This section first deals with several basic conceptual questions about synthesizers. While we have distilled the information as much as possible, some topics have philosophical or complex origins that do not lend themselves to simple explanations. The balance of the section provides an overview of how the CS-80 operates, much of which can also apply to other synthesizers.

What is a Synthesizer

A synthesizer is an audio processor that has a built-in sound generator (oscillator), and that alters the envelope of the sound with voltage controlled circuitry.

Synthesizers can produce familiar sounds and serve as musical instruments, or they can create many unique sounds and effects of their own. The synthesizer operates by creating each basic element of sound and then providing you with separate controls for each element.

You don't have to use all the many controls on the synthesizer to create a complete sound. In fact, often only a handful of the available controls need be used, depending on the sound you wish to achieve.

The Difference Between Synthesizers & Electric Organs

An electric organ offers a wide variety of preset sounds at the touch of a finger. Synthesizers usually offer no presets, or very few of them, instead providing an infinite variety of adjustable sounds. The CS-50, CS-60 and CS-80 offer many presets and infinitely adjustable sounds as well.

Organs utilize different means to generate sound than do synthesizers. Because of this, most organs are polyphonic, meaning that you can play many notes simultaneously, whereas most conventional synthesizers allow you to play only one note at a time. The CS-Synthesizers, however, incorporate additional circuitry that allows you to play several notes at a time (4 on the CS-50 and 8 on the CS-60 and CS-80).

Why Use a Synthesizer

Many of the sounds that can be created with a synthesizer would be either impossible or highly impractical to create with acoustic instruments. Also, the synthesizer can give you common acoustical sounds with much greater convenience than would otherwise be possible. For instance, you can adjust the controls to "stretch" a common instrument, like gradually transforming a piccolo to a Bass flute, or even to a 20' long flute, if there were such a thing. Similarly, the synthesizer allows instant or gradual transitions from the sound of one instrument to another.

The Elements of a Synthesizer

One section, the VCO, establishes the pitch or frequency of the note, as well as the basic tone (timbre). Another section, the VCF, shapes the tone or emphasizes portions of it. Another section, the VCA, affects the loudness of the notes. Either the VCF, the VCA, or both may be used to "turn on" and "turn off" the sound in a controlled pattern, forming the notes as you play the keyboard. The control that forms the notes is provided by Envelope Generators (EG), one for the VCA and one for the VCF. The synthesizer also houses many other functions to modify the basic sounds for a variety of effects.

Yamaha CS-series synthesizers, because they are polyphonic, are actually equipped with several VCO's, VCF's, VCA's and EG's: 16 sets on the CS-80 for creating each of the 8 notes times 2 voices that can be played simultaneously.

Why Voltage Controlled Circuits are used in Synthesizers & How They Work

You can set up voltage controlled circuits to make changes automatically. Suppose you have a sub oscillator that produces a continuously changing voltage (AC), such as the slow sine wave from the CS-80's Sub Oscillator. If you apply that voltage to the control input of a Voltage Controlled Amplifier, the sound passing through that amplifier will go up and down in level—creating a tremolo effect. (This is exactly what happens when you move down the VCA lever in the Sub OscillatorSection.) At this point you are listening to one sound source that is being **modulated** or controlled by something else, a sine wave. If you increase the SPEED of the Sub Oscillator, the rapid changes in control voltage will make the sound level change so fast that beating occurs, producing secondary tones.

You can also adjust a voltage controlled circuit manually, if you wish, just like any conventionally controlled circuit. For example, you might achieve the same slow-speed tremolo effect by continuously moving a Volume control up and down, if you had the fingers free to do it. However, you could not possibly move that volume control fast enough or smoothly enough by hand to produce secondary tones. Thus, voltage controlled circuits enable you to do things that could not be readily accomplished with purely manually controlled circuits.

Amplifiers (VCA's) are not the only voltage controlled circuits in a synthesizer; filters and oscillators may also be voltage controlled. In all instances, the amount of change in the sound is proportional to the voltage applied to the control circuit. The same sine-wave voltage from the Sub Oscillator that created tremolo in the VCA when applied to the control input of a VCF would create wah-wah, or when applied to a VCO would create vibrato.

It is not at all important for a player to understand about voltages and control circuits to program and play the CS-80. When you set the controls and levers so the sound is "right," you are probably adjusting control voltages.

The synthesizer consists of sound producing and sound modifying circuits, all related by a number of signal paths and control circuits. Oscillators and Noise Generators produce the raw ingredients for sounds. Wave Shape Converters, Filters, Amplifiers, a Ring Modulator, a Tremolo, and sub oscillators further modify the sound (the audio signals). These circuits, plus the distinction between audio and control functions, are detailed below. While voltages are discussed, it is not really necessary to understand how voltages work; when you move the controls and knobs, you are adjusting voltages inside the synthesizer.

Audio Signals & Control Voltages

Electric currents that flow through synthesizers can be thought of in two categories: audio signals and control voltages. The audio signals constitute the actual sound as it is generated, modified, and ultimately fed to the output. The control voltages themselves are never heard, but are instead used to adjust the circuits which process the audio.

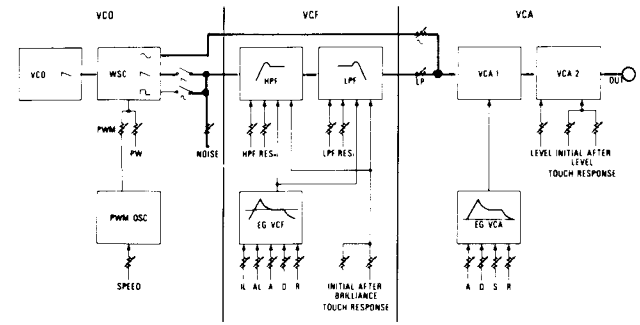
Audio signals are alternating currents (AC) with frequencies in the audible range which, as you probably know, covers about 10 octaves from 20 cycles per second (Hz) to 20,000 cycles per second (Hz). Audio signal voltages vary at different points in the synthesizer, but they average about 0.775 volts at the output when the rear panel HIGH/LOW switch is at HIGH position (0dBm into 600 ohms).

Control voltages are usually 10 volts or less, and may be dc (direct current) or AC (alternating current). AC control voltages vary in frequency from very low, sub-audio frequencies (1/2Hz) up to the audio frequency range (as high as 500Hz or more). The effect produced by a voltage controlled circuit will vary in proportion to the control voltage applied. For example, a VCA (voltage controlled amplifier) will cause the **audio signal** to be higher in volume when the **control voltage** is higher in level. If a steady dc control voltage is applied to the VCA, the volume of sound coming out of the VCA will increase by a proportionate amount and will remain at that level. If an AC control voltage is applied to the same VCA, then the volume will vary up and down, corresponding to the variations of the AC voltage; this is AM, or amplitude modulation.

