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INTEGRATOR FOR NANOSECOND PULSES*

by

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Circuits designed for shaping fast photomultiplier pulses for use in pulse-height analysis are commonly of the peak detecting type. However, the integral of the pulse is of greater relevance than the amplitude, because it is more closely proportional to the energy lost by the particle in its passage through the detector. Pulses arising from particles with equal energy loss could have different pulse heights due to different pulse shapes. This could be caused, for example, by the particles going through different parts of the scintillator and the corresponding differences in light collection paths and reflections.

The circuit described here integrates a typical photomultiplier pulse and shapes it to match the input requirements of a pulse-height analyzer. An active, as distinct from a passive type of integrator, was chosen because the higher signal levels involved allow a greater dynamic range due to a better ratio of signal-to-extraneous noise.

The circuit is shown in Fig. 1. Its specifications are:

Maximum Input:	1.2×10^{-10} coulombs (typically 1 volt into 50 ohms, 6 nsec duration)
Output Corresponding to Maximum Input:	2 volts negative into 93 ohms
Input Impedance:	50 ohms
Rise Time 10 to 90%:	0.3 μsec (can be varied)
Decay Time Constant:	2.0 μsec (can be varied)
Linearity:	Better than 1%

Refer to Fig. 1. Two integrating circuits, at Q_1 and Q_3, determine the rise and fall times of the output pulse, respectively. The voltage on the collector of Q_1 is given by

