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INJECTION PULSE GENERATOR SYSTEM

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Introduction

The function of the Injection Pulse Generator System is to sense the increasing magnetic field intensity in a test magnet of the main magnet string of the AGS and to generate a marker pulse when that field reaches a magnitude which is suitable for the injection and capture of a linac proton beam.

The voltage induced in an electrostatically shielded coil mounted in the 242 test magnet gap is applied to an integrating amplifier, the output of which is then proportional to the change in magnetic field in the test magnet. That voltage is compared to a stable reference in a comparator which generates a trigger when the required field intensity is reached. The comparator output is applied to a pulse generator which generates a standard AGS pulse. That pulse is routed to the linac via patch panels in the Main Control Room to initiate the injection of the proton beam into the AGS.

Search Coil, Cable, Mount

The search coil consists of 1500 turns of #26 magnet wire wound on a pyrex form with a 4½ in. o.d. Successive layers of turns are doped and taped resulting in a coil with a stable 17.3 m^2 area.

The coil itself mounts between two phenolic plates with a recess for the coil end. The shield consists of two "U" shaped pieces. A .031 in. piece of aluminum covers the bottom and the top phenolic plates and a .062 in. piece of stainless steel covers three sides. This arrangement limits circulating eddy currents which can decrease the effective area of the coil. Micarta supports, 1 in. thick and shaped to the main magnet contour, are then bolted to the sides of the .062 in. steel shield. The supports can then be bolted in place in the test magnet gap with the center of the coil at a point on a line that would coincide with the beam centerline.

A triaxial cable is used to couple the coil voltage to the Pulse Generator Chassis. This prevents induced shield currents from flowing in the coil return and provides a high degree of shielding of the signal leads.

Injection Pulse Generator Operation (See D04-CE261-3)

In the quiescent state, Q1 presents a low resistance feedback path around the integrating amplifier, A1 and A2. The base emitter drop of Q2 is applied to Q3 causing the Q3 collector current to be independent of temperature. This current source causes conduction in IC1, the UA726 temperature controlled transistor pair which provides a stable front end for the amplifier. The IC1 collectors drive OA-1, a UA-741 op amp. In addition to the integrating capacitor, a low leakage diode clamp is used in the feedback path. Zeroing is accomplished with R_2. When the magnet cycle begins, a T_o pulse is coupled into the monostable multivibrator composed of IC2-6,8 via IC3-6 and IC2-11. The resulting negative gate at IC2-8 is coupled into Q4 via Q5. Q4 drives the gate of the FET, Q1, to -15V switching it to a high resistance state.

The voltage induced in the search coil by the increasing magnetic field in the test magnet is then applied to IC1 and OA-1. The amplifier effectively causes the sum of the charge flowing into R_B to charge the integrating capacitor, C. The OA-1 output voltage is then proportional to the magnetic field intensity. That output is applied to a comparator, OA-2, which compares it to a variable reference level. When the OA-1 output equals the negative of the reference level the OA-2 output begins to rise generating a trigger via Q11,12 to Q13, a blocking oscillator, which forms the output pulse. The pulse voltage at the collector of Q13 is also used to reset the IC2-6,8 monostable prior to the end of its natural period. This causes Q1 to return to its conducting state and to discharge the integrating capacitor.

With an input from the coil of NA $\frac{dB(t)}{dt}$, neglecting offsets, the output from OA-1 is

$$e_o(t) = -\frac{1}{CR_B}\int_o^t \left[NA\frac{d}{dt}B(t)\right]dt = -\frac{NA}{R_BC}\left(B(t) - B_o\right)$$

where NA is the effective coil area, B(t) is the time varying field and B_o is the remnant field at t_o. The currents thru R_F and R_9 into the comparator summing junction (assuming equal and opposite supplies (V_1) for the control pots) are

$$i_F = \frac{\frac{V_1}{R_F}(2\alpha - 1)}{1 + \alpha(1-\alpha)\frac{R_1}{R_F}} \approx \frac{V_1}{R_F}(2\alpha-1) \text{ and } i_9 = \frac{\frac{V_1}{R_9}(2\alpha - 1)}{1 + \alpha'(1-\alpha')\frac{R'}{R_9}} \approx \frac{V_1}{R_9}(2\alpha' - 1)$$

where α is the fractional setting of the local potentiometer, R_1 (α = 1.0 when the pot is fully clockwise). α' is the fractional setting of the remote fine adjust pot, R'.