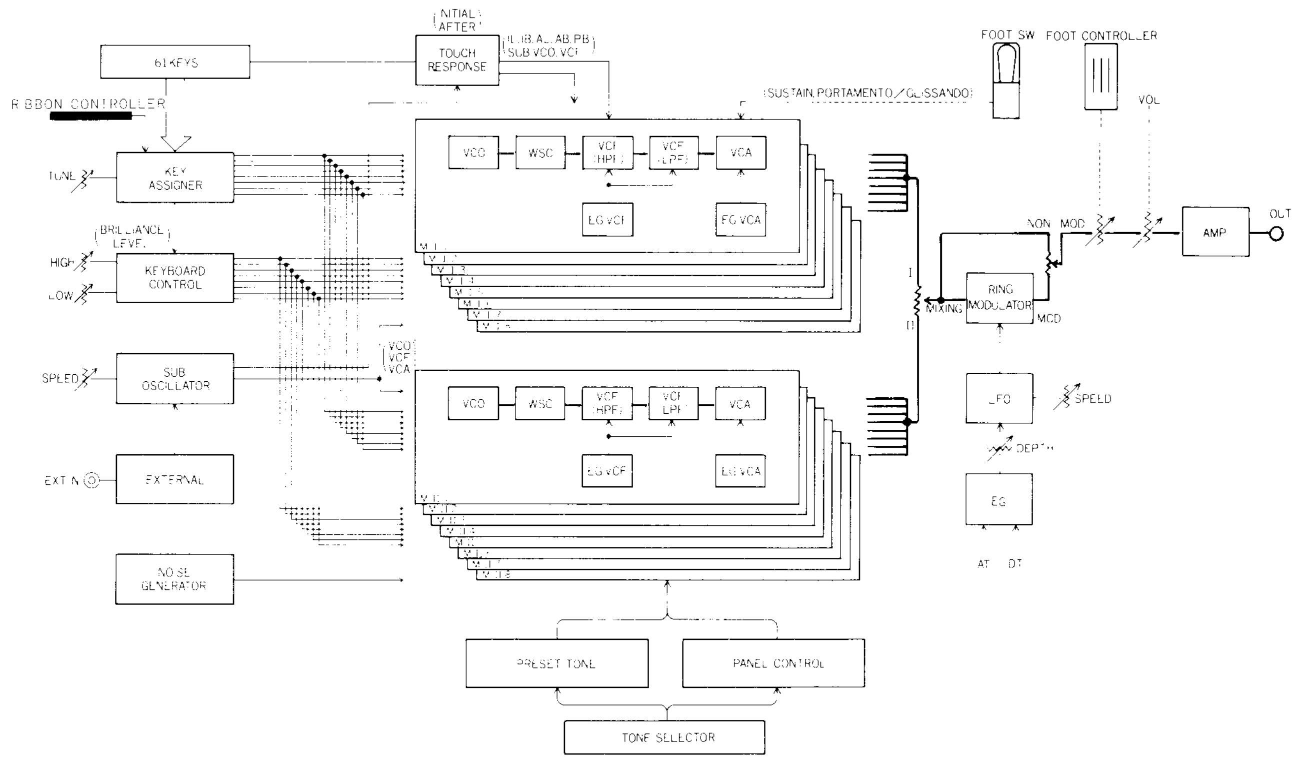
When a dc voltage is applied to a VCO (voltage controlled oscillator), the oscillator increases its frequency. When an AC control voltage is applied to a VCO, the frequency varies up and down, producing an effect known as vibrato or FM (frequency modulation). Similarly, when AC or dc voltages are applied to VCF's (voltage controlled filters), the filter characteristics change; the cutoff points move up or down. Refer to the programming block diagram on this page, which represents the functions of one of the programmable panels. This is the same diagram appearing on the memory panel cover, and is often helpful as a reminder of how the panel functions are related to one another. A key to the block diagram symbols is shown below the diagram. Audio signal paths run from left to right, as shown by the horizontal lines that join the blocks (colored lines). All vertical lines that point to the blocks represent control voltage paths. The block diagram is divided into three sections which correspond to the VCO, VCF and VCA sections of the panel; the TOUCH RESPONSE section is diagrammed as being part of the VCF and VCA sections, since it actually effects both of these functions.

A more complete block diagram of the full synthesizer is shown below Like the simplified block diagram, audio signal flows from left to right. However, unlike the simplified block diagram, vertical and horizontal lines do not distinguish control and audio signals; audio signals are still shown by the colored lines and control signals are shown by the black lines.

Programmable Panel Block Diagram



A = Attack Time
AL = Attack Level
AMP = Amplifier
D = Decay Time
EG = Envelope Generator
EXT IN = External Input
HPF = High Pass Filter
IL = Initial Level
LPF = Low Pass Filter
PW = Pulse Width
R = Release Time
S = Sustain Level
TUNE = Pitch Controls
AFTER = After Touch Response (Pressure)
INITIAL = Initial Touch Response (Velocity)
LFO = Low Frequency Oscillator
M1-M8 = Main Sound Generating Circuit Boards
MOD = Modulation or Modulated Signal
PWM = Pulse Width Modulation
PWM OSC = Pulse Width Modulation Sub Oscillator
RES_H = High Pass Filter Resonance
RES_L = Low Pass Filter Resonance
VCA = Voltage Controlled Amplifier
VCF = Voltage Controlled Filter
VCO = Voltage Controlled Oscillator
WSC = Wave Shape Converter (Part of VCO)



Overall Synthesizer Block Diagram

Oscillators

An **oscillator** is a circuit that produces AC voltage, generating voltages which go up and down in level according to some regular, defined pattern (waveform) and at some defined rate (frequency). There are many types of oscillators, some for very low frequencies and others for audio frequencies. Oscillators that operate in the audio frequency range are generally used as sources of sound.

The **VCO** is a voltage controlled oscillator. The CS-80 has sixteen main VCO's, one VCO for each of 8 notes times the two voices. Any main VCO is capable of producing all the notes, but only one note at a time. When you play the keyboard, special digital circuitry assigns different control voltages to the available VCO's so that the desired notes are produced.

Wave Shape Converters

The CS-80's main VCO's produce sawtooth waves. These waves may be used, unaltered, as the sound source, but they can also be processed by the **wave shape converter** (WSC) to form square waves or sine waves, as desired. The WSC's are considered to be part of the VCO's.

Noise Generator

A **noise generator** is like an oscillator that is constantly and rapidly changing its frequency and its waveform so that the output appears to be a random mixture of all sounds simultaneously. White noise is a type of noise that has equal level, on the average, across the full audio spectrum. The noise generator is not voltage controlled, but is included in the VCO section of the programmable panels because it introduces noise at the same point in the circuit as the VCO's: just before the filters.

Filters

A **filter** is a circuit that allows some frequencies to pass through it, but eliminates other frequencies. In the CS-80, there are two types of audio filters, high pass (HPF) and low pass (LPF). (Many synthesizers have only a low pass filter.)

A **low pass filter** blocks all audio signals above its cutoff frequency (cutoff point). When the LPF cutoff point is set at a high frequency, it is said to be "wide open" because the fundamental note and all its harmonics (overtones) are below the cutoff point and will pass through the filter. As the LPF cutoff point is lowered, more and more of the harmonics and then the fundamental are eliminated, and the filter is said to be "closed down."

A **high pass filter** blocks all audio signals below its cutoff frequency. When the HPF cutoff point is set at a low frequency, it is said to be "wide open" because the fundamental note and all its harmonics are above the cutoff point and will pass through the filter. As the HPF cutoff point is raised, the fundamental is blocked, then the lower harmonics, and eventually all harmonics, so the filter is said to be "closed down."

A **VCF** is a voltage controlled filter. It can be an HPF or an LPF. In fact, the CS-80's VCF's actually consist of two filter sections each, an HPF and an LPF, as described above. Thus, the CS-80 has 16 VCF's (32 filter sections), one for each of the 16 main VCO's. The cutoffs can be changed automatically by the Filter envelope (IL-AL-A-D-R) or manually by moving a filter slider (HPF or LPF).

When you play a note on the CS-80, the sound generated by a VCO goes through the HPF section of the VCF, then through the LPF section of the VCF. The VCF cutoff frequencies "track" the note played, moving up in frequency as you move up the keyboard, so that the tonal spectrum of the notes remains consistent. Recall that the LPF is wide open when its cutoff point is high, yet the HPF is wide open when its cutoff point is low.

Together, the HPF and LPF sections of the VCF may be considered to be a **bandpass filter** because a defined band of frequencies is allowed to pass between the two filter cutoff points. As the HPF cutoff point is raised and/or the LPF cutoff point is lowered, the width of the bandpass is decreased until there is no bandpass (no sound). Thus, we can speak of the VCF as being a bandpass filter, even though no such label appears on the panels. If either of the two filter sections is completely closed down, then it will block all sound, and the position of the other filter section makes no difference because you won't hear anything.

The HPF and LPF filters each have a **resonance** slider. These controls only have an effect if their corresponding HPF or LPF slider is partially closed. As the resonance of a given filter is increased, a narrow range of frequencies is boosted (increased in level)—the frequencies centered just at the cutoff point—because the cutoff point is resonating.

