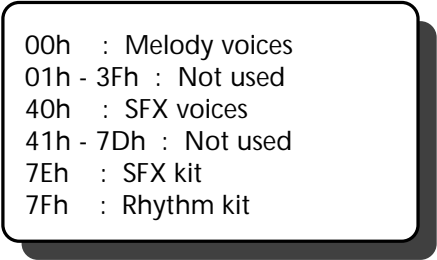
GM does not restrict the total number of available voices to the 128-voice Sound Set, but it provides no support for Bank Select messages, so there is no instruction as to how additional voices may be accessed.

### ***GS***

The GS format refers to a “Tone Map,” which allows for 128 banks, each containing 128 “tones.” However, the GS format only defines 98 “Variation” tones in addition to the 128-voice GM Sound Set (called “Capital” tones), making for a total of 226 voices (some GS-compatible instruments do offer more voices). These Variation tones are accessed through the use of Bank Select messages (the GM Sound Set is located in Bank 0, which is the default). In most instances, only the Bank Select MSB is used and the LSB value is simply set to 0. If a GS-compatible instrument receives a Bank Select message followed by a program change message that points to an empty voice slot, the instrument plays silence.



XG-compatible instruments expand greatly on the GS format by giving the Bank Select MSB and LSB separate meanings. The Bank Select MSB is used to select any of four bank types: Melody voices, SFX (Special Effects) voices, SFX kit (the SFX sounds, mapped one to a key), or Rhythm kit (various drum and percussion sounds, mapped one to a key):

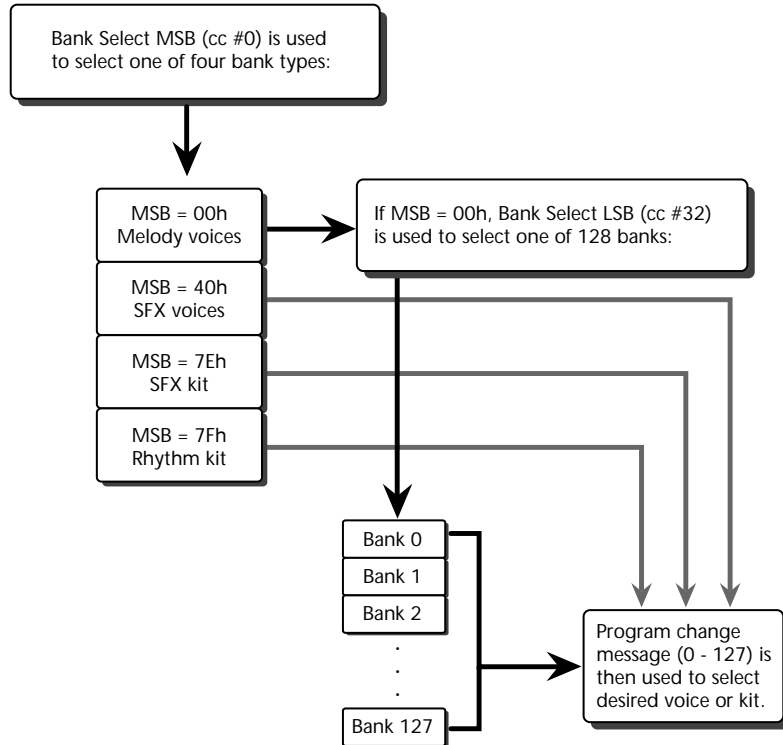


- 00h : Melody voices
- 01h - 3Fh : Not used
- 40h : SFX voices
- 41h - 7Dh : Not used
- 7Eh : SFX kit
- 7Fh : Rhythm kit

If the MSB is set to 00h (thus selecting Melody voices), the Bank Select LSB is then used to select any of 128 banks of voices, each containing 128 presets (which are accessed by standard MIDI program change messages).<sup>\*</sup> Program change messages are also used to select different SFX voices, SFX kits or Rhythm Kits. The illustration on the following page shows how this works:

*\* Even though the Bank Select LSB is unused when selecting SFX voices, SFX kits, or Rhythm Kits, it should be transmitted (with a data value of 0) regardless.*

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In all XG instruments, Bank 0 of Melody voices (the default setting) contains the standard GM Sound Set. Other banks contain what are known as “Variation” voices. These voices are **grouped in banks by their musical characteristics**, making it easy to locate particular kinds of sounds. The current XG Specification defines a minimum of 520 melody voices (including the GM Sound Set), and more may be added (the Yamaha MU80, for example, provides 729 XG voices). Unique sounds which are not direct variations on the GM Sound Set are located in their own “SFX” bank, accessed by setting the Bank Select MSB to 40h.

In line with the GM format, program changes take effect starting with the next Note On message. This ensures that XG instruments will not cut off voices which may be sounding when a program change message is received on a particular channel. Also, the processing of a Bank Select message is suspended until the next received program change message. This means that a Bank Select message by itself will not cause the sound to change.

In contrast to GS, when an XG instrument receives a Bank Select MSB/LSB message followed by a program change message that points to an empty melody voice slot, the instrument substitutes the corresponding GM Sound Set voice, ensuring that the voice will be heard with a sound that is at least similar to the one intended. (However, if a Bank Select MSB value of 01h - 7Eh [SFX voice, kit or unused MSB] is received and the tone generator does not have a voice corresponding to the last received LSB and program change, the tone generator will produce no sound for that channel.)

The XG format allows any MIDI channel to be easily utilized as a rhythm channel simply by transmitting a Bank Select MSB value of 7Fh, followed by an LSB of 00h and the desired program change message (for more information, see the [next section in this Guidebook](#)). Conversely, a channel which defaults for use as a rhythm channel (channel 10 and, in some XG instruments, channel 26 as well) can be easily converted for use as a Melody voices channel simply by transmitting a Bank Select MSB value of 00h, followed by an LSB of 00h and the desired program change message.



### Rhythm Channels

The MIDI Specification makes no reference to the use of *percussion voices* (voices where multiple rhythm sounds are mapped one to a key) or to the use of *rhythm channels* (MIDI channels dedicated to carrying rhythm information to be played by percussion voices).

#### **GM**

GM specifies that MIDI channel 10 is to be used exclusively as a rhythm channel, and further designates a single standard GM “Percussion Map,” in which note numbers 35 - 81 are assigned particular drum and percussion sounds. As with the GM Sound Set of melody voices, there is no requirement that precise names be used for the percussion voices themselves, and, in some cases, the same sound may be used for two or more voices. Again, there is no stipulation as to the type of process to be used for sound generation, so that the quality of the various percussion voices can vary greatly from manufacturer to manufacturer or from model to model. GM ensures compatibility only to the degree that a “Snare” sound played on one GM instrument will sound more or less like the “Snare” sound played on any other GM instrument.

#### **GS**

As with GM, GS-compatible instruments use channel 10 for rhythm parts. GS expands on GM, however, by expanding the range of the GM Percussion Map to include note numbers 27 - 87 and by adding a minimum of nine alternate “drum kits” and a single SFX kit (which add some variation drum sounds to the GM Percussion Map), accessed by transmitting program change messages over MIDI channel 10. However, when a GS-compatible instrument receives a program change message on channel 10 pointing to a drum kit that doesn’t exist, no sound is heard. A GS system exclusive message can be utilized to designate an additional rhythm channel which can optionally access an alternate percussion map. This message cannot be used for realtime change.



