Character 82, bits 4, 2 and 1 program the RISETIME/FALLTIME RANGE. The front panel RANGE switch markings are 1 μs, 100 ns, 10 ns and 1 ns. 1 ns is obtained by setting the three bits to 0. Both characters 81 and 82 are digital programmed characters.

offset format

Characters 83 and 84 program the OFFSET MULTIPLIER. The MULTIPLIER control is a potentiometer and may be set over the range 0 V through ±5 V. Bit 8 of character 83 is a switch closure bit which programs - OFFSET. If this bit is 0 then + OFFSET is automatically programmed. Bits 4, 2, 1 of character 83 and all of character 84 analog program the amount of offset. A maximum of ±5 V of offset may be programmed. Therefore, binary code higher than 0101 may not be programmed in character 83. If character 83 is programmed 0101, then character 84 must be programmed 0000. For example, if +4.8 V of offset is required, character 83 is programmed 0100 and 84 is 1000. No correction formula is required in this case.

Characters 85 and 86 program the WIDTH MULTIPLIER. The correction formula here is M - 5 = P since the WIDTH MULTIPLIER is calibrated between 5 and 55. Bit 8 of character 87 is a digital bit and programs the output pulse POLARITY. With bit 8 made true the output pulse will be negative. Bits 4, 2 and 1 of character 87 program the units of the AMPLITUDE MULTIPLIER. Bits 8, 4, 2 and 1 of character 88 program the tenths. The minimum dial setting of the AMPLITUDE MULTIPLIER is 2, therefore the correction formula is M - 2 = P.

Characters 89 and 90 program the RISETIME MULTIPLIER. Characters 91 and 92 are duplicates of 89 and 90 except they program the FALLTIME MULTIPLIER. The MULTIPLIER dials for either RISETIME or FALLTIME are labeled X1 to X11. The correction formula is M - 1 = P. Character 89 programs units while character 90 programs tenths.

11

THE TYPE R293 PROGRAMMABLE PULSE GENERATOR AND POWER SUPPLY

The Type R293 is a programmable pulse generator and two programmable power supplies. Fig. 11-1 is a front and rear view of an R293. The principal system's use of the R293 is the pulse generator section which the following discussion emphasizes. Recall from the discussion that the R116 has a minimum calibrated risetime and falltime of 10 ns. Many measurements require pulses with t_r and t_f of less than 10 ns. The Type R293 generates pulses with risetime and falltime equal to or less than 1 ns but t_r and t_f are not programmable. The pulses

pulse output

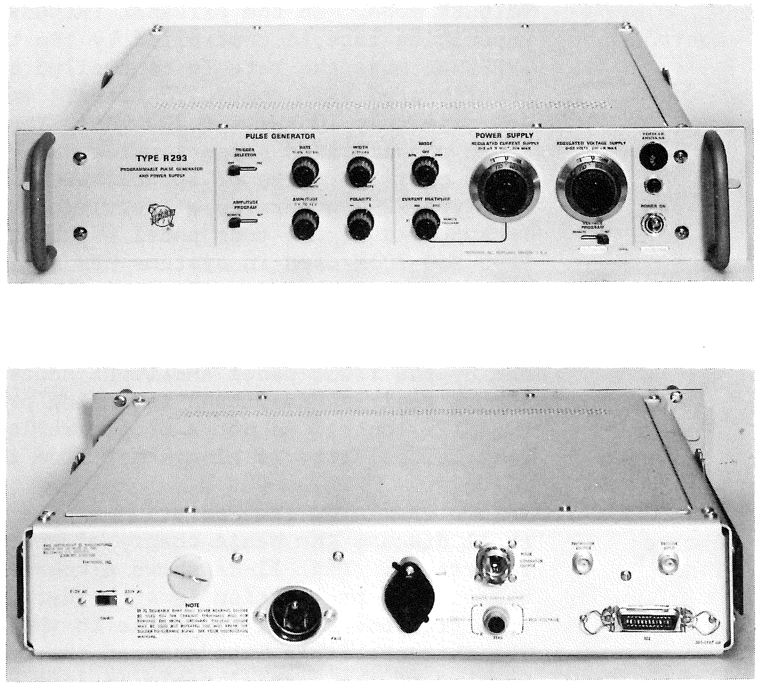

Fig. 11-1. R293 Mod 703M front and rear view.