Triggering then occurs at t_1 when the magnetic field is $B(t_1)$ or B_T. $e_o(t_1)/R_A + V_D/R_D + L_F + L_9 = 0$. The magnetic flux density at triggering is then

$$B_T = B_o + \frac{R_A R_B C V_D}{N A R_D}\left[1 + \frac{V_1}{V_D}\,\frac{R_D}{R_F}\,(2\alpha - 1) + \frac{V_1}{V_D}\,\frac{R_D}{R_9}\,(2\alpha' - 1)\right] .$$

Very stable components are used for R_A, R_B, R_D, C and V_D. As a result the cumulative system errors including amplifier offsets are of the order of the required 100 ppm over 24 hours and ± 10°C when the unit is operated in the TEST mode. The peak to peak adjustment obtainable with the remote fine adjust post is

$$\frac{V_1}{V_D}\,\frac{R_D}{R_9}\,.2 = \frac{15V}{9.3V}\,\frac{10K}{300K}\,2 = .107 \text{ or } 10.7\% \;(\alpha' = 0 \text{ to } \alpha' = 1.0).$$

The range of the local potentiometer is 43% (α = 0 to α = 1.0).

Troubleshooting

A. Self-Test Operation

When S1 is in the TEST position, the astable multivibrator, Q6 and Q7, generates voltages which, (1) provides an alternate T_o pulse once per second, and (2) energizes K1. The T_o pulse opens the Q1 switch and K1 applies the reference zener voltage to the integrator input. These simulated inputs induce circuit action which can be used to check pulse generator stability or to localize faults. Voltage waveforms should appear as in Fig. 1. The COUNTER START, COUNTER STOP are 5 μsec pulses which go negative to 0V from + 5V and are obtained directly at the beginning and end of the integration interval. Thus, when these pulses are applied to the GR1192 counter mounted in the cabinet, a direct readout of the period and stability of the integrator interval can be obtained.

B. Bias Levels

In the event that the integrator does not respond in TEST as in Fig. 1, although the input to R_B is proper, bias levels at IC1, OA-1 should be checked. Typical values with the system in NORM, search coil input open, are as follows:

	V_{DC}
+ 5V	+5.141
IC1-9	+4.953
IC1-4	+4.956
(Q3-E)-(Q2-E)	+.0992

	mV_{DC}
IC1-1	-0.72
IC1-2	-0.65
IC1-3,10	-325.3
OA-1-10	+1.4

Investigation of large variations from these levels can pinpoint the faulty compoment.

C. R2 Adjust

R2 is adjusted dynamically by removing K1, and grounding R_B at the input from S1A with S1 in TEST. A voltage ramp at the output of OA-1 will be generated due to the integrator offsets during the interval in which Q1 is open. The offsets are balanced out dynamically by minimizing this ramp with the adjustment of R2.

D. Alarm Operation

Also included in the chassis is an informational alarm circuit, i.e., it is not used to de-energize the system. The alarm is energized if a T_O pulse is received and no output pulse is generated. The inverted T_O pulse at IC3-6 is applied to the IC3-8,11 flip-flop. The voltage at IC3-11 then goes to ov discharging C8. If the voltage on C8 drops low enough to stop conduction in Q15, dropping out K2, L1 lites indicating an alarm condition. Normally, the pulse voltage at the collector of Q13 resets IC3-8,11 keeping K2 energized.

K2 will drop out if the + 15V supply is lost. It also may go into the alarm state when power is switched on and remain in that state until the first output pulse is generated.

System Installation

Three pulse generators are mounted in the injection pulse generator rack. The rack is located adjacent to the #242 magnet enclosure in the basement of the Power Supply Building (#929). The GR1192 counter used for checks of the integrator interval stability is also mounted in the rack.

In addition, a coincidence checker assembly is included in the rack. It can be used to check the time variation of the pulse generated by a test system with respect to the time position of a pulse generated by a reference or spare system. A mechanical counter in the coincidence checker is energized whenever the test system generates a pulse outside an interval that must be initiated by a pulse from the reference system. This device can be used for long term system stability checks.