Following the GM convention, XG-compatible instruments normally use MIDI channel 10 as a rhythm channel (though, unlike GM, channel 10 can optionally be designated to play melody voices). However, as noted in the [previous section in this Guidebook](#), the XG format expands on GM by allowing additional channels to be designated for rhythm parts as well (and in real time), by simply transmitting a Bank Select MSB value of 7Fh, followed by an LSB of 00h and the desired program change message. XG-compatible instruments which support 32 MIDI channels normally use both channel 10 and channel 26 (the tenth channel in the second set of 16) as rhythm channels.

As with GS, program change messages transmitted on a rhythm channel are used to select alternate rhythm kits. The current XG Specification describes **eight alternate rhythm kits in addition to the GM Percussion Map** (assigned to Rhythm Kit #1, which is the default), and more may be added in future. In contrast to GS, when an XG-compatible instrument receives a program change message pointing to a rhythm kit that doesn't exist, it is ignored and the currently selected rhythm kit (the default Rhythm Kit #1, if none has been selected) is used, ensuring that sound is heard.

In addition, a full bank of “SFX Kits” (each containing SFX voices, mapped one to a key) is designated and can be accessed by transmitting a Bank Select MSB value of 7Eh, followed by an LSB of 00h and program change message (to select the desired kit). Again, when an XG-compatible instrument receives a program change message pointing to an SFX kit that doesn't exist, it is ignored and the currently selected SFX kit (the default SFX Kit #1, if none has been selected) is used, ensuring that sound is heard.

### Effects

The addition of effects—reverb, echo, chorus, flanging, phasing, distortion, and other types of signal processing—has become an integral part of modern electronic sound design. It is fair to say that a defined procedure for setting effects is an important requirement for music data compatibility. However, when MIDI was adopted in 1983, few if any electronic musical instruments had onboard effects. For this reason, the MIDI Specification does not provide any guidance for the use of MIDI messages to control effects. However, five controller numbers are designated for use as follows:

cc #91 : External Effects Depth  
cc #92 : Tremolo Depth  
cc #93 : Chorus Depth  
cc #94 : Celeste (Detune) Depth  
cc #95 : Phaser Depth

The interpretation and use of these is basically left to the discretion of the manufacturers of MIDI instruments. However, these MIDI control change messages are most commonly used to set send levels for different internal effects, with cc #91 usually used as a send level for reverb, which is the most commonly provided onboard effect. Because these are channel messages (as opposed to system messages), they may be used to set effects send levels for individual channels in a multitimbral instrument—and they can also be used for realtime change of send levels (the processing of system messages often causes audio output to be muted and so cannot be used for realtime change).

### ***GM***

GM makes no mention of the usage of effects.

### ***GS***

GS adds optional (though recommended) support for two internal effects: reverb and chorus. If these effects are provided, a minimum of eight preset varieties of each of these two types of effects are included, with system exclusive “Macro” messages used to select from among them.

If these effects are provided, reverb send level is determined by cc #91, and chorus send level is determined by cc #93. Non-Registered Parameter Numbers (NRPNS) can then be used to set reverb and chorus send levels for individual sounds within drum instruments. (See the [“NRPNS”](#) section in this Guidebook for more information.)



XG greatly expands upon GS by mandating the use of a minimum of three onboard effects: reverb, chorus, and “Variation.” The Variation effect may be used either in a standard send-return configuration, or in a **unity gain “insert” configuration**, and a system exclusive message is used to set the desired condition.

The XG Specification defines 4 basic and 4 extended preset reverb effect types; 3 basic and 5 extended preset chorus effect types; and 26 basic and 10 extended preset Variation effect types. System exclusive messages are not only used to select preset effects types but are also used to specify effects routings (allowing for **parallel** or variable amounts of **serial** routing) or even to make parameter changes to the effects themselves. Together, this allows the user to completely customize a sound’s effects from the ground up. Moreover, a user-defined realtime controller (such as a footpedal or wheel) can optionally be used to alter one effects parameter (usually dry/wet mix) in the selected Variation effect.

In XG-compatible instruments, reverb send level is determined by cc #91, chorus send level is determined by cc #93, and Variation send level is determined by cc #94. Non-Registered Parameter Numbers (NRPNs) are used to set reverb, chorus, and Variation send levels for individual sounds within drum instruments. (See the “[NRPNs](#)” section in this Guidebook for more information.)

XG also provides support for an optional fourth insertion effect as well as for an optional five-band master graphic equalizer. System exclusive messages are used to choose from among preset insertion effects types or eq curves and/or to alter the parameters of the selected effect (in the case of the five-band equalizer, to set the gain, center frequency, and **bandwidth** of each of the five bands).

### External Audio Input

The ability to input external audio signal into a MIDI tone generator and then control that signal via MIDI messages is a relatively new phenomenon, largely made possible through the increased availability of affordable **analog-to-digital converter chips**. This advanced feature enables realtime participation in the MIDI music being generated and effectively forges a bridge into the worlds of karaoke and multimedia.

Although the MIDI Specification provides no mention of, or support for, external audio input, it is worth noting that MIDI control change messages are utilized by some advanced audio mixers in order to provide automated mixdown capabilities under realtime control. The control data for these mixes can then be recorded into and played back from any standard MIDI sequencer.

#### *GM*

GM makes no mention of external audio input.

#### *GS*

GS makes no mention of external audio input.



XG is the first and only format to specifically provide support for one or more optional external audio inputs, called “A/D channels.” The digital signal from these channels (derived from the onboard A/D converter) is processed in the same way as the tone generator signals being produced by MIDI channels: overall level and pan position can be controlled in realtime, as well as send levels to any or all internal effects.

System exclusive messages are used to set A/D channel input gain, MIDI receive channel number, and on-off reception status for incoming volume (cc #7), pan (cc #10), and expression (cc #11) messages. System exclusive messages are also used to select from among various A/D channel presets, each of which call up complete settings complementary to the instrument type. For example, an A/D preset for a mic input might include reverb and compression effects, whereas one for guitar might include chorusing, echo and distortion effects.

### Control Change Messages

One of the most important aspects of making music is *expressivity*. The trained musician is able to impart subtle changes in volume, timbre, and pitch as notes are played. This integral part of the musician's craft is what makes music really come to life. MIDI enables expressivity in electronic musical instruments through the use of special channel messages called *control change* ("cc") messages. Here, realtime controllers such as wheels, sliders, and footpedals—or software emulations of these devices—can be used to impart change to a sound as it is playing. The MIDI Specification defines 128 different controllers, each given a unique *control number* from 0 to 127. Some of these numbers are defined (such as the previously discussed Bank Select MSB and LSB, provided by cc #0 and cc #32, respectively), while others are undefined and are reserved for future use. The most commonly used defined controllers are cc #1 (Modulation), cc #7 (Volume), cc #10 (Panpot), cc #11 (Expression), and cc #64 (Sustain).