have a repetition rate variable from about 10 kHz to 100 kHz. The output pulse polarity may be positive or negative with the amplitude variable from 6 V to 12 V. It is important to note that the minimum output pulse amplitude is 6 V. Pulse width is variable from 2 ns to 250 ns. Programmable parameters of the pulse generator are repetition rate, amplitude and width.

power supplies

The Type R293 mainframe also contains a programmable voltage supply which may be programmed between 0 and +50 V with a maximum current of 200 mA. The second supply is a programmable current supply. The current available is variable between 300 μA to 300 mA with a maximum source voltage of ±20 V.

controls

The pulse generator controls are located on the left half of the front panel. Refer to Fig. 11-1. Six controls are associated with the pulse generator. A TRIGGER INPUT BNC connector (rear panel) and the TRIGGER SELECTOR switch allow the Type R293 to be operated in either INTERNAL TRIGGER mode or EXTERNAL TRIGGER mode. In the EXTERNAL TRIGGER mode pulse repetition rate is controlled by the trigger and in INTERNAL mode the rate is controlled by the uncalibrated RATE control. Rate is variable between approximately 10 kHz and 100 kHz. The WIDTH control is an uncalibrated potentiometer which varies pulse width over the range of approximately 2 ns to 250 ns. The Type R293 generates a Pretrigger. The Pretrigger is supplied at the rear panel BNC connector. The R293 Mod 703M used in systems has all input and output connectors on the rear of the instrument. An AMPLITUDE PROGRAM switch is located below TRIGGER SELECTOR. In the INTERNAL position the amplitude is set by the front panel AMPLITUDE control. In the REMOTE position amplitude is analog programmed. The POLARITY control is not a programmable function. That is, polarity is always set from the front panel.

charge line

Before examining the operation of the Type R293 we shall discuss the basic theory of charge line pulse generators. Fig. 11-2A shows a coaxial cable whose velocity of propagation is such that the transit time from one end of the cable to the other is 10 ns. The characteristic impedance of the cable is 50 Ω. One end of the coaxial cable is left open and the cable is said to be terminated by an open circuit. The opposite end of the cable is connected