Resonance has no effect when a filter is wide open because the cutoff point is well beyond the limit of the fundamental or overtones, so the boost falls in an area where no signal is present. However, as a filter is closed down, the effect of resonance becomes more noticeable; resonance will tend to emphasize a given harmonic or the fundamental, depending on the filter cutoff (HPF or LPF setting). Resonance also causes additional phase shift which can be heard if the filter cutoff point is changed while a note is being played.

Amplifiers

An amplifier is a device that increases the volume or the power of a signal. Some amplifiers, especially VCA's, also can be used to decrease the power or volume. When an amplifier decreases the volume to inaudibility, it is turning the sound OFF; conversely, when an amplifier increases the volume to audibility, it is turning the sound ON.

Most of the amplifiers in the CS-80 are **VCA's** (voltage controlled amplifiers), and they generally operate at medium line levels. Thus, external power amplifiers, such as a PA system or guitar amplifier head, are required to boost the power sufficiently to drive loudspeakers.

VCA's offer several advantages for synthesizers in addition to their ability to attenuate (lower) the volume as well as increase it. With conventional type amplifiers, audio signals must be routed through complex paths and it may be necessary to have a separate amplifier to achieve each effect—volume control, tremolo, note definition by an envelope, and so forth. With a VCA, on the other hand, numerous control voltages can be mixed together and fed to one amplifier, producing all the desired effects with a minimum of amplifiers. Thus, VCA's enable the circuitry to be simplified while reducing the potential for noise and distortion.

There are two VCA's for each of the 16 main VCO/VCF sound sources. These VCA's are used to "define" notes—to turn them on, vary their volume, and turn them off—as each note is played; this is done by a control signal from the amplitude envelope generator, as described in subsequent text. The VCA's will also vary the volume in a regularly modulated fashion when they are provided with an AC control signal from the sub oscillator.

Sub Oscillators

A **sub oscillator** generates AC voltages which are used to modify existing audio signals. The CS-80 has an overall SUB OSCILLATOR [11] and several other sub oscillators. For example, the PULSE WIDTH MODULATION (PWM) available on the panels and memory is produced by sub oscillators. The TREMOLO/CHORUS effect also includes a sub oscillator, as does the RING MODULATOR.

To understand how a sub oscillator is used, one should recognize that AC and dc control voltages are often mixed (summed) for combined functions. For example, the VCA's level (volume) control input is fed by several sources of AC and dc voltages. The level can be varied up and down for a tremolo effect by applying an AC control voltage which is produced by the SUB OSCILLATOR section [11]. The depth of the tremolo effect would be adjusted by applying more or less of the AC voltage produced by the sub oscillator to the VCA. The speed of the effect would be adjusted by changing the sub oscillator's frequency. The average volume around which the tremolo is centered is adjusted by changing the dc control voltage, using the LEVEL slider [41].

Pulse width refers to the amount of time a square wave is OFF, and is also known as "duty cycle." A perfectly symmetrical square wave would have a 50% duty cycle (OFF as much as ON), and a narrow pulse width square wave might have a 90% duty cycle (which sounds the same as a 10% duty cycle—ON 10% of the time). The PW control [22] applies a dc control voltage to the WSC circuit which sets the basic pulse width (duty cycle) of the square wave at any point between 50% and 90%. The PWM control [21] applies an AC control voltage to the same point in the WSC (wave shape converter) circuit, thereby varying (modulating) the pulse width. That PWM signal is created by a sub oscillator, and the SPEED [20] of pulse width modulation is actually changed by adjusting the frequency of the PWM sub oscillator.

The sub oscillators in the RING MODULATOR and TREMOLO/CHORUS sections function similarly to the main SUB OSCILLATOR and the PWM sub oscillators described above. Changing the amount of AC voltage applied varies the depth of the effect, and changing the frequency of the sub oscillator varies the speed of the effect.

Envelope Generators

An envelope generator is a circuit which produces a single, carefully defined waveform – a one-shot voltage pattern – when the generator is stimulated by a pulse (trigger impulse) from the keyboard. The envelope itself is a changing dc voltage which rises from zero (no voltage) to some maximum point, and eventually falls back to zero in a pattern which is varied by using the envelope generator's controls.

No sound goes through the envelope generator itself. Instead, the envelope generator's output is fed to the control input of a VCF or a VCA. There are actually 16 envelope generators for the VCF's and another 16 for the VCA's.

Envelope generators (EG) which control VCF's are known as filter envelope generators. In the CS-80, the filter EG's are unique envelope generators, having 5 sliders: Initial Level (IL), Attack Level (AL), Attack Time (A), Decay Time (D) and Release Time (R). These sliders all change the "shape" of the envelope, which in turn creates changes in HPF and LPF filter cutoff points each time a note is played. When all the filter EG sliders are set at minimum, there is no output from the EG, hence no change in filter characteristics.

Envelope generators which control the VCA's are known as amplitude envelope generators. In the CS-80, the amplitude EG's have 4 sliders: Attack Time (A), Decay Time (D), Sustain Level (S) and Release Time (R). These sliders change the "shape" of the envelope, which in turn creates changes in the volume (amplitude) of the sound when you play a note. When all amplitude EG sliders are set at minimum, there is only a very brief pulse of output voltage from the EG, hence only a brief "blip" of sound can be heard.

Conventional synthesizers sometimes have simplified EG's, with only Attack Time (A) and Release Time (R) sliders; the same A-R effect can be achieved on the CS-80 by setting the VCA Decay Time (D) and Sustain Level (S) sliders at maximum, and using only the A and R sliders.

The Keyboard & Related Circuits—General

As suggested in the preceeding paragraphs, each channel of the CS-80 has eight sets of note-generating circuit components, each set consisting of a VCO, WSC, VCF and VCA, and two EG's. When you move any one of the panel programming controls, it actually affects all 8 sets of note-generating components on the corresponding channel. While there is 8 note simultaneous capability, there are 61 keys on the keyboard. Thus, there has to be a way of assigning the keys you play to those 8 different note generating circuits. This is the function of the Key Coder and Key Assigner circuits.

The Key Coder & Key Assigner

The key coder and key assigner are digital circuits, a sort of micro-computer. The key coder produces a digital "word" that describes the note (or notes) played. The key assigner "looks" to see which, if any, of the note-generating circuits is available and, at the same time, it continuously monitors the key coder to see which notes are being played. The assigner then feeds the digital word for each note to one of the note-generating circuits. If a ninth key is depressed while 8 other keys are already being played, the assigner cannot do anything with that additional information, so no new note will be heard until one of the first 8 keys is released.

If you play only one key, and play it 8 times in succession, the key assigner will successively feed the "word" for that note to each of the 8 note-generating circuits. Since each circuit's VCO, VCF and VCA will differ slightly from the next due to normal component tolerances, the 8 notes will not be identical. This is how the CS-80 produces such natural sound, rather than a mechanical, "too perfect" sound.

D-to-A Converters

The note-generating circuits each have a D-to-A Converter (digital to analog) which changes the digital code for a note into a corresponding dc voltage. That dc voltage level is fed to the VCO, which reacts to set the pitch (frequency) of the note. The voltage is also fed to the VCF, which reacts by moving the HPF and LPF filter cutoff frequencies so they maintain the desired relationship to the frequency of the note (so they track).

Trigger Output

The instant a key is depressed, the keyboard produces a trigger output, in addition to the digital word. The trigger is a brief voltage pulse that occurs once, and it is routed to two envelope generators, the filter EG in the VCF section and the amplitude EG in the VCA section. The amplitude EG reacts to the trigger and generates a one-shot waveform to "shape" the volume of the note according to the preset or programmed A-D-S-R characteristics. The filter EG reacts to the trigger and produces a one-shot waveform which changes the tone of the note if the IL-AL-A-D-R controls are appropriately programmed (or if VCF envelope is part of the preset patch).

Touch Sensitivity

To understand how the touch sensitivity works, it is necessary to understand the method by which the keyboard itself functions. The CS-80 keyboard has a proprietary, patented technique for switching a note ON when you strike a key, plus a secondary system for adding effects by pressing harder after the key hits bottom.