Four similar interchangeable coils are mounted in the #242 magnet gap and these can be used with any pulse generator. Two systems can be controlled from the Main Control Room (MCR). Lines for two T_o pulses to initiate the interval, two remote adjust controls and two output pulses are routed to the MCR area.

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S1 IN TEST

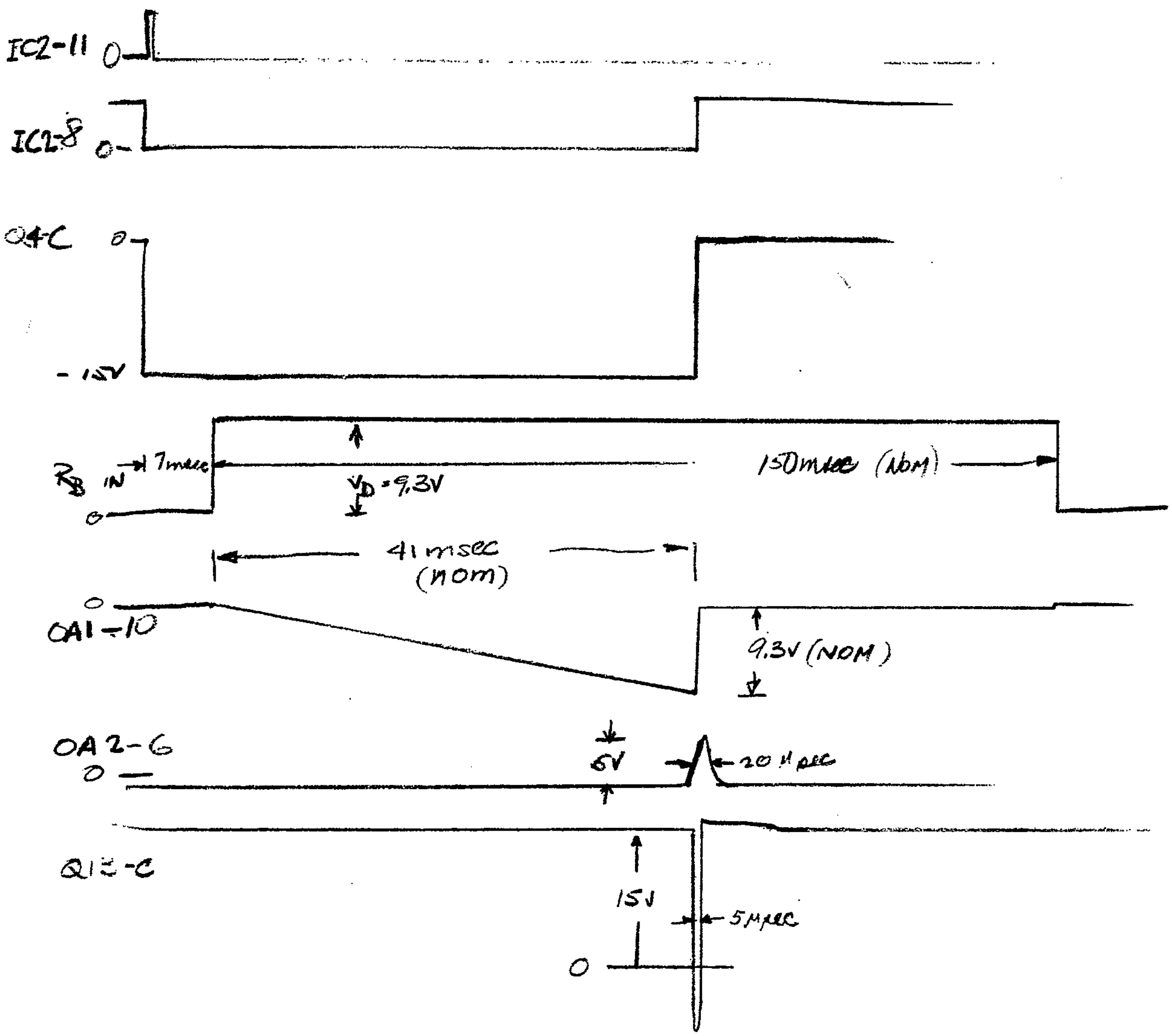

FIGURE 1.