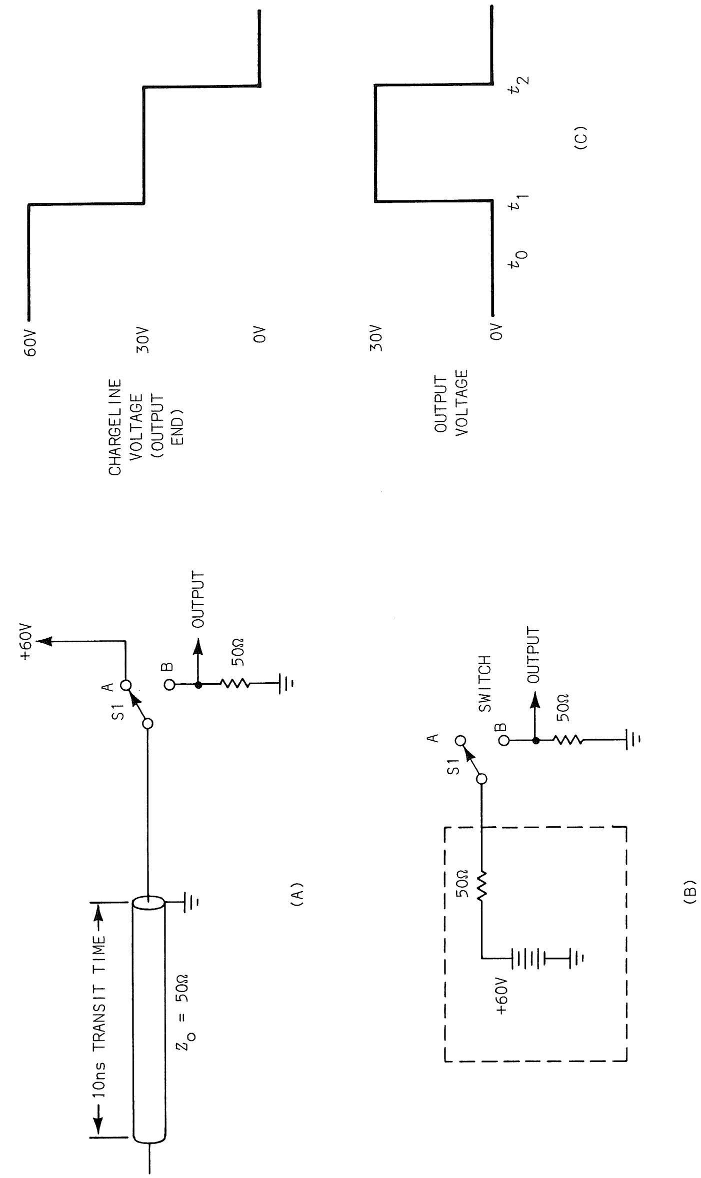

Fig. 11-2. Simplified charge line pulse generator and voltages.

through S1 to a +60 V power supply. Assuming that the switch has been in position A for a long time the distributed capacity of the cable is charged to +60 V. Since this is true the coaxial cable is called a "charge line." Fig. 11-2B shows an equivalent circuit for this condition. Because of the +60 V charge, the equivalent circuit shows a +60 V source. In series with the voltage source a 50 Ω impedance is shown which represents the 50 Ω Z_0 of the charge line.

discharging charge line

The switch for this example is assumed to be a perfect switch. It closes in 0 time and has 0 Ω contact resistance. A waveform ladder diagram for the simplified circuit is shown in Fig. 11-2C. At time t_0 the charge line voltage is +60 V and the output voltage across the 50 Ω output load is 0 V. At time t_1 assume the switch closes in 0 time and that there are no capacitances associated with the output load. At t_1 when the switch closes, the output voltage immediately steps to +30 V. At t_1 when the output load voltage steps up from 0 V to +30 V, the voltage at the output end of the charge line steps down from +60 V to +30 V, creating a negative step. This -30 V step is propagated down the delay line discharging the distributed capacity of the charge line from +60 V to +30 V as it goes.

After 10 ns the incident -30 V step reaches the open end of the charge line. An incident pulse which reaches an open terminated end of a coaxial cable is immediately doubled. The incident step at the open end of the charge line steps from +30 V to 0 V. This is the same as doubling the initial -30 V step to -60 V.

restated sequence

Another way of looking at the action within the charge line is to say that at the time the switch closes the capacitance at the output end of the charge line is discharged instantaneously from +60 V to +30 V. This results in a negative 30 V step at the output end of the charge line. Each portion of the distributed capacity of the charge line is discharged to +30 V in turn as this incident wave travels down the charge line. When the incident step reaches the open end of the charge line it discharges that capacity from +30 V to 0 V. The step from +30 V to 0 V is reflected back towards

the output end of the cable discharging the distributed capacity to 0 V as it goes.

pulse width

As each bit of distributed capacity in the line is discharged the energy released is delivered to the output load. For the first 10 ns the output voltage is +30 V due to this delivered energy. After 10 ns the incident pulse reaches the open end termination and at this time the reflected -30 V step travels back down the line toward the output end taking an additional 10 ns. This energy released by the discharge is also delivered to the output load at a +30 V level. The reflected step reaches the output at time t_2. At t_2 all of the energy stored in the charge line has been removed and the output voltage steps to 0. Note that the output voltage at t_1 steps from 0 to +30 V and remains there for twice the transit time of the charge line. That is, the output pulse is 20 ns wide. The output remains at 0 V until S1 is cycled back to position A. At that time the switch again connects the charge line to the +60 V in a time interval determined by the capacity of the line and the 50 Ω Z_0. At this time no output voltage is being delivered and the amount of time it takes the charge line to recharge is unimportant.

note

Two things should be noted from this example. The output voltage (using an ideal switch) is 1/2 the initial charge line. In addition the pulse width is equal to twice the electrical length of the charge line. If a wider pulse is required, then a longer line is used: For a narrower pulse a shorter charge line is substituted. If a different value of output voltage is required the charge line is connected to a power supply which has twice the desired voltage.

avalanche "switch"

For the example of Fig. 11-2 we assumed an ideal switch. Unfortunately, ideal switches do not exist. The switch used in the Type R293 is an avalanche transistor. This is a transistor whose normally back biased collector to base junction may be triggered into reverse breakdown. When reverse breakdown occurs the collector of the transistor effectively goes into saturation at a speed limited only by the circuit and transistor capacities. The resistance of a saturated transistor is quite low but not zero ohms.