Velocity Sensitivity

At the rear of each key, there is a single pole/double throw leaf switch. When you begin to press down a key, the first set of switch contacts open. Then, as the key nearly hits bottom, the second set of switch contacts close. The closing of the second set of contacts activates the key coder, key assigner, and subsequent circuits to generate the note. However, the time interval between the opening of the first contact pair and the closing of the second contact pair is used by another circuit to produce a control signal.

The Key Timing Circuit utilizes sophisticated logic that converts the time interval between switch contact opening and closing into a brief output voltage pulse. The faster a key is pressed down, the shorter the time of switch contact action, and the higher the voltage level of the pulse. The key timing circuit pulse is used to create various initial touch sensitivity (velocity sensitive) effects, depending on how the presets, programming, and TOUCH RESPONSE sections are set.

PITCHBEND [12] is an initial touch sensitivity effect whereby the timing circuit pulse is reversed in polarity and applied to the VCO. Thus, the frequency of the VCO is initially forced lower by the negative voltage pulse from the Key Timer Circuit, and then comes up to the note's designated frequency as the pulse dies out.

The INITIAL LEVEL lever [43] in the programming panel applies the key timing pulse to the VCA, thus increasing the volume of the note for the duration of the pulse. The faster you strike a key, the higher the voltage pulse and the higher the volume. This effect is programmed into some of the preset patches. Similarly, the INITIAL BRILLIANCE lever [42] applies the key timing pulse to the VCF, thus raising the cutoff frequency of both filters. This increases the amount of high frequencies which can pass through the VCF by an amount proportional to the voltage of the timing pulse, and only for the duration of the pulse.

Pressure Sensitivity

A sensor beneath the front of each key is used for the AFTER (pressure sensitive) effects. The harder you press a key after it first touches bottom, the higher the voltage allowed to get through a variable pad in the key's sensor. Various effects are produced by the voltage, depending on how the presets, programming, and TOUCH RESPONSE sections are set; the keyboard's after voltage is applied to the control input of the appropriate voltage controlled circuits.

Keyboard Control

The keyboard control HIGH and LOW levers affect the upper and lower portions of the keyboard separately, with increasing effect toward the ends of the keyboard. This is done for LEVEL and for BRILLIANCE. The effect is actually achieved by a digital circuit which interprets the position of each note played on the keyboard and produces a proportional amount of dc voltage. With the HIGH levers, the higher the note, the higher the voltage. With the LOW levers, the lower the note, the higher the voltage. If a BRILLIANCE lever is engaged, the extra voltage is added to the VCF, raising the cutoff point for a more brilliant sound. If a LEVEL lever is engaged, the extra voltage is added to the VCA, increasing the volume of the note. (BRILLANCE and LEVEL are decreased by reversing the polarity of the keyboard control voltage.)

Portamento/Glissando

The glissando effect is produced by a digital circuit which "looks at" the last note played and at the note being played. Instead of allowing the voltage fed to the VCO to jump instantly to the voltage called for by the note being played, the glissando circuit gradually moves the voltage from that of the previous note to the currently played note. A digital circuit causes the voltage to increase or decrease in quantized increments that correspond to half-step increments (a chromatic scale).

The portamento effect is actually produced by the same circuit that produces the glissando, except that an additional circuit element is added. This element "integrates" the steps of voltage, smoothing the transition from one note to the next. Thus, the change is continuous rather than stepped.

Ribbon Controller

The ribbon controller is a felt strip beneath which is located a flat resistive pad and a conductive cord. When you press down on the felt, the cord contacts the pad and establishes a given resistance. Voltage passes through the pad and the cord, the value varying in proportion to where the strip is pressed down. The actual voltage produced when the ribbon is first pressed down is not important; it serves only as a reference point. The output from the ribbon circuit then becomes proportional to the difference between the reference point and any other point touched on the ribbon.

A comparator circuit "looks at" the change in voltage and produces a positive dc output when the second point touched on the ribbon is to the right of the reference point. A negative dc output is produced when the second point is to the left of the reference point. The further away the second point from the reference point, the higher the voltage output (positive or negative).

No voltage output is produced if only one point is touched. It is necessary to move a finger along the ribbon, or to hold one finger in a given point and then touch another finger elsewhere on the ribbon in order to achieve an effect.

The voltage output from the ribbon controller is fed to the main VCO's, thus changing the pitch of any note or notes being played; a positive voltage would raise the pitch, and a negative voltage would lower the pitch.

Pitch Control & Detune CH II Control

The pitch control adds more or less voltage to "bias" the VCO control inputs, thus raising or lowering the frequency produced when a given key is depressed. The pitch control feeds both channels an equal amount of voltage. The coarse pitch control merely produces a greater range of voltage variation than the fine pitch control. The Detune CH II control really does the same thing as the fine pitch control, but it is connected only to channel II. Thus, only the pitch of channel II changes.

Ring Modulator

A Ring Modulator blends two signals together in a special way, "beating" a sub oscillator against whatever input signal is fed to the modulator input. The output does not contain the input signal frequency (or frequencies), but it does contain what are known as sum and difference frequencies. Sum and difference simply means that the sub oscillator frequency is added to the input frequency, and is also subtracted from the input frequency. (Actually, the mathematics that describe the modulation are somewhat more complex because two times the sub oscillator frequency is subtracted from and added to the input, three times the sub oscillator frequency, etc.). The effect may resemble "ringing," although the term "ring modulator" is believed to be derived from the configuration of the diodes which comprise such modulators; they are wired in a circle.

The sub oscillator frequency is set with the SPEED lever, and the amount of sub oscillator voltage fed to the ring modulator is set with the MODULATION lever. An envelope generator is provided for the sub oscillator, and may be used to change the speed when a note is played. The ATTACK TIME lever and DECAY TIME lever respectively speed up and slow down the effect from whatever speed is set with the SPEED lever to some higher value, and back to the set speed. The amount of change in speed—the amount of envelope voltage fed to the sub oscillator—is set with the DEPTH lever.

Panels, Memories & Preset Patches

The main programmable panels provide a means for the player to adjust the many VCO, VCF and VCA characteristics, as well as touch response characteristics, that together comprise a basic "patch" or sound. The memories are miniaturized versions of the programming panels, and are used in exactly the same way. The preset patches (PRESET TONES) were all derived from actual settings of the main programmable panels. Once a given patch was derived, the resistance value or switch position of each panel control was measured.

A fixed component of the same value was then built into the instrument, creating a kind of internal memory that is recalled whenever the corresponding preset patch is selected. You can always duplicate a preset patch by using the programmable panels, as is suggested by some of the patch charts included in this manual. You may wish to do so, and to then vary one or more controls to obtain variations from the presets.

Foot Switch & Foot Controller

The Foot Switch is just that—an ON-OFF switch which is housed in an assembly designed for foot actuation. The switch can be used to activate the portamento/glissando effect and/or the sustain, depending on the setting of front-panel assignment switches. When the Foot Switch is not plugged into the synthesizer, the jack automatically closes the circuit so the unit acts as though the Foot Switch were pressed down.

The Foot Controller contains more complex circuitry, including a light and a photosensor. As the pedal is rocked back and forth, an aperture varies the amount of light reaching the photosensor. In turn, the sensor varies its resistance, and hence varies the voltage output from the circuit. Depending on the setting of the front panel FOOT PEDAL SELECTOR buttons, the voltage from the Foot Controller is applied to either the VCA (in EXP mode) or to the VCA and the VCF (in EXP/WAH mode).

The Foot Switch has a standard (tip/sleeve) phone plug, whereas the Foot Controller, because it contains more circuitry, requires a stereo (tip/ring/sleeve) phone plug.

Tremolo/Chorus

The tremolo/chorus effect varies the volume of the output signal, and also introduces a phase shift. Together, these effects simulate a rotating speaker when used with a stereo sound system. The volume change is produced by feeding a sub oscillator output to a pair of VCA's. Selecting the CHORUS effect sets a sub oscillator to its very slow speed range (about 1/2 to 5Hz), whereas TREMOLO sets the same sub oscillator to a faster speed range (about 5 to 20Hz); the exact speed is set with the SPEED control. The phase shift is produced by using an analog delay line, changing the delay in a regular fashion with a clocking circuit, and mixing delayed and non-delayed audio together. The amount of tremolo or chorus effect is set with the DEPTH control.