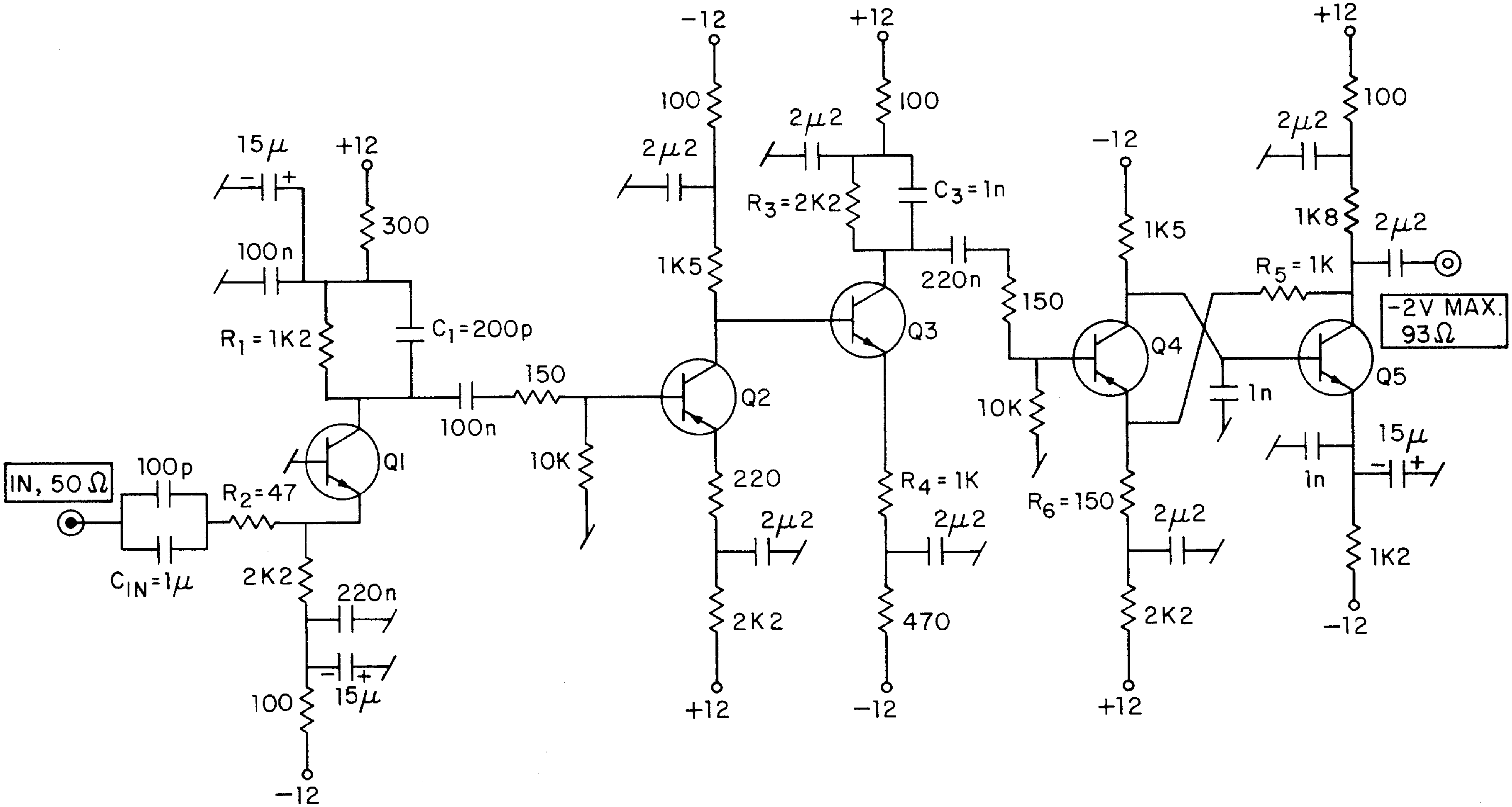
$$V = e_{in} \frac{t}{R_{in} C_1}$$

where t is the duration of the input pulse, and R_{in} is the input impedance comprised of R_2 in series with the emitter impedance of Q_1.

The integrating network $R_1 C_1$ in the collector circuit of Q_1 determines the rise time of the output pulse, its decay time constant being determined by the integrating network, $R_3 C_3$, at the collector of Q_3. Linearity is insured by negative feedback at every state. Q_4 and Q_5 form a feedback pair with a high input impedance so as not to load the second integrator state. The gain of the feedback pair is $\approx R_5/(R_5 + R_6)$. The output impedance is $\approx R_5/\beta_5$, where β_5 is the current gain of Q_5.

Linearity of the complete circuit is shown in Fig. 2. Two widths of pulses were used to establish the curve of Fig. 2: Circles denote points obtained with 5.6 nsec pulses, squares with 9.6 nsec pulses. Figure 3 shows the output amplitude versus input pulse length, for constant input amplitude. A linear relationship is seen in the range of 1.6 and 19.6 nsec. Thus the circuit gives an accurate integral of the input pulse independent of its length.

It is important to note that the coupling condensers to the input should be sufficiently large to avoid differentiation. Figure 4 shows the output as a function of the size of the input coupling capacitance.



NOTES:

RESISTORS: 1/4 W, 5%

CAPACITORS: C_1, C_3 VALUES ARE 5%, (MICA)

MULTIPLYING FACTORS: $K = 10^3$, $\mu = 10^{-6}$, $n = 10^{-9}$, $p = 10^{-12}$

TRANSISTORS: NPN = 2N918, PNP = 2N2905A

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FIG. 1 -- PULSE INTEGRATOR, SCHEMATIC

