THEORY OF OPERATION OF AR-313 * * * KEYBOARD INTERFACE
(WITH AR-311 KEYBOARD)

The AR-311 keyboard has a string of 60 precision 10 ohm resistors in series, forming a voltage divider. One end is grounded, the other end fed by a constant-current source, consisting of C1 and R124, biased by R122, R123, D62, and adjusted by P1. One set of key contacts connects a different tap on the voltage divider to the bus called "KBD,VOICE". The lowest key connects to the grounded end, and the highest key to the other end, of the divider. When one key is depressed, the "VOICE" bus will have a voltage proportional to the number of keys up from ground. The current source is adjusted for 1/12 volt per key, or 1 volt per octave. When two or more keys are depressed simultaneously, the "VOICE" bus voltage depends only on the position of the LOWEST key, since the current through the resistors between the lowest key and ground is constant. However, the voltage at the top of the divider (connection called "KBD HIGH") will drop by 1 volt for each octave interval between the lowest and highest keys depressed simultaneously. When only one key is depressed there is no change in this voltage from no keys depressed. This voltage will be 5 volts (1 volt per octave times five octaves).

In addition, there is a second set of contacts, called "Keyboard Gate Switches". Each note has a capacitor (C1 thru C61), resistor (R61 thru R121) and diode (D1 thru D61). The capacitors are normally charged to +15 volts. When a note is depressed, the capacitor discharges partially through the diode into the resistors R132 and R133, causing the voltage at the output bus to momentarily reach about +14 v. The capacitor will discharge until the 1M resistor supplies enough current to equal that lost through R132, at which time the bus voltage will be 2.4 volts. It will remain at this voltage as long as the key is held down.

Now, when any one key is depressed, there are 4 signal paths affected:
A. The voltage at pin 3 of op amp U3 will reach 7 volts, then remain at 1.2 volts, due to the divider R132 and 133. (C66 filters out any contact bounce noise.) U3 acts as a comparator, since it is open-loop. The voltage on pin 2 is biased by R134 and R135 to +0.7 volts. Therefore, the output will normally be -15 volts, but will jump to +12 volts (saturation voltages of U3) when a key is depressed. This turns on FET switch Q2, which charges up holding capacitor C64 to the voltage on the "KBD. VOICE" bus, which is buffered by voltage follower U9. This same positive output from U3 is inverted by U4A (1/4 of a quad 2- input NOR gate), which goes to logic "0" level (near 0v). U4B will have a similar "low"output unless both inputs (pins 12 and 13) are low.

B. Capacitor C75 couples a momentary pulse (0.8ms) of about +14 volts into Darlington emitter follower Q4, which couples the pulse into pin 3 of U6. U6 is a"one shot" whose output (pin 8) first goes "high" (near +5 volts) when turned on by the pulse at pin 3. After a delay of 7ms (determined by C69), the output goes"low" again. Meanwhile, when the output first goes high, U4B now has one input low and one high, so its output stays low. Therefore, the output of op-amp comparator U5 stays low (-15 volts.) This keeps pin 1 of U6 low, which enables Pin 3 input to work.

However, after the delay of 7 ms, pin 8 of U6 goes low again. Assuming the key is still down, this means both inputs of U4B are low, so its output (pin 11) goes high.This turns on U5 (+12 volts) which causes a gate (+10 v) to appear at the GATE OUTPUT. Notice that the gate is delayed, to give the sample hold (Q2 and C64) a chance to acquire the correct keyboard voice (control voltage) before the gate turns on.

C. The third signal path is through U4C, which inverts the 0.8ms pulse through C75. The resulting negative pulse (actually from +5v to around **0V**) is coupled through emitter follower Q5 to pin 2 of U7.

Now, before depressing the key, pins 3 and 1 of U7 were low, and pin 2 was high. When the key is depressed, the rising gate at U5 output turns on the output of U7 (pin 8) for a time of 1.6ms, determined by C71, after which it goes low again. This pulse is amplified by op amp comparator U8 to produce an output trigger pulse of +10 volts and 1.6ms duration, simultaneous with the start of the gate output. 10 microseconds after the start of the gate and trigger, however, C70 charges enough to turn on pin 1 of U7. This inhibits the input at pin 3 from keeping the output of U7 on.

Incidentally, the connection of U5's output to pin 1 of U6 prevents additional pulses due to the depression of more than one key from turning on U6, which would cause a momentary "notch" in the gate output

Now back to U7. Although the positive input at pin 1 inhibits pin 3 from holding U7 high, pin 2 is still free to act. When one or more keys are held down, any additional key will still generate a pulse through C75. The resulting negative pulse at pin 2 of U7 will cause it to generate a trigger pulse.

D. The fourth signal path in from the "KBD VOICE" bus.As already mentioned, Q2 turns on as soon as a key is depressed, charging C64 to the right control voltage. When the key is released, Q2 is open, and the high impedance follower consisting of Q3 and U10 buffers the voltage on C64, without discharging it. This circuit, then "remembers" the keyboard bus voltage.

Now, U10 and follower U11 comprise a feedback circuit to give two types of variable lag (Portamento) to changes in the input.

With S2 in the linear mode, a positive change in voltage across C64 will immediately cause U10's output to go fully positive, since it is open loop. Then, C79 will charge through the counter-clockwise section of P3, the Portamento part. It will charge exponentially toward about 12 volts, but as it nears the new input voltage, feedback from U11 will, after a time, neutralize the input of U10. Since the total change of voltage across C79 is small compared to the initial charging voltage of 12v, the rate of change in output voltage is nearly linear.

On the other hand, putting S2 in the "normal" position adds negative feedback around U10, preventing it from saturating. This causes C79 to charge exponentially, except for large keyboard intervals, when some saturation does occur at first. Thus, the "normal" position is a compromise between exponential and linear portamento.

The output of U11 is coupled into U12, which is a differential amplifier. U11's output appears at U12's output noninverted, with unity gain. Thus, the VOICE OUTPUTS are 1 volt per octave.

The tuning pot, P4, provides a variable voltage from +15v to -15v. (0 volts in the center). However, there is a range near the center where the voltage, after being divided by R165 and R166, is less than the forward drop of D69 and D70, so virtually no voltage appears across R164 and R163. When this range is exceeded, however, the resulting positive or negative voltage gets inverted and summed into the VOICE output, detuning the note flat or sharp, respectively. The "dead space" in the middle of P4's rotation provides a quick return to original tuning (for example, concert pitch, where A=440 Hz.)

There is one additional signal patch when more than one key is depressed simultaneously. This lowers the "KBD High" voltage from its normal 5 volts value. The voltage is buffered by U1, and inverted by U2, R154 compensat for the normal 5 volt level so the AUX VOICE output is normally near 0 volts. The AUX VOICE INTERVAL trim, P2, adjusts the gain for 1 volt change in the AUX VOICE output, per one octave interval between the lowest and highest keys depressed. When summed with the regular VOICE output, by plugging both into the same VCO, the VCO will respond to the highest note played. Together with another VCO only connected to a VOICE output, two notes can be played together.