All MIDI controllers have at least 8-bit resolution, so they can impart data values from 0 (full off) to 127 (full on), with a value of 64 (40h) representing a center detented position, if one exists. In addition, control numbers 0 through 31 can be given 14-bit resolution (allowing them to impart data values from 0 to 16,383) when used in conjunction with control numbers 32 through 63, which are reserved for optional use as the LSB (Least Significant Bit) for control numbers 0 through 31. This is the reason why the Bank Select message can allow access to up to 16,384 different voices when both the MSB (cc #0) and LSB (cc #32) are used.

Control numbers 16 - 19 and 80 - 83 are defined as "General Purpose Controllers," with no intrinsic function assigned to them. They may be freely used by a manufacturer for any added functions that require the transmission or reception of undefined controller data.

Control numbers 64 through 69 are assigned to functions normally associated with switches such as sustain or soft pedals (although they can also be used to send any continuous value from 0 to 127). For these controllers, a data value of 0 is used to represent a "switch off," and a data value of 127 is used to represent a "switch on."



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Control numbers 70 through 79 are defined as being “Sound Controllers” and, although manufacturers have the freedom to map functions to them, are intended to be used to alter voice parameters in real time. Default assignments for five of these controllers have been specified as follows:

Control #	Name	Default Assignment
70	Sound Controller #1	Sound Variation
71	Sound Controller #2	Harmonic Content
72	Sound Controller #3	Release Time
73	Sound Controller #4	Attack Time
74	Sound Controller #5	Brightness

Control numbers 120 - 127 are used to carry what are known as *Channel Mode messages*—see the “[Channel Mode Messages](#)” section in this Guidebook for more information.

For reference, [a chart in this Guidebook](#) shows a complete listing of commonly used MIDI controllers along with an indication as to whether these messages are utilized by GM-compatible, GS-compatible, or XG-compatible instruments.

### ***GM***

GM-compatible instruments are required to respond to the following seven control change messages: Modulation (cc #1), Volume (cc #7), Panpot (cc #10), Expression (cc #11), Sustain (cc #64), and RPNs (Registered Parameter Numbers) (cc #100 [LSB] and cc #101 [MSB]).

GM specifies that Modulation (cc #1) “will change the nature of the sound in the most natural (expected) way, i.e. depth of LFO; change of timbre; add more tine sound, etc.” This rather loose definition gives different manufacturers some leeway in how instrument voices respond to Modulation messages.

Volume (cc #7) is to be used to set the overall volume of the channel prior to music data playback, while Expression (cc #11) is to be used during music data playback to attenuate the programmed MIDI volume, thus creating diminuendos and crescendos. In the case of rhythm instruments, the balance between individual sounds is preset, and Volume and Expression messages adjust the overall level of the instrument.

Panpot (cc #10) is used to place the stereo position of the sound between hard left (0) and hard right (127), with a value of 64 (40h) indicating center position. GM-compatible instruments are not required to necessarily provide 128 steps of adjustment (few do), but at least three points (hard left/center/hard right) are necessary. It is not required that a currently-sounding note be moved when a Panpot message is received; it is acceptable to apply the new pan position starting with the next note. Some GM-compatible instruments therefore do not allow the pan position to be changed while a note is sounding. It is not required that rhythm instruments respond to Panpot messages since pan is preset for each individual sound. If a GM-compatible instrument does allow reception of Panpot over the rhythm channel, the entire set of percussion sounds will be shifted left or right.

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The Sustain message (cc #64) is the only pedal-related message whose reception is required by GM. In general, only On and Off values are recognized by GM-compatible instruments for Sustain, but some may accept continuous data for piano-type sounds, this allowing half-damper and re-damper effects. For this reason, GM specifies that Sustain data of 0 - 63 be considered Off and data of 64 - 127 be considered On.

RPNs (Registered Parameter Numbers) (cc #100 and #101) are discussed in detail in the “[RPNs](#)” section in this Guidebook.

### GS

GS-compatible instruments follow all GM guidelines concerning control change messages and also require that the following be recognized: Bank Select (cc #0 [MSB] and cc #32 [LSB]); Portamento Time (cc #5); Data Entry (cc #6 [MSB] and cc #38 [LSB]); Portamento (cc #65); and and NRPN (Non-Registered Parameter Numbers) (cc #98 [LSB] and #99 [MSB]). There is also optional support for the following control change messages: Sostenuato (cc #66); Soft (cc #67); Portamento Control (cc #84); External Effects Depth (cc #91); and Chorus Depth (cc #93). In addition, GS makes a recommendation that cc #16 and #17 be used for General Purpose Controller 1 (CC1) and General Purpose Controller 2 (CC2) respectively, where required.

As discussed in the “[Voice Organization and Selection](#)” section in this Guidebook, GS-compatible instruments provide a number of “Variation” tones in addition to the 128-voice GM Sound Set. These tones are accessed with the use of Bank Select messages although, in most instances, only the MSB (cc #0) is used and the LSB (cc #32) is set to zero.

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Portamento (cc #65) is a pedal-related On-Off function, with a data value of 127 interpreted by GS-compatible instruments as On, and a data value of 0 interpreted as Off. When On, Portamento Time (cc #5) sets the speed of a glide between consecutively played notes, while Portamento Control (cc #84) sets the key number that the new note will glide from. If the new note is the same as the Portamento Control value, it will sound without re-triggering (that is, it will play legato). When Portamento (cc #65) is Off, there is no glide regardless of the Portamento Time or Portamento Control values.

The Data Entry MSB and LSB (cc #6 and cc #38) are used in conjunction with optional NRPNs (Non-Registered Parameter Numbers) (cc #98 and #99), as discussed in detail in the [“NRPNs”](#) section in this Guidebook.

Sostenuto (cc #66) and Soft (cc #67) are pedal-related On-Off functions, with a data value of 127 interpreted by GS-compatible instruments as On, and a data value of 0 interpreted as Off. These replicate the actions of the center and left pedals of an acoustic grand piano, respectively. As indicated by its “chord hold” notation, the Sostenuto pedal sustains only those notes played at the time the pedal was depressed, with all new notes given no sustain. In an acoustic piano, the Soft pedal quiets the sound by shifting the hammers to fewer strings or by lowering the damper; the MIDI controller of the same name creates a similar effect by means of filtering.

As discussed in the [“Effects”](#) section of this Guidebook, GS-compatible instruments that provide (optional) internal effects use External Effects Depth (cc #91) to set the amount of reverb send level and Chorus Depth (cc #93) to set the amount of chorus send level.



XG-compatible instruments utilize all control change messages specified by both GM and GS (including all optional GS control change messages), and enable even greater expressivity because they are also able to receive a number of additional ones. These additional messages are as follows: Harmonic Content (cc #71); Release Time (cc #72); Attack Time (cc #73); Brightness (cc #74); and Celeste (Detune) Depth (cc #94).