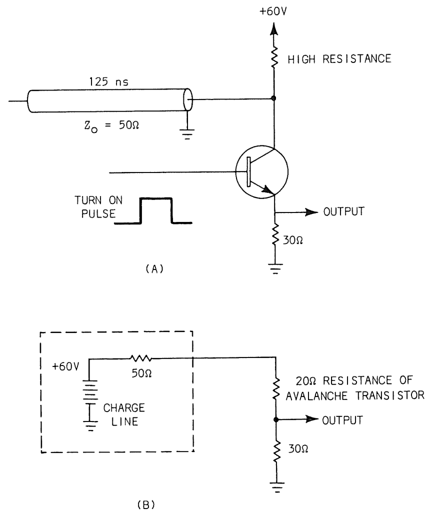

Fig. 11-3. Charge line pulse generator using an avalanche transistor.

Fig. 11-3A shows a simplified Charge Line Pulse Generator which utilizes an NPN avalanche transistor as the switch. A positive pulse delivered to the base switches the transistor to avalanche. The 125 ns charge line is connected to the +60 V supply through a high resistance which also acts as the DC collector load for the transistor. The resistance is large enough that the junction of the transistor collector and the charge line is isolated from the supply. Fig. 11-3B shows an equivalent circuit. The resistance of an "on" avalanche transistor is approximately 20 Ω. From the equivalent circuit it is apparent that when the transistor avalanches, the output voltage will step from 0 V to +18 V across the 30 Ω output load. The output pulse will continue at the +18 V level for a total time of 250 ns, twice the transit time of the charge line. In Fig. 11-3 the effects of capacity have been ignored. The capacity associated with the avalanche transistor and the output load is such that the risetime of the pulse delivered to the output load is on the order of 1/2 to 1 ns.

charge line pulse generator

R293 charge line generator

In the R293 actually two avalanche transistors are used. In Fig. 11-4 whenever the Rate Generator delivers a trigger, the trigger couples to a Fixed

