Section 7 describes the function and symbolic conventions of block diagrams. We have shown a number of common variations of the symbols used to identify various electronic components and functions. Since manufacturers seem to invent their own symbols on a regular basis, some interpretation will undoubtedly be required in order to read any given block diagram. Still, the majority of symbols and signal flow indications are reasonably standardized so study of this material will be valuable in gaining an understanding of block diagrams.

7.1 General Discussion

In order to take full advantage of the properties of any piece of equipment, we must fully understand how that equipment works — both in and of itself, and also in relation to any components to which it is connected. One important tool for gaining that understanding is the block diagram.

A block diagram is a graphic description of the signal path through a device. The block diagram treats the device as a system constructed of individual functional entities that are connected in a specific way. It employs simplified notation, representing the various functions of the device as single blocks.

The purpose of this method of notation is to present the logical structure of the equipment in a simple, readily accessible form.

Most manufacturers of active signal processing equipment (consoles, delay lines, equalizers, and so on) provide block diagrams of their products. A block diagram may be found in the product data sheet (this is usually the case with complex equipment such as consoles), or it may be published in the instruction manual.

The block diagram is different, both in appearance and function, from another type of diagram called the schematic. Schematics present the component-level details of the actual circuitry of a device. Manufacturers may or may not publish schematic diagrams in instruction manuals (depending upon internal corporate policies and restrictions dictated by Underwriter's Laboratories where U.L. approvals are sought), but schematics are always included in the service manual.

The reason for this is that the information given in a schematic is necessary for servicing the unit, but not normally necessary for operating it. The method of organization and notation used in schematics is tailored to the needs of the service technician — needs which are different from those of the end user.
Schematic diagrams are sometimes organized according to component location on various circuit boards (to facilitate parts identification for servicing). This can make the actual signal flow difficult to follow. Block diagrams may be organized to show parts locations within modules, etc., but they are primarily organized to make it easy to see the signal flow. Schematics must show all connections, including power and grounding, whereas block diagrams often omit these connections to avoid visual clutter. Schematics must show all components in a circuit, whereas block diagrams show only the significant functional items, for example, an amplifier instead of a collection of transistors, diodes, capacitors, and resistors.

To the technically sophisticated user, block diagrams and schematics can be used as complementary tools. The block diagram serves as an invaluable aid in interpreting a schematic — since it presents the logical organization of the device — and aids in identifying the functions of various sections of the circuitry. Likewise, the schematic provides information that may be useful, for example, in unusual interfacing situations.

The needs of the end user are generally best served by the block diagram, rather than the schematic. After all, he or she needs first to know how the equipment works, and how it can be used — not how it is constructed at the component level.

Figure 7-1 shows the symbols that are commonly used in block diagrams. Some of these symbols also appear in schematics.

The following note applies to figure 7-1:

**NOTE 1:** This symbol is subject to the greatest variation in usage of any of the common block diagram symbols. The strict constructionist philosophy of block diagrams holds that this symbol is used to represent only simple amplifier functions (gain stages, drive amplifiers, active summing amplifiers, and so on). All other active (as distinguished from passive) functions are represented by a rectangle, appropriately labeled.

A looser attitude, which holds that the symbol should be used for all active functions (equalization stages, for example), is also common. In this case, the symbol is accompanied by a label defining its function.
### 7.2 Symbolic Conventions

<table>
<thead>
<tr>
<th>HEADPHONES</th>
<th>Direct Radiator (Cone) Speaker</th>
<th>Compression Driver &amp; Horn</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPEAKER COMPONENTS</td>
<td>(Pictorial) (Block Symbol)</td>
<td>LINEAR FADER</td>
</tr>
<tr>
<td>MICROPHONES</td>
<td>Fader or Trim Pot</td>
<td>Trim Pot</td>
</tr>
<tr>
<td>ELECTRIC MOTOR</td>
<td>Fader or Level Control</td>
<td>Fader or Level Control</td>
</tr>
</tbody>
</table>

**Fixed Resistance**
- Signal (AC)
- Current (AC or DC)
- Battery

**Sources**
- K1 (Cont)
- SPDT Relay
- Thermal Relay

**Relays**
- SPST (N.O.)
- SPST (N.C.)
- Box (Crosspoint) # of Poles Varies

**Illuminated Switches**
- Pushbutton Switches
- Toggle, Rotary or Slide Switches

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**Figure 7-2. Block diagram symbols: miscellaneous components**

**Figure 7-3. Block diagram symbols: transformers**

**NOTE 2:** On rare occasions, symbols (2) and (3) are reserved for internal trim controls that are not normally accessible to the user. In this case, symbol (4) may be used for a screwdriver-adjustable trim that is user-accessible. Symbols (2) & (3) also may be used to denote a linear fader.