The first four of these play a particularly important role since they allow continuously variable timbral changes to be made easily—and in real time—to any XG voice. Since these are all adjustments that are relative to the existing voice parameter settings, the end result will depend upon the original programming of the voice. The default setting for each is a data value of 64 (the zeroed center value), which produces no change. Harmonic Content (cc #71) modifies the resonance of the voice's lowpass filter. Data values higher than 64 cause the sound to become more nasal, while data values lower than 64 cause the sound to become more open. Brightness (cc #74) modifies the cutoff frequency of the voice's lowpass filter. Data values higher than 64 enable higher frequencies to pass through, (making the sound more brilliant), while data values lower than 64 cause increased filtering, making the sound warmer. The Attack Time (cc #73) and Release Time (cc #72) messages allow adjustments to be made to the voice's envelope. Attack Time describes how long it takes an envelope to reach maximum level after a note is played, while Release Time is the opposite, describing how long it takes an envelope to reach minimum level after a note is released. Data values higher than 64 cause the sound to attack or release more slowly, while data values lower than 64 cause the sound to attack or release more rapidly.

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As noted in the [“Effects”](#) section in this Guidebook, XG instruments must provide a minimum of three internal effects (in contrast to the optional use of internal effects in GS instruments). Despite its name, the Celeste (Detune) Depth message (cc #94) is used by XG-compatible instruments to determine the voice Variation effect send level. External Effects Depth (cc #91) is used to set the amount of reverb send level and Chorus Depth (cc #93) is used to set the amount of chorus send level. For more information, see the [“Effects”](#) section of this Guidebook.

Another area of XG that expands upon GS is that, for pedal-related controllers (Sustain, Portamento, Sostenuto, and Soft), data values in the range 0 - 63 are considered “Off,” while data values in the range 64 - 127 are considered “On.”

**Table of Control Change Messages (page 1 of 8)**

Ctrl. #		Function	GM	GS	XG
Decimal	Hexadecimal				
0	00	Bank Select (MSB)	No	Yes	Yes
1	01	Modulation (MSB)	Yes	Yes	Yes
2	02	Breath Controller (MSB)	No	No	No
3	03		No	No	No
4	04	Foot Controller (MSB)	No	No	No
5	05	Portamento Time (MSB)	No	Yes	Yes
6	06	Data Entry (MSB)	Yes	Yes	Yes
7	07	Main Volume (MSB)	Yes	Yes	Yes
8	08	Balance (MSB)	No	No	No
9	09		No	No	No
10	0A	Panpot (MSB)	Yes	Yes	Yes
11	0B	Expression (MSB)	Yes	Yes	Yes
12	0C		No	No	No
13	0D		No	No	No
14	0E		No	No	No
15	0F		No	No	No

**Table of Control Change Messages (page 2 of 8)**

Ctrl. #		Function	GM	GS	XG
Decimal	Hexadecimal				
16	10	General Purpose Controller 1 (MSB)	No	Opt.	No
17	11	General Purpose Controller 2 (MSB)	No	Opt.	No
18	12	General Purpose Controller 3 (MSB)	No	No	No
19	13	General Purpose Controller 4 (MSB)	No	No	No
20	14		No	No	No
21	15		No	No	No
22	16		No	No	No
23	17		No	No	No
24	18		No	No	No
25	19		No	No	No
26	1A		No	No	No
27	1B		No	No	No
28	1C		No	No	No
29	1D		No	No	No
30	1E		No	No	No
31	1F		No	No	No



**Table of Control Change Messages (page 3 of 8)**

Ctrl. #		Function	GM	GS	XG
Decimal	Hexadecimal				
32	20	Bank Select (LSB)	No	Yes	Yes
33	21	Modulation (LSB)	No	No	No
34	22	Breath Control (LSB)	No	No	No
35	23		No	No	No
36	24	Foot Control (LSB)	No	No	No
37	25	Portamento Time (LSB)	No	No	No
38	26	Data Entry (LSB)	Yes	Yes	Yes
39	27	Main Volume (LSB)	No	No	No
40	28	Balance (LSB)	No	No	No
41	29		No	No	No
42	2A	Panpot (LSB)	No	No	No
43	2B	Expression (LSB)	No	No	No
44	2C		No	No	No
45	2D		No	No	No
46	2E		No	No	No
47	2F		No	No	No

**Table of Control Change Messages (page 4 of 8)**

<b>Ctrl. #</b>		<b>Function</b>	<b>GM</b>	<b>GS</b>	<b>XG</b>
<b>Decimal</b>	<b>Hexadecimal</b>				
48	30	General Purpose Controller 1 (LSB)	No	No	No
49	31	General Purpose Controller 2 (LSB)	No	No	No
50	32	General Purpose Controller 3 (LSB)	No	No	No
51	33	General Purpose Controller 4 (LSB)	No	No	No
52	34		No	No	No
53	35		No	No	No
54	36		No	No	No
55	37		No	No	No
56	38		No	No	No
57	39		No	No	No
58	3A		No	No	No
59	3B		No	No	No
60	3C		No	No	No
61	3D		No	No	No
62	3E		No	No	No
63	3F		No	No	No

**Table of Control Change Messages (page 5 of 8)**

Ctrl. #		Function	GM	GS	XG
Decimal	Hexadecimal				
64	40	Damper Pedal (Sustain)	Yes	Yes	Yes
65	41	Portamento	No	Yes	Yes
66	42	Sostenuto	No	Opt.	Yes
67	43	Soft Pedal	No	Opt.	Yes
68	44		No	No	No
69	45		No	No	No
70	46	Sound Variation	No	No	No
71	47	Harmonic Content	No	No	Yes
72	48	Release Time	No	No	Yes
73	49	Attack Time	No	No	Yes
74	4A	Brightness	No	No	Yes
75	4B		No	No	No
76	4C		No	No	No
77	4D		No	No	No
78	4E		No	No	No
79	4F		No	No	No

**Table of Control Change Messages (page 6 of 8)**

Ctrl. #		Function	GM	GS	XG
Decimal	Hexadecimal				
80	50		No	No	No
81	51		No	No	No
82	52		No	No	No
83	53		No	No	No
84	54	Portamento Control	No	Opt.	Yes
85	55		No	No	No
86	56		No	No	No
87	57		No	No	No
88	58		No	No	No
89	59		No	No	No
90	5A		No	No	No
91	5B	Effects Send Level 1 (Reverb)	No	Opt.	Yes
92	5C	Effects Send Level 2 (Tremolo)	No	No	No
93	5D	Effects Send Level 3 (Chorus)	No	Opt.	Yes
94	5E	Effects Send Level 4 (Variation)	No	No	Yes
95	5F	Effects Send Level 5 (Phaser)	No	No	No

**Table of Control Change Messages (page 7 of 8)**

Ctrl. #		Function	GM	GS	XG
Decimal	Hexadecimal				
96	60	Data Increment	No	No	Yes
97	61	Data Decrement	No	No	Yes
98	62	NRPN (LSB)	No	Opt	Yes
99	63	NRPN (MSB)	No	Opt	Yes
100	64	RPN (LSB)	Yes	Yes	Yes
101	65	RPN (MSB)	Yes	Yes	Yes
102	66		No	No	No
103	67		No	No	No
104	68		No	No	No
105	69		No	No	No
106	6A		No	No	No
107	6B		No	No	No
108	6C		No	No	No
109	6D		No	No	No
110	6E		No	No	No
111	6F		No	No	No