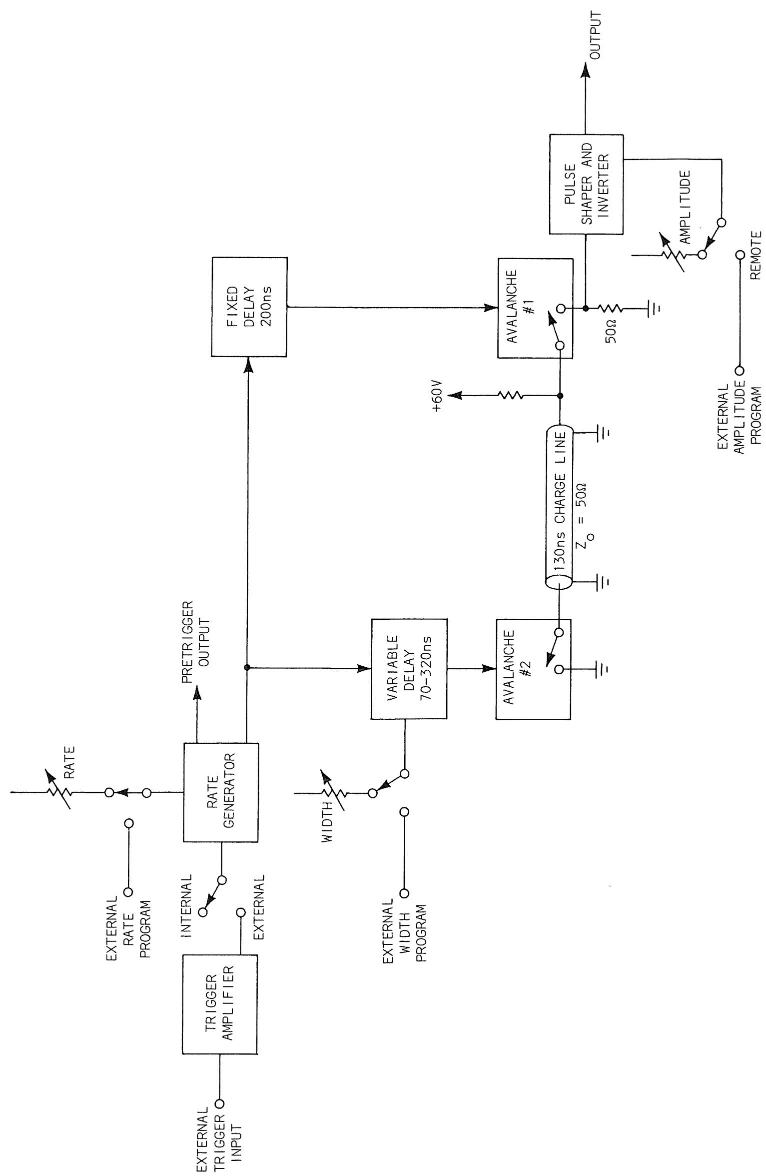

Fig. 11-4. Simplified diagram of R293 pulse generator.

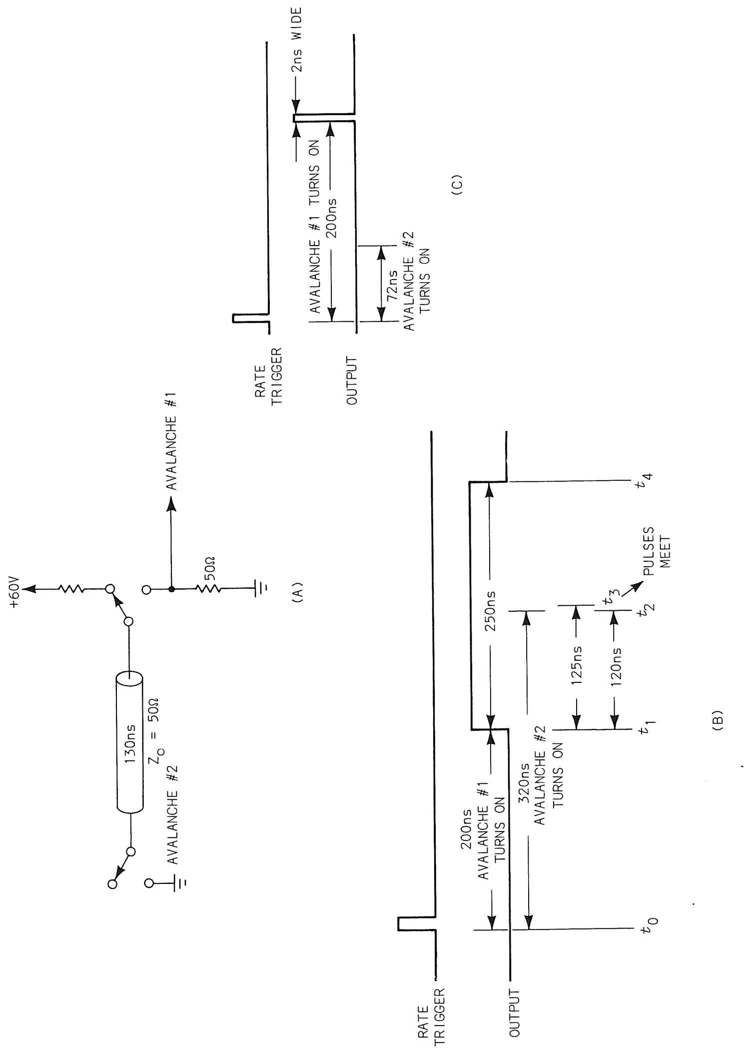

Fig. 11-5. Pulse timing relationships.