WHERE'S THE SOUND

A Brief Troubleshooting Guide

Many times the unit will be connected and basically adjusted properly, yet there may not be sound. The difficulty can be caused by a playing technique that is inappropriate for a given patch; it can sometimes be cured by a change in playing style or by minor adjustment of one or two control settings.

1. Be sure all equipment is plugged in and the POWER is ON, and all controls are set a nominal, as shown by the inside cover illustration.
2. Play one or more notes, and continue to play notes, holding the key(s) down for a few seconds rather than playing staccato.
3. Check the sound system to verify it is properly connected, turned on, and working. If the rear-panel HIGH/LOW switch is at LOW, try the HIGH position (if that doesn't help, switch HIGH/LOW back to LOW). It may be necessary to check the sound system with a sound source other than the CS-80, or use headphones to check the CS-80.
4. Check the EXPression pedal and VOLUME control settings.
5. Use a preset patch rather than a memory or panel-programmed patch, and play in the middle of the keyboard.
6. If you hear nothing, check the setting of the BRILLIANCE control [7]. If sound dies only at the upper and/or lower extremes of the keyboard, center the KEYBOARD CONTROL levers.
7. Check to be sure the FEET selector sliders [5] are set at a detented position and not in between settings.
8. If the sound goes away only with a panel or memory programmed patch, check the following:
   a. A basic waveform or noise level must be turned ON in the VCO section [23, 24, 25] and VCF level in the VCA section [35] must be up **or** sine wave [36] in the VCA section must be up.

   b. If the LPF slider [28] is set at the same height or below the HPF [26] slider, it may be necessary to raise LPF or lower HPF [26].

   c. VCA LEVEL [41] must be up.

   d. Some envelope must be up (Sustain [39] and/or Decay [38]). If a long Attack Time is used [37], then you may have to hold a key for a second or more before you begin to hear the sound.

TIPS ON RECORDING

In any recording situation, the levels are extremely important. The CS-80 has very low inherent noise, high output capability, and hence a large usable dynamic range. If you use a lot of expression and touch sensitivity to create very wide playing dynamics, the recording engineer will be forced to use compression and/or limiting to avoid severe distortion on the tape and, ultimately, on the record. If you want to have the recorded sound be very similar to what you play in the studio, then you can hold back your playing dynamics so that less compression and limiting are needed. You might also reduce the amount of Initial Level or After Level touch sensitivity in your programmed patches.

The synthesizer output is capable of driving low impedance studio console or tape machine inputs, but it is unbalanced. Where long cable runs are required, it may be a good idea to use a balancing transformer or direct box at the synthesizer output, since this will help to reduce susceptibility to hum, noise and radio frequency interference. The LOW/HIGH switch should be set at HIGH and the VOLUME control at 12 o'clock or higher, whenever possible, so that signal levels between the synthesizer and recording equipment are as high as possible. In most cases, the level can then be turned down (attenuated) at the console input.

As you know, with overdubbing the first track recorded is the one against which the rest of the music is played. Therefore, make it clean and rhythmically precise. For large multi-track machines, you might use a click track (metronome), or a rhythm line with a pair of bass and piano tracks. On the other hand, with 4-track machines, it is usually better to start with a rhythm sound that is as close to the midrange as possible. This avoids excess high frequency loss or low frequency irregularities that might occur after multiple "sound-on-sound" transfers. (Head bumps, a very common tape machine characteristic, produce irregular low frequency response that would be emphasized more by a bass track than by a mid-range track.)

The following suggestions apply to all orchestration, whether you are playing with a large band, over-dubbing one synthesizer on multiple tracks of a tape machine, or not using any synthesizer at all. There is sometimes a trade off between clarity of voices and richness of sound, often because too much music is being played in one frequency band. To avoid competition between voices, try to make a sound full and complete as possible, but keep it within a given frequency range. The secret to a richer sounding orchestration is to use a variety of waveforms, counter lines, envelopes and sub oscillator frequencies for the different voices; try not to layer many voices that are nearly identical. This principle of distinct voices and frequency bands is useful, but it does not mean that frequencies should never be duplicated by two or more voices; it is only a guide line. If two sounds are played in the same register, a slight detuning of one sound can make the mix more dense.

TIPS ON LIVE PERFORMANCE

When rehearsing, try to set up a logical progression of patches—logical in that a given patch is changed slightly to achieve the next sound. You never need to start "from scratch" because you can start with a preset patch and adjust the sub oscillator, touch sensitivity, ring modulator, etc. to modify that sound. In a live performance, you can then quickly get another sound by selecting a different preset, or by readjusting one or more of the modifying circuits.

Two different approaches can be taken with regard to use of programmed patches. In one instance, you may wish to program a unique and different sound on each panel and memory. These would essentially add to the variety of existing preset patches. However, you may instead wish to pre-program two or more very similar patches, patches that differ only slightly, but in areas where control settings are critical. Then, the different sounds can be pushbutton selected without concern about instantly getting sliders and levers "just right."

The preset patches make it easy to get different sounds quickly and with excellent repeatability. However, a very wide range of variation can be achieved within any given preset by merely changing the Brightness lever [7]. Use of the keyboard control section, the sustain foot switch, the Feet selectors, and various sub oscillator functions will add even more possibilities to each preset. Therefore, instead of switching from preset to preset, it is often more interesting and exciting to explore the full scope available within a single preset patch.

Yamaha polyphonic synthesizers enable you to get a very wide range of keyboard dynamics, plus further dynamic control via the expression pedal. Thus the playing level can change quite dramatically depending on what voices you have programmed and how you play. Therefore, be sure to check levels for a specific patch ahead of time so that when you come on stage to play the first notes, they are at the right volume level.

If one of your programmed patches doesn't work and you suspect some control(s) was accidentally moved, don't panic; just go to a preset while you check the panel levers and switches.

TIPS ON AUXILIARY SIGNAL PROCESSING

Phasers, echo boxes, reverbs, digital delay lines, parametric equalizers, fuzz boxes, wah-wah pedals, graphic equalizers, etc. are all auxiliary signal processing devices that may be used with a synthesizer. The synthesizer output is higher in level than most electric guitar pickups, but it can still be plugged into many guitar-type pedals and boxes if the HIGH/LOW switch is at LOW and the Volume control is set at a moderate level. On the other hand, it may be better to use an external attenuation pad to match the level of the synthesizer output to a high-sensitivity (low level) effects device. Signal processing equipment made to interface with studio equipment can usually be driven directly from the synthesizer output with the HIGH/LOW switch in HIGH position. In all cases it is a good idea to check the level (sensitivity) specifications for the auxiliary signal processing unit against the synthesizer specifications.

Many of the sounds you might wish to achieve with an outboard effects device can actually be achieved with controls and circuits that are built into the synthesizer. For example, tremolo, vibrato and wah-wah can all be obtained using the sub oscillator. Where practical, use the built-in capability of the synthesizer, since the sound will be going through fewer circuits and will therefore have the lowest noise and best frequency response.

Many patches are greatly enhanced by auxiliary signal processing. The realism of "acoustic " instrument patches can be very much heightened by using reverb.

The synthesizer's External input can afford some interesting effects. To obtain strange "vocal" effects, plug in a source of a very pure, high-frequency sound, such as a 10kHz or higher sine wave oscillator.* Then engage the VCF (filter) on the sub oscillator, and add a lot of Resonance [8 and/or 27 & 29]. The External input is not made for use with guitars or microphones, and even if a preamplified guitar or mic is used, the results could be disappointing. Some preamplified (electric) instrument outputs will produce interesting results when connected to the External input.

The purer the sine wave fed to the external input, the better-sounding the result will be.

DIRECT BOX

A "direct-box" is a type of adapter. In some cases, rather than connect the CS-80 directly to a mixer, one could connect the synthesizer to an instrument amp. The direct box would then be used to interface the instrument amplifier's speaker output (guitar amp, P.A. amp, etc.) with the mic or line level mixer input, thus including the amplifier's reverb, tremolo, brightness and other effects in the mix. Another application for a direct box is to achieve grounding isolation between an unbalanced line level output and a balanced mic or line level input.