**Table of Control Change Messages (page 8 of 8)**

<b>Ctrl. #</b>		<b>Function</b>	<b>GM</b>	<b>GS</b>	<b>XG</b>
<b>Decimal</b>	<b>Hexadecimal</b>				
112	70		No	No	No
113	71		No	No	No
114	72		No	No	No
115	73		No	No	No
116	74		No	No	No
117	75		No	No	No
118	76		No	No	No
119	77		No	No	No
120	78	All Sound Off	No	Yes	Yes
121	79	Reset All Controllers	Yes	Yes	Yes
122	7A	Local Control	No	No	No
123	7B	All Notes Off	Yes	Yes	Yes
124	7C	Omni Off	No	Yes	Yes
125	7D	Omni On	No	Yes	Yes
126	7E	Mono On	No	Yes	Yes
127	7F	Poly On	No	Yes	Yes

### RPNs

Registered Parameter Numbers, or “RPNs” for short, are simply a standardized list of voice parameters (for all MIDI instruments) that can be changed in real time using control change messages. Currently, the MIDI standards committees have approved three RPNs: Pitch Bend Sensitivity, Fine Tuning, and Coarse Tuning. To access these parameters, control change #101 (carrying the RPN MSB) and #100 (carrying the RPN LSB) are used, as shown below:

RPN MSB (cc #101)	RPN LSB (cc #100)	Parameter
00h	00h	Pitchbend Sensitivity
00h	01h	Fine Tuning
00h	02h	Coarse Tuning

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Following the transmission of these control change messages, a data value must be sent using either the Data Entry (cc #6 [MSB] and cc #38 [LSB]) or Data Increment/Decrement (cc #96 and cc #97, respectively) messages. If Data Entry is used to change the RPN and a range of 128 values is sufficient, the MSB alone (cc #6) can be used. If greater resolution is required, both the Data Entry MSB and LSB (cc #38) can be used. If Data Increment/Decrement are used to change the RPN, they will have the effect of adding or subtracting 1 from the current RPN value. However, neither can be used to change a setting that is already at its maximum or minimum value. For example, incrementation or decrementation of the Fine Tuning value never carries over into the Coarse Tuning value.

In order to conclude matters and “lock in” the changed RPN, a “Null” message must be sent. This is accomplished by transmitting an RPN MSB (cc #101) value of 127 (7Fh), followed by an RPN LSB (cc #100) value of 127 (7Fh). The example on the next pageshows how the Fine Tuning of a voice is adjusted (making the voice slightly detuned) using Data Entry (MSB only):



### Example: Changing The Fine Tuning With Data Entry

Bnh	65h	00h
-----	-----	-----

 RPN MSB (cc #101)

Bnh	64h	01h
-----	-----	-----

 RPN LSB (cc #100)

\_\_\_\_\_ (selects the Fine Tuning parameter)

Bnh	06h	dd
-----	-----	----

 Data Entry MSB (cc #6)

Bnh	26h	dd
-----	-----	----

 Data Entry LSB (cc #38)

\_\_\_\_\_ (sets the Fine Tuning value)

Bnh	65h	7Fh
-----	-----	-----

 RPN MSB (cc #101)

Bnh	64h	7Fh
-----	-----	-----

 RPN LSB (cc #100)

\_\_\_\_\_ (sets RPN to null)

*Note: n = MIDI channel number. dd = Data Entry value (00h - 7Fh, corresponding to a decimal range of -64 to +63).*

The Pitch Bend Sensitivity RPN determines the range of the pitch bend effect for the selected voice (for more information, see the [“Pitch Bend and Aftertouch”](#) section in this Guidebook). The Data Entry MSB (cc #6) sets the range in **semitones**, and the optional LSB (cc #38) sets the range in 100/128 **cent** steps.

Taken together, the Coarse Tuning and Fine Tuning RPNs represent a Master Tuning control for the selected voice. Each is set relative to the standard of A = 440. Coarse Tuning enables pitch to be adjusted from -6400 cents (a data value of 0) to +6300 cents (a data value of 127) in 100 cent steps. For the Coarse Tuning Parameter, the Data Entry LSB is ignored. A Coarse Tuning data value of 64 (the zeroed center position) produces no change. Fine Tuning enables pitch to be adjusted from -100 cents (an MSB/LSB data value of 0,0) to +100 cents (an MSB/LSB data value of 127,127) in 100/8192 cent steps. A Fine Tuning MSB/LSB data value of 64,0 (the zeroed center position) produces no change.

### ***GM***

GM-compatible instruments must be capable of receiving all three RPNs, as described above. GM does not support the Data Increment/Decrement control change messages (cc #96 and #97), however, so all data values are set using Data Entry MSB/LSB (cc #6 and #38) only.

### ***GS***

GS adds no new features to the GM guidelines stated above.



XG instruments comply with all GM guidelines regarding RPN. However, Pitch Bend Sensitivity is set in semitones only (the Data Entry LSB is ignored).

### **NRPNs**

Non-Registered Parameter Numbers (NRPNs) are similar to RPNs except that they provide a list of voice parameters unique to a particular instrument. This is an area of MIDI that is quite open, since manufacturers are given the freedom to implement NRPNs as they like. Control change #99 (carrying the NRPN MSB) and #98 (carrying the NRPN LSB) are used to access manufacturer-specified NRPNs.

As with RPNs, Data Entry messages (cc #6, carrying the MSB, and cc #38, carrying the LSB) or Data Increment/Decrement (cc #96 and #97) are used to enter or alter the data value. Also, as with RPNs, a “Null” message must be sent in order to “lock in” the changed data. This is accomplished by transmitting an NRPN MSB (cc #99) value of 127 (7Fh), followed by an NRPN LSB (cc #98) value of 127 (7Fh).

### ***GM***

GM makes no mention of NRPNs.

### GS

GS-compatible instruments may optionally use NRPNs as follows:

MSB	LSB	Description
01h	08h	Vibrato rate
01h	09h	Vibrato depth
01h	0Ah	Vibrato delay
01h	20h	Filter cutoff frequency
01h	21h	Filter resonance
01h	63h	Envelope attack rate
01h	64h	Envelope decay rate
01h	66h	Envelope release rate
18h	rr	Pitch coarse of specified drum sound
1Ah	rr	Level of specified drum sound
1Ch	rr	Panpot of specified drum sound
1Dh	rr	Reverb send level of specified drum sound (optional)
1Eh	rr	Chorus send level of specified drum sound (optional)

*Note: rr = drum instrument key number*

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Data Increment/Decrement (cc # 96 and #97) is not supported and the Data Entry LSB (cc #38) is ignored; all NRPN values are set with the Data Entry MSB (cc #6) only.

Note that NRPN MSB values 18h through 1Eh (drum parameters) are effective only for rhythm parts. When the drum instrument panpot data value (MSB = 1Ch) is 0, panning for that sound is random.



XG-compatible instruments expand on the GS use of NRPNs, as shown in the illustration on the following page.

The major improvements XG provides to the GS usage of NRPN is the addition of individual drum sound parameters to alter the filter cutoff frequency and resonance, envelope attack and decay rates, fine pitch, and Variation effect send level. Taken together, these NRPNs allow a much greater degree of customization over rhythm kits than is permitted by GS.