Delay circuit and a Variable Delay circuit. After the Fixed Delay interval of 200 ns, Avalanche Transistor No. 1 is switched on. This is equivalent to closing the switch shown within the Avalanche No. 1 block. The Rate Generator trigger also couples to the Variable Delay circuit whose delay is variable between 70 and 320 ns. The transit time of the charge line is 130 ns. After the variable delay interval, Avalanche No. 2 is triggered into operation. Avalanche No. 2 connects the left end of the charge line to ground when it is switched on. When Avalanche No. 2 is turned on, it discharges the charge line completely. That is, with the charge initially at +60 V the charge line is discharged to 0 V whenever Avalanche No. 2 is turned on. This -60 V step is not seen at the output end of the charge line until after 130 ns. A simplified diagram for this portion of the circuit is shown in Fig. 11-5A.

Avalanche No. 1 is connected to the 50 Ω output load. When it is turned on, the output end of the charge line steps to approximately +30 V. When Avalanche No. 2 is fired the left end of the charge line steps to 0 V. A waveform ladder diagram relating Avalanche No. 1, Avalanche No. 2 and the Rate Trigger is shown in Fig. 11-5B.

130 ns line and 250 ns pulse

For the first example, assume that the Variable Delay is set for maximum. At t_0 the Rate Trigger appears. 200 ns later at t_1 Avalanche No. 1 fires. 320 ns later at t_2 Avalanche No. 2 fires. The incident pulse from the output end of the charge line has been traveling down the line for a total of 120 ns (320 ns - 200 ns = 120 ns). It has 10 ns to go before reaching the left end of the charge line. When Avalanche No. 2 is turned on, all charge at the left end of the charge line is removed. This forms an incident -60 V pulse traveling to the right on the schematic. The -60 V pulse traveling to the right and the -30 V pulse traveling meet 5 ns later at t3 and the -30 V step traveling to the left disappears. The -60 V pulse becomes a -30 V pulse traveling to the right. Since the distributed capacitances of the charge line are charged to only

+30 V, they are discharged the rest of the way to ground by this pulse. At time t_3 when the pulses met, the original pulse had traveled down the charge line for a period of 125 ns. The pulse generated by Avalanche No. 2 from time t_3 travels from left to right down the charge line until it reaches the output end. This requires 125 ns. At t_4 the output will step to zero because all charge has been removed. The output will have a duration of 250 ns.

no. 1 vs no. 2

It is important to realize the difference between the pulse caused by Avalanche No. 2 and the pulse caused by Avalanche No. 1. Avalanche No. 1 discharges the line only halfway. Avalanche No. 2 discharges the line to 0 V. The timing relationships just mentioned are those that will exist when the output pulse is programmed to be 250 ns.

2 ns pulse

For a second example, let us assume that the Variable Delay is set to be almost minimum, 72 ns. The Rate Trigger appears at t_0 and 72 ns later No. 2 turns on. The -60 V step travels from left to right down the charge line discharging it to 0 V. 200 ns after t_0 Avalanche No. 1 is turned on. At this time the Avalanche No. 2 pulse has traveled 128 ns down the charge line. It has 2 ns yet to go to reach the end of the line. As Avalanche No. 1 turns on, a -30 V pulse begins to travel from right to left down the charge line and at this time each pulse has 1 ns of the charge line to traverse before they meet. When they meet the -60 V negative pulse cancels -30 V of the incident pulse from Avalanche No. 1 and continues to travel from left to right as a -30 V pulse. The output load therefore, sees a 30 V pulse for a total time duration of 2 ns. The student should note that by programming the Variable Delay or changing the front panel control between 72 ns and 320 ns any pulse width between 2 ns and 250 ns can be generated.

rate generator

Refer to Fig. 11-4. The Rate Generator controls the repetition rate of the pulses. Rate may be internally programmed by the front panel RATE control or externally programmed by an analog resistor. The Rate Generator may operate in External Trigger mode. The External Trigger is amplified by the Trigger Amplifier and applied to the Rate Generator, which in this mode acts as a monostable multivibrator. The recovery time is 10 μs so if the External Trigger

rate exceeds 100 kHz, the output of the Rate Generator will count down to 100 kHz. Whenever the Rate Generator cycles, a Pretrigger is coupled out to the Pretrigger Output jack. Pretrigger appears approximately 200 ns before the leading edge of the pulse. The Rate Generator output is used to trigger the two Delay circuits. As previously explained, controlling the Variable Delay interval controls the width of the pulse generated. The Variable Delay Generator may have its delay set by the front panel WIDTH control or in the REMOTE position may be programmed by an external analog resistor.