The CS-80 output has a low source impedance so that it will drive a low impedance (600-ohm) or high impedance input without adapters. The CS-80 output is unbalanced, meaning that the signal, which flows through a single-conductor shielded cable, is grounded on one side (the shield) and ungrounded on the other side (the center conductor). This arrangement is perfectly suitable for cables of up to 3 m (10') in length. When a longer distance separates the CS-80 output from the mixer input, it is desirable to use a balanced line rather than an unbalanced line for better rejection of potential hum, noise and interference. In a balanced line, the cable shield is grounded, but carries no audio signal; two center conductors, neither of which is grounded, carry the signal. Provided the mixer input is balanced (transformer isolated), a balanced line will be obtained by connecting a direct box at the CS-80 output.

If two or more CS-80 outputs are connected to one mixer, it is a good idea to use a direct box on each output so that the ground to all but one of the inputs can be interrupted without breaking the signal path. This avoids so called "ground loops," multiple grounding circuits between the mixer and the synthesizer that might otherwise introduce hum.

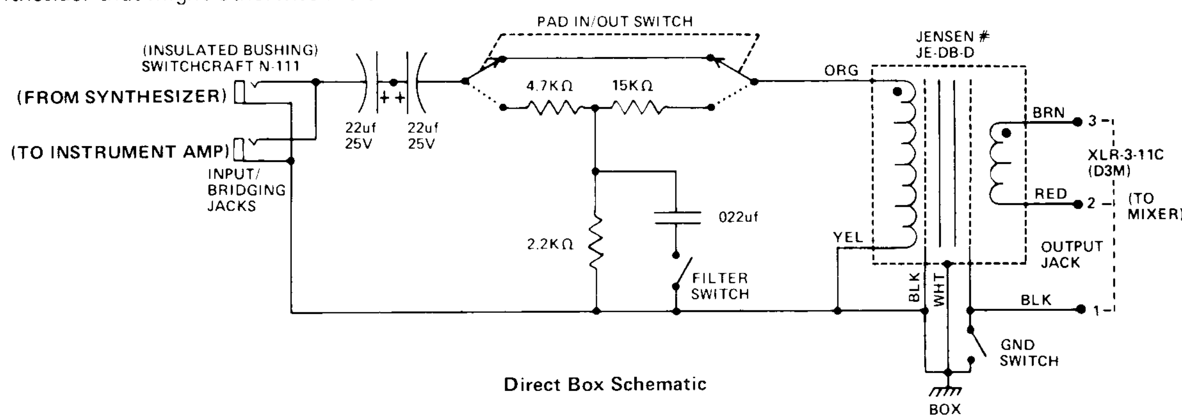
The direct box illustrated can be used in three ways, as indicated below, and its three switches should be set as required. The **ground** switch breaks the ground (shield connection) in the XLR output, and should be set for minimum hum. The **Pad** drops the signal level so that high level outputs do not overdrive lower level mixer inputs. The Filter, which only works when the Pad is switched IN, simulates the high frequency roll off of a typical guitar amp's speaker. Since clipping distortion in a guitar amp often creates high frequency harmonics, the filter switch, by lowering high frequency response, also cuts distortion.

Assemble the unit in a small metal mini-box, and keep the phone jacks isolated from the chassis of the box. Also keep the box away from the chassis of the instrument amplifier or any other grounded object. If you chose a transformer other than the JE-DB-D, it should have similar characteristics: an impedance ratio of 20k-ohms (primary) to 150-ohms (secondary), dual faraday shields, very low capacitance on the primary winding, and full audio spectrum response.

A commercial direct box may be purchased, or a qualified technician can build one from the schematic diagram shown here. The design, courtesy of Deane Jensen (Hollywood, CA), is included in this manual for the benefit of the synthesizer user, and does not represent an endorsement by Yamaha of the specific products mentioned. This direct box also works well with electric guitars, maintaining good high frequency response because the pickup is not loaded.

The JE-DB-D transformer is available directly from:

Jensen Transformers
1617 North Fuller Avenue
Hollywood, CA 90046



Direct Box Schematic

Direct Box Use Chart

	PAD*	GROUND†	FILTER
1. Between any of the three CS-80 outputs and a mixer line input.	IN	IN/OUT	OUT
2. Between any of the three CS-80 outputs and the input of an instrument amplifier, while also feeding a mixer line input.	IN	IN/OUT	OUT
3. Between the speaker output of an instrument amplifier and a mixer line input.	IN	IN/OUT	IN/OUT

**We recommend setting the CS-80 output HIGH/LOW switch to HIGH, and using the direct box pad to reduce the signal level. This protects the transformer from saturation and the mixer input from overdrive. (It is possible to set the HIGH/LOW switch to LOW, and to switch OUT the direct box pad. This does present a much lower impedance to the direct box transformer, causing some transient distortion. While the resulting sound will be brighter and less accurate, there is no harm if you like it.) ALWAYS USE THE PAD WHEN YOU CONNECT A SPEAKER LEVEL OUTPUT TO THE DIRECT BOX.*

†Set for minimum hum and noise. If in doubt, leave IN.

TRAVEL CASE

The CS-80 is built into a durable plywood case, with a removable cover, which is suitable for light duty traveling, such as in a station wagon or van. For heavy cartage (i.e., commercial trucking or air freight), we recommend you use an additional travel case. If you buy a custom built case, it should meet "ATA-300" specifications (ATA=Air Transport Authority). The case should be lined with 3-inch thick foam on all sides; 3/4" plywood or its equivalent is recommended for adequate strength. Consult the specifications for inside case dimensions.

Keyboard
61 Keys, C through c_4 (5 octaves).

Transposition
FEET selector for each channel. Nominal 8′ setting, range from 1 octave below nominal (16′) to 2 octaves above (2′).

Available Fundamental Frequency Range *(Harmonics higher than these specified frequencies may be present, although not specified.)*
32Hz to 8kHz (from 16′ and lowest note on keyboard to 2′ and highest note on the keyboard, PITCH controls centered and ribbon controller not in use).

0Hz to 11kHz (approx.) using the PITCH controls and ribbon controller to extend the lowest and highest keyboard pitches.

Pitch Tuning Range
COARSE TUNE: approximately 1 octave (−500 cents to +700 cents).
FINE TUNE: approximately ±1 semi-tone (±30 cents).
DETUNE CH II: channel II may be offset in pitch from channel I by approximately ±1 semi-tone.

Simultaneous Notes
Up to 8 notes may be played simultaneously. However, since each note played can cause separate voices to be generated by the two channels, up to 16 notes actually may be heard at once.

Simultaneous Voices
Two independent voices may be generated, one on channel I and one on channel II; a MIX control assigns either voice, or any blend of the two, to additional synthesizer circuitry and ultimately to the outputs.

Total Number of Voices
Each channel is provided with 11 different preset patches, two memory-programmable patches, and one panel programmable patch.

Preset Patches *(Preset Tones)*
STRING (1, 2, 3 & 4), BRASS (1, 2 & 3), FLUTE, ELECTRIC PIANO, BASS, CLAVICHORD (1 & 2), HARPSICHORD (1 & 2), ORGAN (1 & 2), GUITAR (1 & 2), FUNKY (1, 2, 3 & 4)

Envelope Generator Time Ranges *(VCF-EG & VCA-EG)*
Attack Time: 1 millisecond (min.), 1 second (max.).
Decay Time: 10 milliseconds (min.), 10 seconds (max.).
Release Time: 10 milliseconds (min.), 10 seconds (max.).

Glissando/Portamento Time Range
10 seconds maximum to change oscillator frequency from the lowest to the highest note on the keyboard.

Ring Modulator
Simultaneous, sine-wave ring modulation of all outputs. Variable SPEED, depth of MODULATION. Envelope Generator for varying the speed of the Ring Modulator has variable ATTACK TIME, DECAY TIME, and DEPTH of speed change.

Sub Oscillator Functions
Sine wave, sawtooth wave, inverted sawtooth, square wave, white noise, or an external input can be used to modulate any combination of the following:
VCO, VCF, VCA. Modulation is applied equally to both voices and all notes played. SPEED (frequency) range is adjustable from 0.7Hz to 60Hz.