**NOTE 3:** Symbol (1) indicates a transformer without indicating the polarity of connection. It is assumed to be connected in phase unless otherwise explicitly stated. The symbol (2) shows a common way of indicating transformer polarity. The dot corresponds to the + (in-phase) connection of the windings. If one dot is on top and the other below, the output is reversed in polarity.
Figure 7-4. Block Diagram Symbols: Grounds

**NOTE 4:** Some manufacturers do not distinguish between circuit ground and earth (or chassis) ground in block diagrams. In such a case, one or another of these symbols might be used to indicate simply ground. This practice is confusing, at best.

Figure 7-5. Block Diagram Symbols: Indicators

Figure 7-6. Block Diagram Symbols: Connectors
Figure 7-7. Block Diagram Symbols: Filters and Equalizers

In some block diagrams, you may see other symbols than those shown here. This may be because there is no convention for indicating what is shown in the diagram, or simply because the draftsman was feeling creative. Generally speaking, a responsible technical draftsman will label his drawings clearly, and provide a key to any nonstandard symbols.

Figure 7-8. Block Diagram Symbols: Other Functions

NOTE 5: A simple rule regarding symbols in block diagrams is, "When in doubt, draw a box and label it." This solution is becoming increasingly common, particularly in diagrams of digital signal processors. Some block diagrams consist of nothing but labeled boxes interconnected with lines. This purist approach has considerable merit in that it avoids any potential confusion arising from varying standards of symbol usage.
7.3 Notational Conventions

Block diagrams are drawn to conform to the way Western languages are written: the signal flow is normally left-to-right and, as necessary, top-to-bottom. This practice is only violated in rare instances, and generally only for reasons of clarity, aesthetics, or economy of space.

Functional blocks, however they may be drawn, are connected with lines representing the signal path. Arrows may or may not be used to indicate the direction of signal flow; if the left-to-right rule is followed, they are not necessary.

Figure 7-9 presents some standard notational conventions.

Figure 7-9. Block diagram notation
**EXAMPLE 1.** Figure 7-10 shows the block diagram of a microphone preamplifier. From it, we can deduce a number of things about the unit.

Beginning from the left (following the convention for signal flow), we see first that the unit has an XLR-type input connector. While not specifically labeled, we can assume pin 1 is the ground connection.

We can also assume pins 2 and 3 of the input connector are both signal pins, as they are connected to the primary winding of a transformer. The input is shown to be transformer-isolated.

The transformer secondary is connected to a differential input amplifier (as indicated by the '+' and '-' amplifier connections... single-ended amplifiers are normally shown with just a single line going in and a single line going out). A rotary gain control is shown, and from the way that it is drawn we surmise that it directly controls the gain of the amplifier (rather than being a level control that precedes or follows a fixed-gain amplifier). From the labeling beside the control, we see that the gain is variable from 6 dB to 40 dB.

The amplifier stage has a balanced output, and is not transformer-coupled, but rather drives the output connector directly.

This diagram gives us sufficient information to determine the input/output polarity of the preamp. Tracing from pin 2 of the input, we note that it is connected to the '+' side of the transformer primary. The '+' side of the secondary is connected to the '+' input of the amplifier, and the '-' output of the amplifier we can assume is connected to pin 2 of the output connector (since this is the prevailing standard). Likewise, pin 3 follows the '-' connections from input to output.

For this preamplifier, therefore, pin 2 of the XLR-type connectors is the '+' or non-inverting pin.