As with GS, Data Increment/Decrement (cc # 96 and #97) is not supported and the Data Entry LSB (cc #38) is ignored; all NRPN values are set with the Data Entry MSB (cc #6) only.

Note that NRPN MSB values 14h through 1Fh (drum parameters) are effective only for rhythm parts. As with GS, when the drum instrument panpot (MSB = 1Ch) data value is 0, panning for that sound is random.

### XG NRPNs:

MSB	LSB	Description
01h	08h	Vibrato rate
01h	09h	Vibrato depth
01h	0Ah	Vibrato delay
01h	20h	Filter cutoff frequency
01h	21h	Filter resonance
01h	63h	Envelope attack rate
01h	64h	Envelope decay rate
01h	66h	Envelope release rate
14h	rr	Filter cutoff frequency of specified drum sound
15h	rr	Filter resonance of specified drum sound
16h	rr	Envelope attack rate of specified drum sound
17h	rr	Envelope decay rate of specified drum sound
18h	rr	Pitch coarse of specified drum sound
19h	rr	Pitch fine of specified drum sound
1Ah	rr	Level of specified drum sound
1Ch	rr	Panpot of specified drum sound
1Dh	rr	Reverb send level of specified drum sound
1Eh	rr	Chorus send level of specified drum sound
1Fh	rr	Variation send level of specified drum sound

*Note: rr = drum instrument key number*

The example below shows how an NRPN might be used to change Vibrato rate. As illustrated, simply transmit an NRPN MSB (cc #99), followed by an NRPN LSB (cc #98), and then a Data Entry MSB (cc #6). Conclude with an NRPN Null message in order to “lock in” the data change:

### Example: Changing The Vibrato Rate



Bnh	63h	01h
-----	-----	-----

 NRPN MSB (cc #99)

Bnh	62h	08h
-----	-----	-----

 NRPN LSB (cc #98)

(selects Vibrato Rate parameter)

Bnh	06h	dd
-----	-----	----

 Data Entry MSB (cc #6)

Bnh	26h	00h
-----	-----	-----

 Data Entry LSB (ignored) (cc #38)

(sets the relative Vibrato Rate value)

Bnh	63h	7Fh
-----	-----	-----

 NRPN MSB (cc #99)

Bnh	62h	7Fh
-----	-----	-----

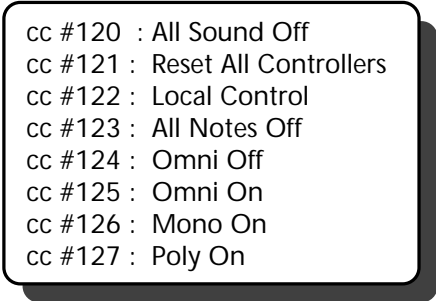
 NRPN LSB (cc #98)

(sets NRPN to null)

*Note: dd = Data Entry value (00h - 7Fh, with 40h the center value, corresponding to a decimal range of -64 to +63).*

### Channel Mode Messages

The MIDI Specification designates control change numbers 120 - 127 for carrying what are known as **Channel Mode messages**:



- cc #120 : All Sound Off
- cc #121 : Reset All Controllers
- cc #122 : Local Control
- cc #123 : All Notes Off
- cc #124 : Omni Off
- cc #125 : Omni On
- cc #126 : Mono On
- cc #127 : Poly On

Channel Mode messages #120 (All Sound Off) and #123 (All Notes Off) are used to mute all notes currently playing. The two messages differ in that when an All Sound Off message is received, all notes are turned off and all envelopes are zeroed as soon as possible; when an All Notes Off message is received, all notes are turned off but are allowed to cycle through their natural envelopes.

Channel Mode message #121 (Reset All Controllers) is used to reset the condition of tone generator controllers to what is considered to be an “ideal” state (discretion is left to individual manufacturers as to exactly what that state is).



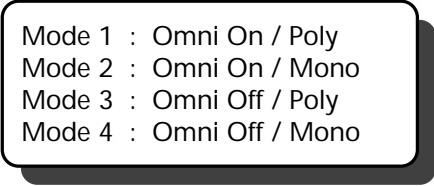
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Channel Mode message #122 (Local Control) is used by most keyboard synthesizers but is rarely received by tone generators. It determines the internal routing between the keyboard and sound-generating circuitry. When a Local Control Off message is received (data value of 0), this routing is interrupted so that the sound-generating circuitry is controlled only by incoming MIDI data—this is the desired state when connected to a MIDI sequencer that is capable of echoing back incoming data via its MIDI out port. When a Local Control On message is received (data value of 127), this routing is restored and the instrument returns to normal operation.

Channel Mode messages #124 - #127 determine how the device will receive all subsequent channel messages, including whether it will play notes polyphonically (Poly On) or monophonically (Mono On) and whether individual voices will respond selectively to MIDI data on specific channels (Omni Off) or non-selectively to MIDI data on all channels (Omni On). Every MIDI instrument must either be set to Omni On or Omni Off and it must either have Poly On or Mono On. This means that there are four basic modes of operation:



Mode 1 : Omni On / Poly  
Mode 2 : Omni On / Mono  
Mode 3 : Omni Off / Poly  
Mode 4 : Omni Off / Mono

Most devices are normally set to Mode 3, so that they respond to MIDI data on a selected channel or channels (as opposed to all channels) and can be played polyphonically (that is, chords can be sounded).

### ***GM***

GM-compatible instruments must be capable of receiving the following two Channel Mode messages: Reset All Controllers (cc #121) and All Notes Off (cc #123). When a Reset All Controllers message is received, the GM guidelines specify that data on all channels be reset as follows:

- Pitch bend is centered
- Channel pressure is zeroed
- Modulation is zeroed
- Expression is set to maximum (data value of 127)
- Sustain is set to Off (data value of 0)
- RPN is set to Null

### ***GS***

In addition to following the GM guidelines described above, GS-compatible instruments are also capable of receiving all other Channel Mode messages except Local Control (cc #122). GS instruments normally operate in Mode 3 but are changed to Mode 4 upon receipt of a Mono On message. Receipt of either Mono On or Poly On cause the same processing operation as an All Sound Off message. Because they cannot operate in Modes 1 or 2, receipt of Omni On or Omni Off causes the same processing operation as an All Notes Off message and Omni remains off.



XG-compatible instruments respond to Channel Mode messages in the same way as GS-compatible instruments.

### Pitch Bend and Aftertouch

Pitch bend and aftertouch are two additional realtime controllers that enable expressivity in MIDI instruments. As its name implies, Pitch Bend messages are used to alter a sound's pitch as it is being played, giving the MIDI musician the ability to "bend" notes up or down just as a guitarist can alter pitch in real time by physically bending strings. At first glance, it may seem as though Pitch Bend could have been included as one of the defined MIDI control change messages. However, it was given its own separate status not only because it is a frequently-used and indispensable function on synthesizers but also because of the human ear's unusual sensitivity to changes in pitch. For this reason, smooth pitch changes cannot be created using only a single data byte (yielding 8-bit resolution, or 128 possible data values); instead, two data bytes are required in order to provide 14-bit resolution (with 16,384 possible data values). Pitch change is created relative to a zeroed central value of 64,00 (40h,00h).