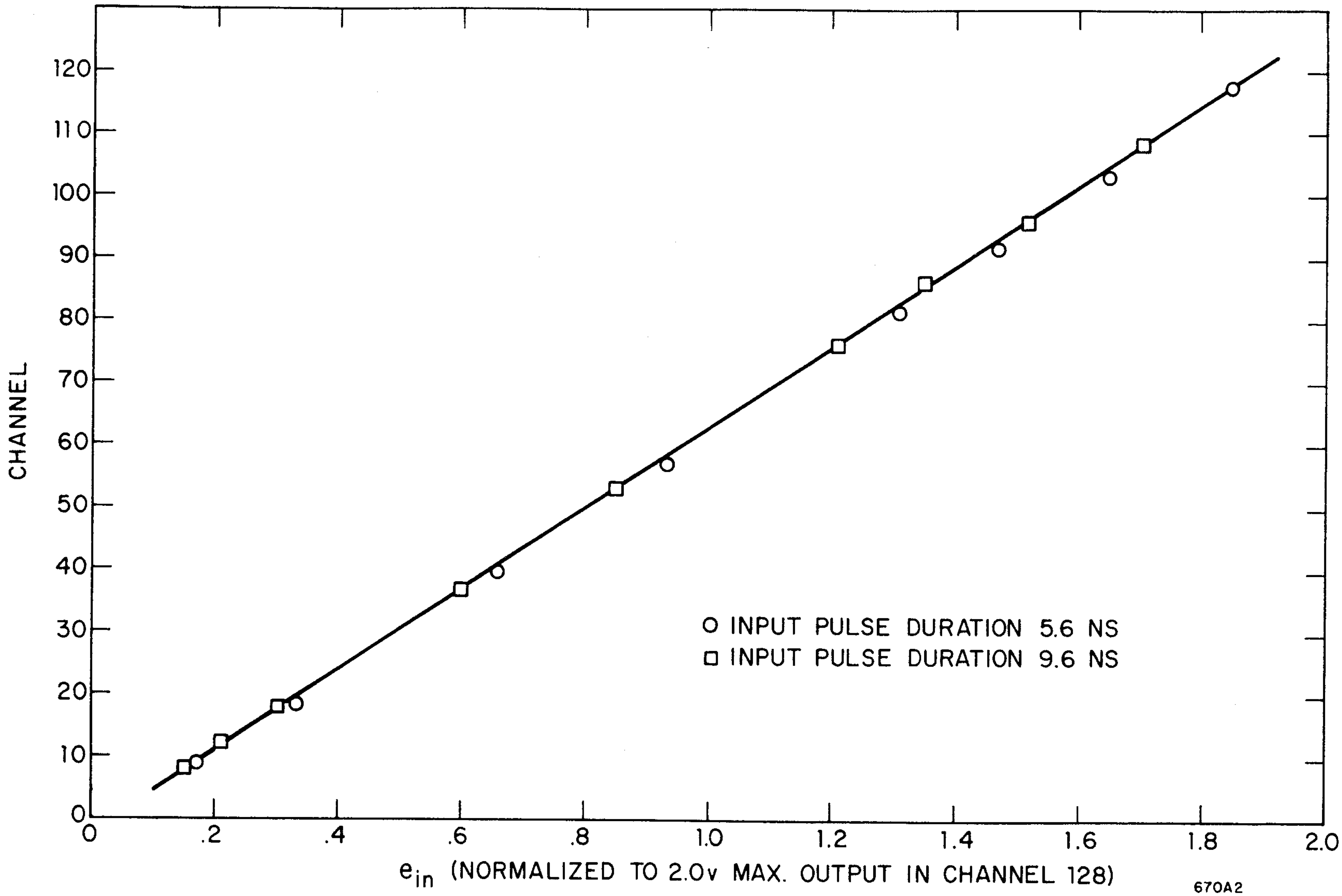

Fig. 2--PULSE INTEGRATOR OUTPUT VERSUS INPUT

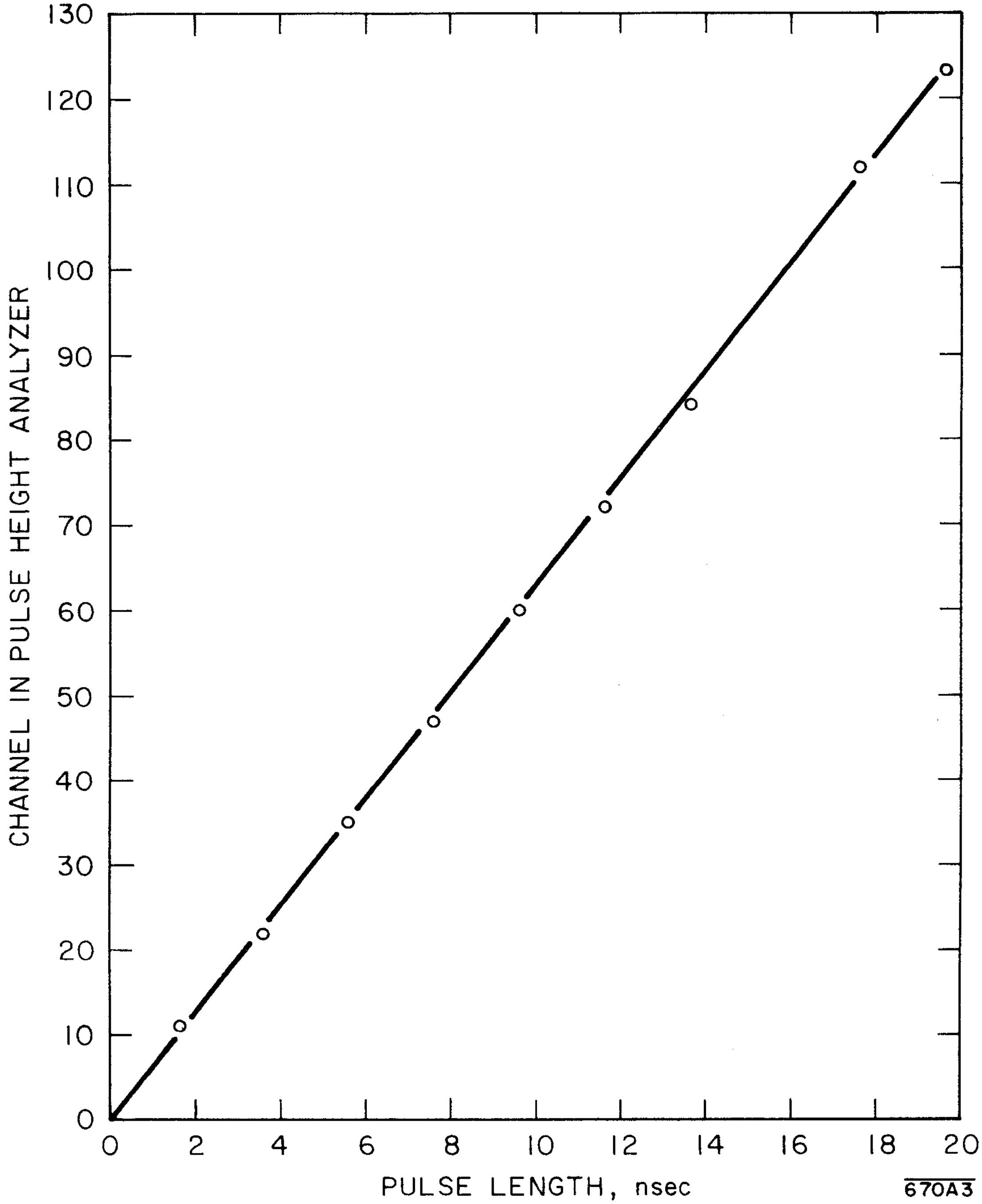