**NOTE:** In most single-ended, inter-stage amplifiers, the signal source is actually connected to the '-' (inverting) input of the amplifier. This reverses the polarity of the signal, but allows gain and distortion controlling feedback to be more easily routed in the circuit. The reason the output is not reversed in polarity is that either (A) there are an even number of amplifier stages so the polarity reversals cancel out, or (B) the input or output terminals are internally reversed in polarity.

**EXAMPLE 2.** Figure 7-11 (next page) shows a block diagram of a graphic equalizer.

This unit also uses XLR-type connectors, but the pins have not been labeled. Knowing the pin arrangement of such connectors, however, and knowing that pin 1 is always ground, we can deduce what the connections are.

Pins 2 and 3 are connected as the inputs to a differential amplifier, and no transformer is shown, so we know that this is an electronically balanced input. We do not know for certain that pin 2 is "high" and pin 3 is "low," but it
appears so from the layout of the XLR. The input amplifier appears to have a fixed gain (although there is no indication of what that gain is), and is followed by a level control.

At this point, the signal path splits, and one branch goes to the output amplifier, while the other goes to a side chain of filter stages. These are obviously the equalization stages, and they are shown connected in series.

The first is a high-pass filter with a variable cutoff frequency. While its frequency range is not shown, it seems reasonable to conclude that this stage is a variable low-cut acting on the lowest frequencies. (This we can check by looking at the data sheet.)

The high-pass filter is followed by a variable-frequency low-pass filter. This is undoubtedly acting on the highest frequencies, functioning as a high-cut filter. Again, the data sheet should give us its frequency range.

The succeeding stages are the familiar bandpass stages of the graphic equalizer. Two are shown, with the dotted connecting line and accompanying bracket and label telling us that these are representative of nine stages, all presumably identical except for frequency range. Each is shown to have a single boost/cut control. While the block diagram does not indicate this, we might assume that the design uses sliders for these controls. This is another question that the data sheet should resolve.

The output of the last filter stage connects to the other pole of the switch that feeds the output amplifier. This is labeled “EQ/Bypass.” We can see the logic of its operation. The wiper of the switch connects to the output amplifier. In the BYPASS position (wiper up), the output amplifier sees only the signal coming from the input. It is assumed that signals do not back up in the signal path, so nothing from the filter stages moves into the circuit immediately after the level control.

With the EQ/BYPASS switch in the EQ position (wiper down), the output amplifier sees the input signal after it has passed through the filter and EQ stages.

The output amplifier is shown using the simple, general symbol for an amplifier stage. We make the assumption that it is non-inverting, since there is no indication to the contrary. (This may be checked in the data sheet or instruction manual to verify signal polarity.)

The output amplifier drives a transformer, which is connected across pins 2 and 3 of the output connector (again, an XLR type), indicating the output is balanced and transformer-coupled.

To trace polarity in this device, we might make certain assumptions:

1) The output amplifier is non-inverting;
2) The transformer is wired in phase (polarity is not indicated);
3) The EQ path is non-inverting.

Given these three assumptions, we could conclude that the unit is noninverting and that pin 2 of the XLR-type connectors is the ‘+’ pin.

Any of the three assumptions above could be wrong. The fact is that this block diagram gives little information regarding polarity. For instance, many output amplifiers are inverting (the polarity is reversed as signal passes through the amp)... and sometimes pin 3 is the + or high connection in an XLR. Making assumptions can be misleading, and we should consult the data sheet or manual in order to learn what the input/output polarity of this device really is.

**EXAMPLE 3.** Figure 7-12 shows the block diagram of a digital delay unit.

This is the most simplified (but not the most simple) diagram that we have dealt with. Neither the input nor output connector is shown, and some of the blocks represent fairly complex functions. This block diagram clearly concerns itself only with the logical structure of the device. Details such as connectors, input or output coupling, and input/output polarity and gain all must be obtained from the specifications section of the data sheet or instruction manual.

Nonetheless, we can learn a great deal about the device from the block diagram.

The input is buffered by an amplifier whose gain is determined by a control marked “Input Level.” The buffer is followed by a low-pass stage, whose function presumably is to reject hypersonic frequencies.