The MIDI Specification does not dictate the way in which an instrument is to implement Pitch Bend messages, so the end result will depend upon the particular instrument and voice selected. As discussed in the "[RPNs](#)" section in this Guidebook, the sensitivity of a particular voice to incoming Pitch Bend messages can be modified in real time using the Pitch Bend Sensitivity RPN. Keyboard instruments that provide a physical pitch bend controller (usually a center-detented wheel or paddle control) generally have a Pitch Bend Range parameter that sets the amount (in semitones) of pitch change that will take place when the controller is moved the maximum distance possible. If, for example, the Pitch Bend Range parameter is set to 12, moving the controller to its highest position will raise the pitch one full octave (that is, 12 semitones) and moving it to the lowest position will lower the pitch one full octave. Obviously, different Pitch Bend Range settings will result in different amounts of pitch change, but even if the same settings are used on two instruments made by different manufacturers, differences in the pitch shift curve (which describes the relationship between pitch bend controller position and pitch change) sometimes cause discrepancies in the pitch during a pitch bend. The MIDI Specification does not define a standard pitch shift curve.

Aftertouch is another specialized controller message that is generated by many MIDI keyboards. It is a stream of continuous data that reflects how hard a key is physically being pressed down (or, more rarely, how a key is moved from side to side) while a note is being played. This data can then be used by the receiving instrument to alter timbre, volume or pitch in real time; for example, a sound can be made brighter, louder, or given vibrato as a key is pressed down with increased force. As with Pitch Bend, the MIDI Specification does not dictate the way in which an instrument is to implement aftertouch messages, so the end result will once again depend upon the particular instrument and voice selected.

Actually, MIDI provides for two types of aftertouch: Channel Pressure and Polyphonic Key Pressure. They differ in that Channel Pressure is a message which affects all notes played on a particular MIDI channel, while Polyphonic Key Pressure is a message which is separately transmitted for each note being played. In other words, when a chord is played on an instrument that utilizes Channel Pressure, the pressure of each key will be detected independently and the highest value (that of the key being pressed most strongly) is transmitted as aftertouch. A receiving instrument capable of recognizing Channel Pressure messages then applies that value equally to all notes in the chord. In contrast, when a chord is played on an instrument that utilizes Polyphonic Key Pressure, the pressure of each key will be detected independently and all values transmitted as aftertouch. A receiving instrument capable of recognizing Polyphonic Key Pressure messages will then apply each value independently to each of the notes in the chord.

In practice, most MIDI keyboards are capable of generating Channel Pressure and virtually all MIDI tone generators are capable of receiving it. However, due to the required processing load, few instruments transmit or receive Polyphonic Key Pressure, even though it does provide greater expressive potential. One inherent problem caused by both kinds of aftertouch data (though more severely by Polyphonic Key Pressure) is the unintentional generation of dense streams of data which can sometimes cause timing problems if the **MIDI bandwidth** is exceeded. For this reason, many sequencers are capable of filtering incoming or outgoing aftertouch messages.

### ***GM***

GM-compatible instruments must be capable of receiving Pitch Bend and Channel Pressure messages for all melody voices (rhythm instruments are not required to receive either). The default Pitch Bend Range is specified as  $\pm 2$  semitones with Pitch Sensitivity set by RPN, but the pitch shift curve is not defined, so perfect pitch bend compatibility is not guaranteed between manufacturers. Similarly, the effect of Channel Pressure is not defined, so this is another area of possible incompatibility.

### ***GS***

GS-compatible instruments follow all GM guidelines as described above, and are also capable of receiving Polyphonic Key Pressure. The shift curve used for pitch bend is undefined.



XG-compatible instruments follow all GM guidelines as described above, and are also capable of receiving Polyphonic Key Pressure. The shift curve used for pitch bend is defined as linear by cents, ensuring pitch bend compatibility between XG instruments. The XG Specification also states that Pitch bend can be used to affect rhythm channels as well as melody voices.

### System Messages

MIDI System messages include messages that control the entire instrument and messages that handle data unique to a manufacturer and model. The concept of “channel” does not apply to System messages—they affect all voices. Many of these messages are used only for **synchronization** and the only System messages that are applicable to tone generators are the Active Sensing message (which prevents problems that could result from broken connections) and the broad category of System Exclusive messages (which set global functions such as operating mode and deal with sound and effects parameters). It is worth noting that the category of System Exclusive messages, which were originally intended to handle only proprietary manufacturer-specific data, was later expanded to include some general-purpose messages, known as Universal System Exclusive. Universal System Exclusive messages are further divided into realtime and non-realtime messages.

The Active Sensing message is a “dummy” message that, when recognized, is expected to be received by a MIDI instrument every 300 milliseconds. If it is not received, the instrument turns off all notes that are currently sounding. This acts as a kind of insurance policy against stuck notes caused by broken or inadvertently disconnected MIDI cables.

System Exclusive (“SysEx”) messages always begin with the hexadecimal number F0 (alerting the receiving instrument that a SysEx message is to come), followed by a registered ID code indicating the manufacturer and model of instrument, followed by data bytes. They always conclude with the hexadecimal number F7 (alerting the receiving instrument that the SysEx message has ended). However, the amount, format and use of the data carried by the message is entirely up to each manufacturer. This information is generally published and provided with the instrument owner’s manual. Third-party manufacturers (such as software developers creating editor or librarian applications) are free to use the published messages but not to modify them.

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Universal System Exclusive messages include the non-realtime messages Turn GM System On (hexadecimal “F0 7E 7F 09 01 F7”) and Turn GM System Off (hexadecimal “F0 7E 7F 09 02 F7”) and the realtime messages Master Volume (hexadecimal “F0 7F 7F 04 01 vv vv F7,” where vv = volume data [LSB sent first]) and Master Balance (hexadecimal “F0 7F 7F 04 02 bb bb F7,” where bb = balance data [LSB sent first]).



### ***GM***

GM recommends but does not require that Active Sensing be implemented. Nearly all GM instruments do include this feature.

The only System Exclusive messages that GM-compatible instruments must recognize are Turn GM System On and Turn GM System Off. If a GM-compatible instrument has operational modes that allow it to function other than as a GM instrument, the reception of the Turn GM System On message causes it to switch to GM mode and initialize itself. Even if the instrument functions only in GM mode, reception of this message will cause reinitialization to the following states:

- Program Change                      00 (first program)
- Modulation Depth                    00
- Volume                                100
- Pan                                     64 (center)
- Expression                            127 (maximum)
- Sustain                                00 (off)
- RPN Fine Tune                        64,00 (0)
- RPN Coarse Tune                     64,00 (0)
- RPN Null
- Pitch Bend                            64 (center)
- Channel Pressure (all channels)    0

The Turn GM System Off message is used to exit GM mode, but will be ignored if the instrument functions only in GM mode.