Avalanche No. 1 is turned on 200 ns after the Rate Generator Trigger appears. When Avalanche No. 1 is turned on, the leading edge of the output pulse is generated. Because of the finite resistance of the avalanche transistor and various compensated attenuators needed for pulse shaping, the actual amplitude of the pulse delivered from Avalanche No. 1 is about +16 V. This 16 V pulse with predetermined width is fed to a block labeled Pulse Shaper and Inverter.

pulse shaper

The pulse may be coupled straight into the Pulse Shaper or may be inverted by being switched into an inverting pulse transformer. The Pulse Shaper circuit consists of a variable amplitude clamp circuit and two pairs of snap off diodes. The snap off diode pairs, which are normally on, are turned off by the leading and trailing edges of the pulse. The "snap off" action of the diodes reshapes the leading and trailing edges of the pulse. The risetime and falltime of the output pulse have been degraded because of the presence of shunt capacity within the Pulse Shaper circuitry. In addition, the inverted pulse is degraded considerably by the pulse inverting transformer. The Shaper circuit also contains clamp circuits which establish the amplitude of the pulse. The clamp circuits may be set anywhere between 6 V and 12 V but even with minimum amplitude program, the pulse is still 6 V. The clamping circuits remove ringing, overshoot and flat top aberrations from the top portion of the pulse. The voltage setting for the clamp circuits is controllable by the front panel AMPLITUDE control. In the REMOTE position amplitude may be analog programmed.

250 #2 CHAR	250 #1 CHAR	8	4	2	1	
141	93	UNASSIGNED	4V	2V	1V	AMPLITUDE
142	94	0.5V	UNASSIGNED	200ns	100ns	AMPLITUDE/WIDTH
143	95	80ns	40ns	20ns	10ns	WIDTH
144	96	8ns	4ns	2ns	1ns	

Fig. 11-6. R293 program format when programmed from a Type 250.

The Type R293 is much less flexible than the Type R116. The R116 does not produce pulses with faster than 10 ns risetime/falltime due to the state-of-the art of circuit development. If faster risetime pulses are required the Type R293 is used. The programmer has no control over risetime and falltime. He can control, however, the width of the pulse between 2 and 250 ns, and the amplitude between ±6 V and ±12 V.

character format

The Type R293 when included in a system will normally be programmed from a Type 250. Fig. 11-6 shows the normal program format for Type 250. Programming the Type R293 uses characters 93, 94, 95 and 96. Should a second 250 be used in a system and the Type R293 programmed from it, character assignments would be characters 141, 142, 143 and 144. Character 93, bit 8 is unassigned. Bits 4, 2 and 1 of character 93 and bit 8 of character 94 control the amplitude to the nearest 1/2 V. The operator must recall that the minimum amplitude setting is an output of 6 V. If, for example, 0011 is programmed in character 93, the actual output pulse amplitude will be 6 V + 3 V or 9 V. If character 93 is 0000 and bit 8 of character 94 is a 0, the minimum pulse amplitude of 6 V will automatically be programmed. The amplitude program is restricted to 12 V as this is the maximum output available.

Bits 2 and 1 of character 94 control the 100's digit of the pulse width. Bit 2 is 200 ns, bit 1 is 100 ns. Character 95 bits 8, 4, 2 and 1 control the 10's digit and character 96 bits 8, 4, 2 and 1 control the units portion of pulse width. The 10 bits associated with width may be programmed for any combination between 2 ns and 250 ns. Any width outside these limits should not be programmed.

No provision is made for programming the repetition rate of the Rate Generator. An R293 used in a system usually will have the RATE control set to mid range and left there. The programmable DC voltage and current supplies of the Type R293 are basically operational amplifiers which are analog programmed via an external resistor or the front panel helidial potentiometers. Normally in Tektronix systems, no provision is made for externally programming these supplies.