FIG. 3 -- OUTPUT OF INTEGRATOR vs LENGTH OF INPUT PULSE

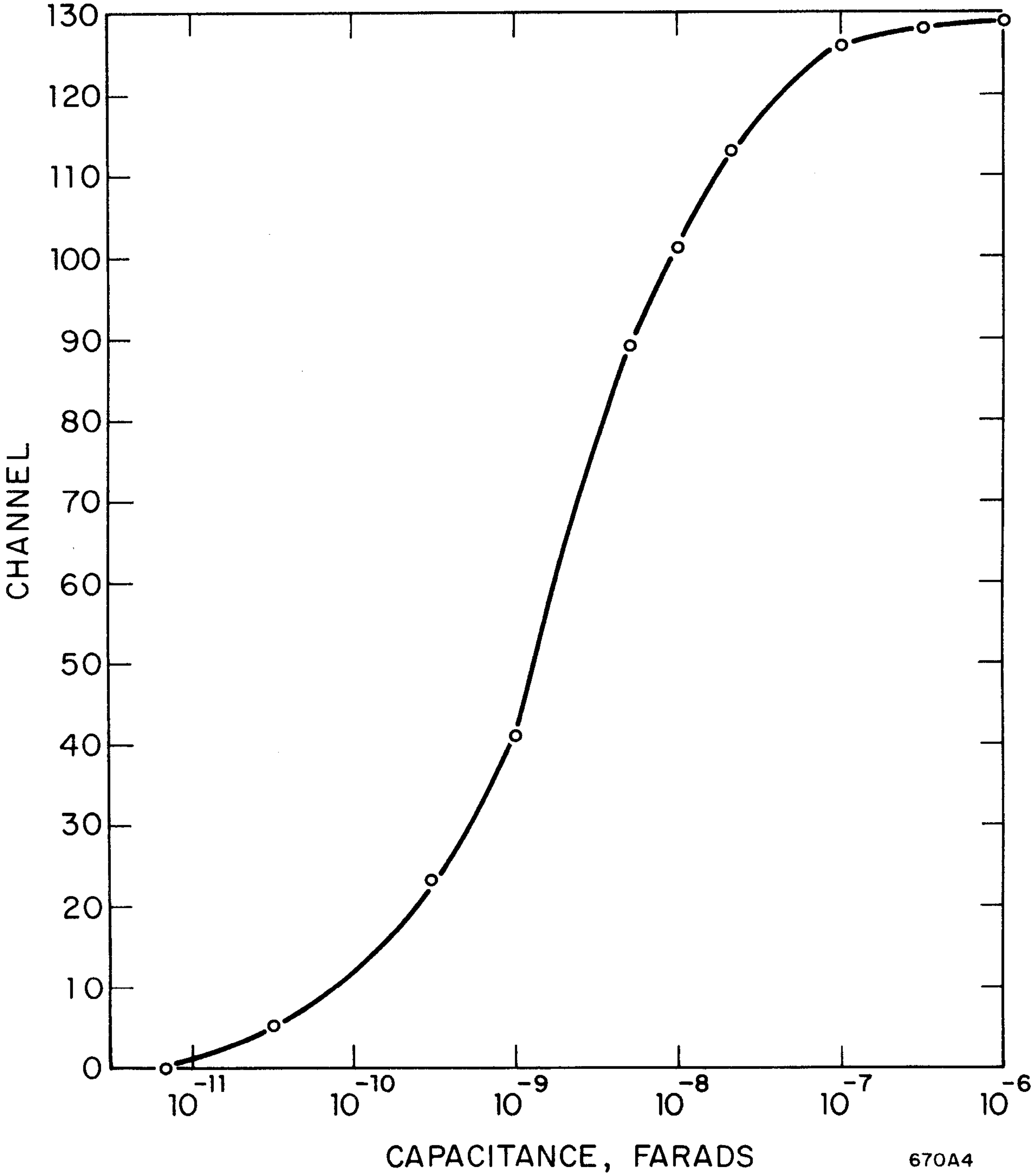

Fig. 4--OUTPUT OF INTEGRATOR versus SIZE OF INPUT COUPLING CAPACITANCE