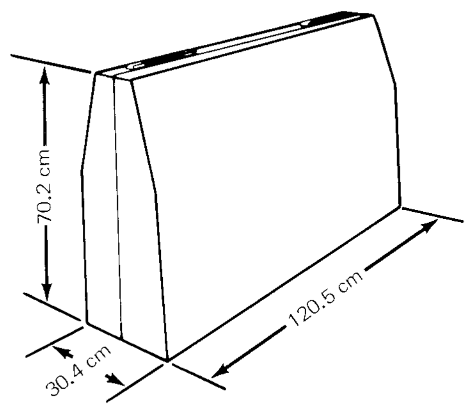
Velocity Sensitive Touch Response *("INITIAL" effects)*
Individual channel programming controls increase the LEVEL (volume) and/or BRILLIANCE (filter cutoff frequencies) as keys are pressed faster; control to increase the amount of PITCHBEND (oscillator pitch change) for any voices being played.

Pressure Sensitive Touch Response *("AFTER" effects)*
Individual channel programming controls increase the LEVEL (volume) and/or BRILLIANCE (filter cutoff frequencies) as keys are pressed down harder; controls to increase the sub oscillator SPEED (frequency), the amount of sub oscillator modulation of the VCO, or the amount of sub oscillator modulation of the VCF for any voices being played.

External Input Characteristics
Unbalanced, standard 1/4" phone jack. 50-kohm actual impedance (for low or high impedance sources). Nominal sensitivity 10 millivolts rms (30mV peak-to-peak) with EXT IN level at maximum; i.e., 10mV rms sine wave external input would produce the same amount of sub oscillator modulation as the maximum from the built-in sub oscillator.

Output Characteristics — *Same for LEFT, RIGHT or GENERAL (mono) out.*
HIGH range, 0dBm (0.775 volts rms) or LOW range, −20dBm (77.5 millivolts rms); nominal output when playing four notes, all volume or level controls at maximum.

Unbalanced, standard 1/4" phone jacks. Actual 600-ohm output source impedance. (Will drive low impedance or high impedance loads.)



Headphone Output
250 millivolts rms nominal. Unbalanced, Tip/Ring/Sleeve 1/4" phone jack for stereo headphones (8-ohm or higher impedance). Located on bottom panel.

Circuitry
All solid state; keyboard and note assigning circuitry is digital; all audio circuitry is analog, with voltage controlled oscillators, amplifiers, filters and envelope generators.

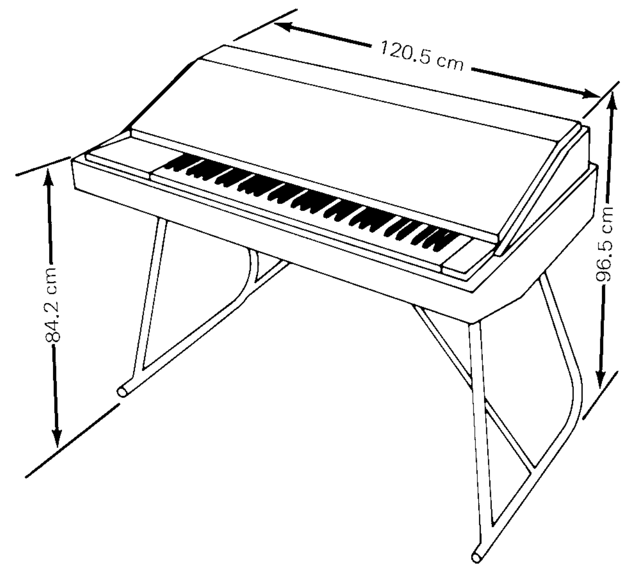
AC Power
AC, 50 or 60Hz, 180 watts.
Power cord stores in covered compartment beneath synthesizer.

Finish
Black leatherette with metal-reinforced corners; walnut veneered side panels.

Dimensions
In Case: 120.5 cm wide x 30.4 cm high x 70.2 cm deep (47-1/2 x 12 x 27-5/8"); (not including leg/accessory bag).
Assembled: 120.5 cm wide x 96.5 cm high x 70.2 cm deep (47-1/2 x 38 x 27-5/8"); Keyboard Height: 84.2 cm (33-1/8").

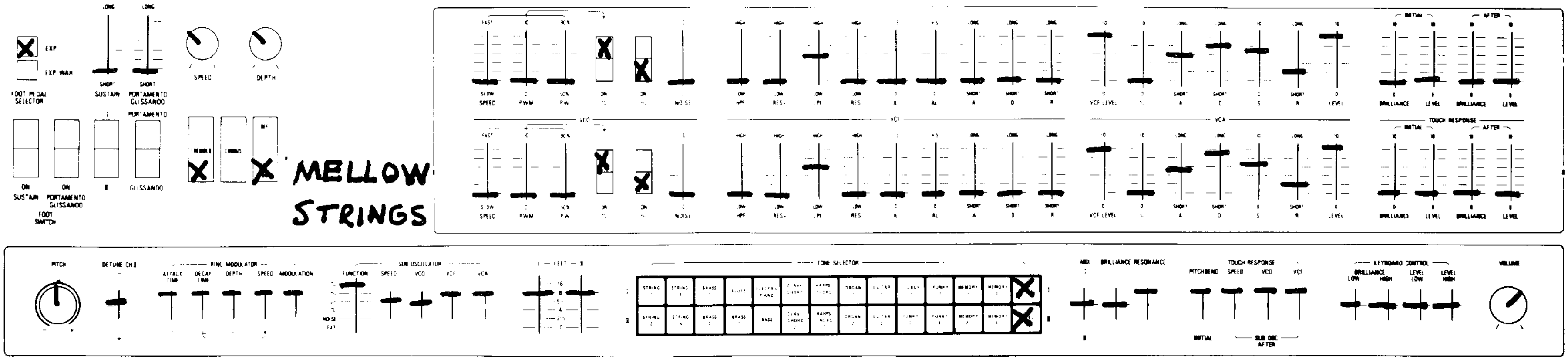
Weight
100 kg (220.5 lbs.) including all standard accessories.

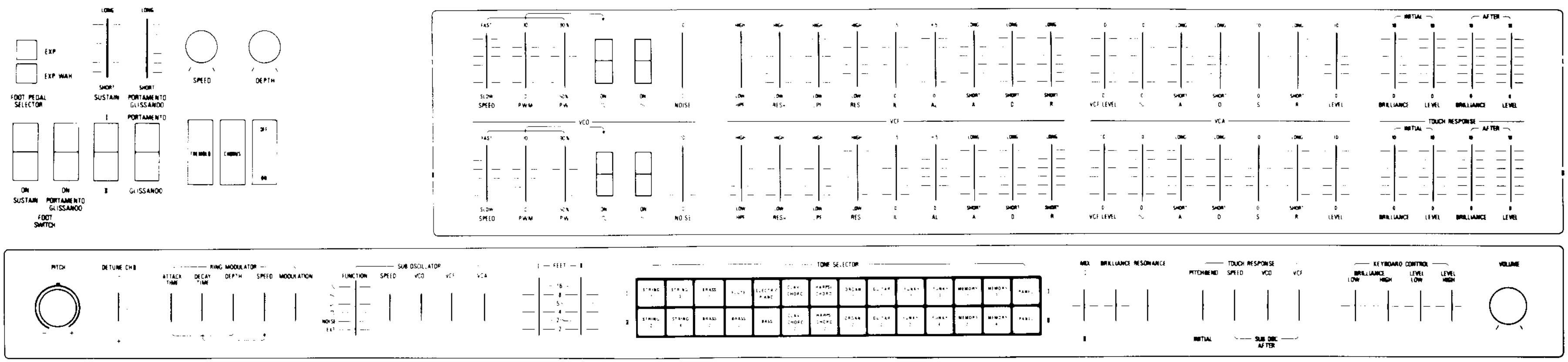
Standard Accessories
Detachable hard cover.
Transparent music rest (stores in hard cover).
Detachable casters.
Foot Controller (expression or expression/wah pedal).
Foot Switch Pedal (sustain and/or portamento ON-OFF).
Vinyl carrying bag for legs, pedal, controller and casters.
Yamaha Key Cleaner Creme.