### **GS**

GS-compatible instruments recognize Active Sensing. They comply with all GM guidelines as stated above and add an initialization message called GS Reset (hexadecimal “F0 41 10 42 12 40 00 7F 00 41 F7”). This not only sets the instrument to a default state but also enables the reception of GS-specific NRPNs. Approximately 50 msec is required for this process to be completed. Older GS instruments defaulted to a GM operational mode on power-up; newer GS instruments default to GS operational mode (with all parameters set as if a GS Reset message were received).

In addition, GS specifies a number of System Exclusive messages for the alteration of voice and effects parameters, as well as global messages to set voice and channel assignments, scale tuning and effects routings.



XG-compatible instruments recognize Active Sensing. They also comply with all GM guidelines as stated above and add a number of new features. XG does not define sound parameters, but does define procedures for System operations common to all instruments: turning on XG mode, setting master volume and tuning, setting parameters, and dumping data. In all XG System Exclusive messages, the hexadecimal “43” that follows “F0” is the Yamaha ID. Next is the device ID (“1n,” where n = device number), and the “4C” that follows is the model ID, indicating an XG instrument.

XG-compatible instruments recognize the Universal System Exclusive message Turn GM System On. When this message is received, the instrument will select melody voices Bank 0 (the GM Sound Set) and resets all values to their default state with the exception of Master Tuning (see below for more information). The XG Specification also defines an initialization message called XG System On (hexadecimal “F0 43 1n 4C 00 00 7E 00 F7,” where n = device number). This not only sets the instrument to a default state but also enables the reception of XG-specific NRPNs. Approximately 50 msec is required for this process to be completed.

XG-compatible instruments must be capable of receiving the Universal System Exclusive realtime message Master Volume (used for fadeins and fadeouts) and also can utilize the Yamaha System Exclusive message Master Tuning (hexadecimal “F0 43 1n 27 30 00 00 mm ll cc F7,” where n = device number, mm = master tune MSB, ll = master volume LSB, and cc = checksum value [ignored]). This message provides a convenient way to tune all channels simultaneously (the Coarse and Fine Tuning RPN messages must be sent individually to each channel). The data values in the Master Tuning SysEx message is essentially the same as are used for the Coarse and Fine Tuning RPNs.

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In addition, XG defines a generic Parameter Change SysEx message, which can be used to alter almost every XG parameter, including voice and effects data, as well as messages to set the A/D input, effects routings, and optional master equalizer. The advantage to using one generic “template” such as this is that the procedure for setting parameters is basically the same for all XG instruments. The power of the XG Parameter Change messages cannot be understated—they allow the user to almost completely customize any XG instrument in order to best enhance the music being created with it.

XG also defines Parameter Request and Dump Request Sysex commands (requests for an instrument to transmit data for one particular parameter or all internal data). Parameter data is dumped in fixed block units, and the starting address of the block is specified by the message. These messages facilitate the use of offline devices such as patch editor/librarians and MIDI data filers for the permanent storage of XG SysEx data.

*Definition:*

**GM** - Abbreviation for “General MIDI.” Instruments that are GM-compatible follow a standardized set of rules for memory organization and drum mapping, as well as meeting a minimum set of requirements for the reception of selected MIDI messages.

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*Definition:*

**GS** - Abbreviation for “General Synthesis,” a standardized set of specifications for Roland tone generators which, though upwardly compatible with GM, expands on a number of areas.

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*Definition:*

**decimal** - A “base 10” mathematical system in which all numbers are represented by combinations of ten digits (0, 1, 2, 3, 4, 5, 6, 7, 8, 9).

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*Definition:*

**hexadecimal** - A “base 16” mathematical system in which all numbers are represented by combinations of sixteen digits (0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F).

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*Definition:*

**realtime changes** - Refers to adjustments which can be made virtually instantaneously, without interrupting music playback.

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*Definition:*

**automated mixdown** - A process by which the dynamic blending of various sounds is computer-controlled.

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*Definition:*

**graphic equalizer** - A signal processor that enables various bands of frequencies to be selectively attenuated or boosted.

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*Definition:*

**serial interface** - A type of computer connection where all data is sent down a single wire, one bit at a time.

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*Definition:*

**dynamically allocated** - A voice priority system whereby unused voices are “robbed” and made available as needed to play new notes.

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*Definition:*

**Hz** - Abbreviation for “Hertz,” the standard unit of measurement of frequency (where 1 Hz = one wavecycle per second).

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*Definition:*

**temperament** - Refers to the scaling difference between adjacent notes. In an “equal tempered” instrument, the difference between all adjacent notes is the same.

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*Definition:*

**velocity curve** - A mathematical representation of the correlation of increasing or decreasing velocity values.

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*Definition:*

**bits** - Abbreviation for “BInary digITS,” numbers which are either one or zero.

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### *Definition:*

### **XG Melody Sounds Bank Definitions:**

Bank #	Description	Bank #	Description
0	GM Sound Set	20	Resonant
1 - 2	Key Scaled Panning (KSP)	24	Attack Transient
3 - 5	Stereo	25	Release Transient
6	Single Element	26	Sweep
8	Slow Attack	27	Rezo Sweep
9	Fast Attack	28	Muted
10	Long Release	32 - 34	Detune
11	Short Release	35 - 36	Octave Layered
12	Fast Decay	37 - 38	Fifth Layered
13	Slow Decay	39	Bend Up/Down
14	Double Attack	40 - 42	Tutti
16 - 17	Bright	43 - 44	Velocity Switch
18 - 19	Dark	45 - 46	Velocity Crossfade
		64 - 127	Other Wave

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*Definition:*

**Rhythm kit -**

XG Rhythm Kits:

MSB	Prog #	Description
127	1	Standard Kit
127	2	Standard Kit 2
127	9	Room Kit
127	17	Rock Kit
127	25	Electronic Kit
127	26	Analog Kit
127	33	Jazz Kit
127	41	Brush Kit
127	49	Classic Kit

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*Definition:*

**unity gain “insert” configuration** - A configuration in which signal is routed directly to and from an effect with no boost or attenuation in signal.

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*Definition:*

**parallel routing** - A configuration in which two or more effects are connected in a freely defined order, making it possible for signals to be routed simultaneously to the inputs of various effects.

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*Definition:*

**serial routing** - A configuration in which two or more effects are connected in strict order, with the output from one being routed directly to the input of the next one in line.

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*Definition:*

**bandwidth** - The range of frequencies being affected.

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*Definition:*

**analog-to-digital converter chips** - Electronic chips that sample incoming electrical (analog) signal at very short, regular intervals and generate a stream of numbers (digital signal) that are equivalent to the voltage received at each interval.

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*Definition:*

**semitones** - In Western music, a semitone is the interval between directly adjacent notes (half a tone, or 1/12 of an octave).

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*Definition:*

**cent** - One hundredth of a semitone.

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*Definition:*

**Channel Mode messages** - Special MIDI control change messages designed to affect the overall operating system of an instrument.

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*Definition:*

**MIDI bandwidth** - 31.25 kBaud, or 31,250 bits of information per second.

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*Definition:*

**synchronization** - The process of having events line up with one another. MIDI clock, song position pointer, and MIDI Time Code (MTC) messages are examples of system messages used for synchronization.

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