After the low-pass stage, the signal path splits. One branch bypasses the bulk of the circuitry, and is connected to a control labeled “Mix.” The other end of this control connects to the output of the main signal processing chain, and the wiper of the control connects to the output block. We can deduce that the control is used to vary the mix between the dry (unprocessed) signal derived just after the input high pass filter and the wet (delayed) signal.

The other branch from the low-pass filter output connects to a switch that accepts a second input coming from farther down the line. The switch is labeled “Feedback In/Out.” We see that the second input to the switch is a feedback path, and the switch allows us to select feedback if we want it.

The next block we encounter is a rectangle labeled “A/D.” We know that this is a digital delay, so this must be the analog-to-digital converter. Hereafter, the audio signal is no longer analog, but instead is in the digital domain.

The output of the A/D converter (sometimes labeled “ADC”) connects to a block labeled “Memory.” This is where the actual delaying of the data occurs. (For a more detailed description of the theory of digital delays, see Section 14.) Two switches connect to the block at the top, and are labeled “Delay Time Select.” From this, we

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**Figure 7-12. Digital delay block diagram**
deduce that delay times are switched in ranges by two front panel switches.

The output of the "Memory" block connects to a block labeled "D/A." This is obviously the digital-to-analog converter (sometimes labeled "DAC") from here on, the signal is once again back in the analog domain.

At the output of the D/A converter, the signal path again splits. One branch connects to the "Mix" control, analyzed earlier. The wiper of the "Mix" control connects to another low-pass filter, whose function we assume to be to remove the memory section's digital clock frequency so that it does not appear at the output. At this point, we have completed the main signal paths, but some branches remain to be analyzed.

The second branch from the D/A output splits once again, with one sub-branch connected to an inverting amplifier that connects to a switch. The other sub-branch is a feed forward path around the inverter to the other pole of the switch. The switch is labeled "Feedback Polarity," and the two positions are labeled + and -. This is the feedback path that we're following, and the switch allows us to select between in-phase and out-of-phase (reversed polarity) feedback. The feedback is used to generate multiple echoes, reverberation effects, or flanging, depending on the delay time.

The wiper of the switch connects to a control labeled "Feedback Level," which connects back to the "Feedback In/Out" switch. We know we can control the amount of feedback, as well as defeating the feedback function if we so desire. We also know the signal flows right-to-left due to the arrow on the line exiting the "feedback level" control.

All that remains for us to analyze is a side chain at the bottom of the diagram. This side chain provides the clock signal for the digital processing section of the device. It is a control signal path, not an audio signal path. The clock signal for all three digital blocks comes from a block labeled "VCO." The letters stand for voltage controlled oscillator. We know that the clock rate of this device, which controls the delay time, is voltage-controllable.

We also see that there is a panel control associated with the VCO, labeled "Delay Time." Within ranges determined by the range switches, we have continuous control of the delay time.

Another signal path enters the VCO at the side. Tracing this path back, we see that it originates with a block labeled "LFO." The letters stand for low frequency oscillator. This designation is normally reserved for oscillators designed to work at sub-audio frequencies (from as low as .001 Hz up to 20 Hz... or as high as 100 Hz). This section is labeled "Modulation." The LFO therefore provides a modulating signal for the clock VCO, varying the basic clock rate in a periodic pattern (from experience, we assume the modulation wave to be a triangle waveform unless otherwise noted).

The LFO is connected to the clock VCO through a control labeled "Depth." This controls the amplitude of the modulating signal, and thus the extent to which it affects the clock rate. Finally, we see that the LFO frequency is varied with a panel control labeled "Modulation Rate."

7.5 SUMMATION

Techniques similar to those used in the previous examples can be used to analyze far more complicated block diagrams. The basic principles remain the same in all cases: read the signal flow left-to-right unless explicitly notated otherwise, and proceed logically through one path at a time.

Some detective work will occasionally be necessary to ferret out the meaning of a symbol or a notation method. This is the mark of a poorly made block diagram. A little logical thought is almost always rewarded.

The technique of block diagrams is easily extended to the diagramming of whole sound systems. Doing so often reveals potential problem areas, and a good system diagram can be a handy aid in operating the system. Some examples of system block diagrams may be found in Sections 17 and 18, which describe "putting it all together" in terms of the electronics and the loudspeakers.