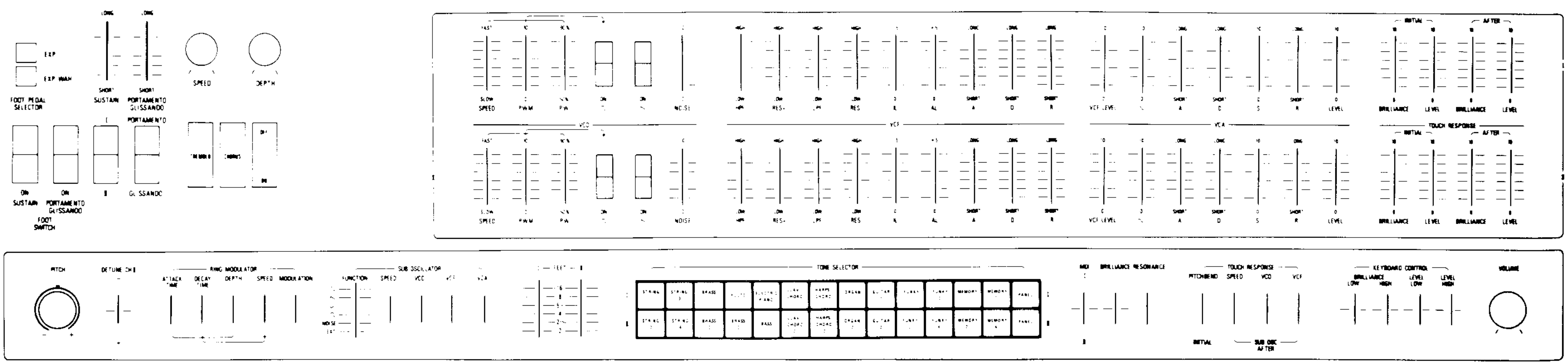


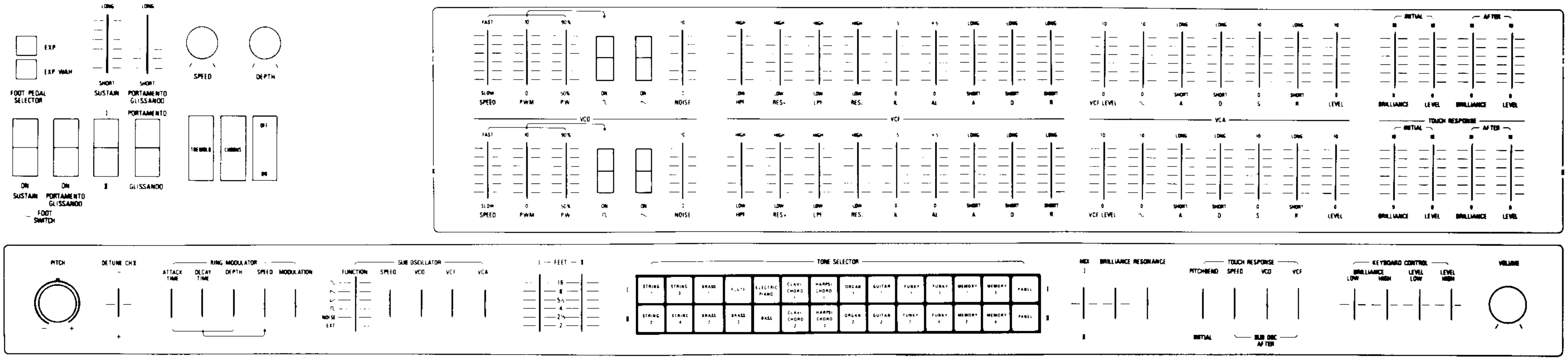
Specifications subject to change without notice.

These blank patch diagrams are provided for your convenience. Copies may be made of page 51 and filled in according to your own requirements. We suggest using a bright-colored felt-tipped pen, as shown in the example below.





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PORTAMENTO GLISSANDO
SPEED
DEPTH
GLISSANDO
FOOT SWITCH
VCO
VCF
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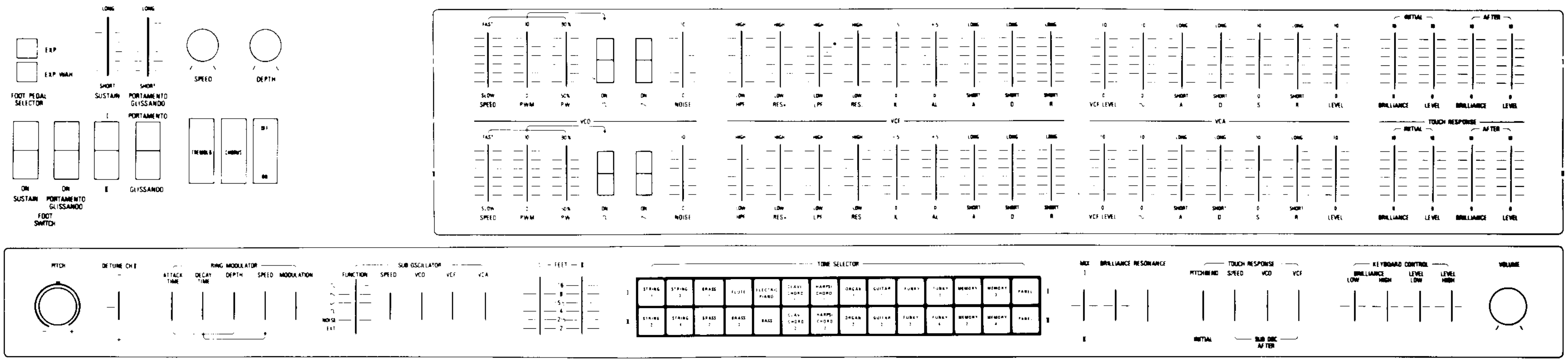
TOUCH RESPONSE
PITCH
RING MODULATOR
SUB OSCILLATOR
TONE SELECTOR
KEYBOARD CONTROL
VOLUME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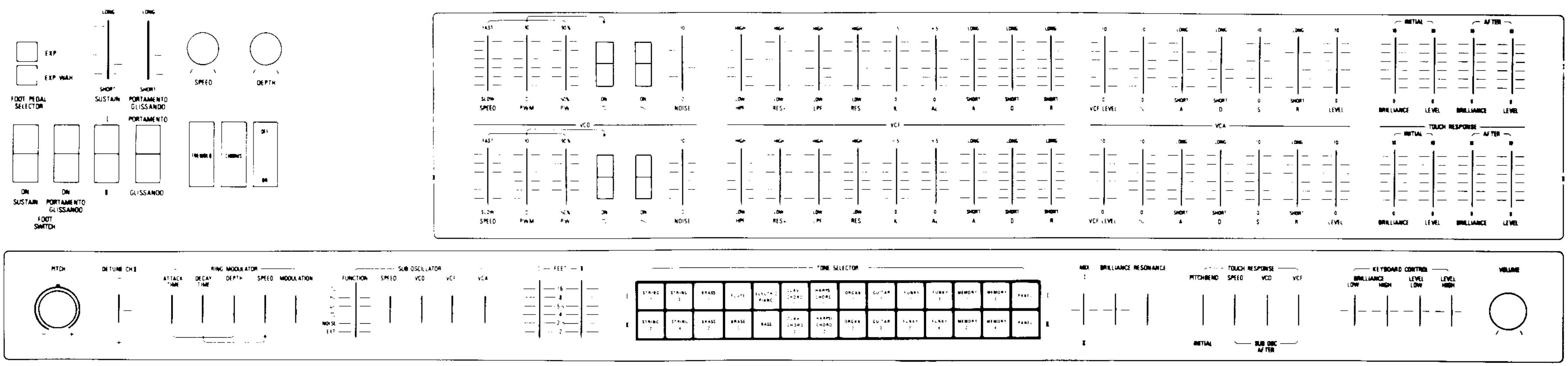
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