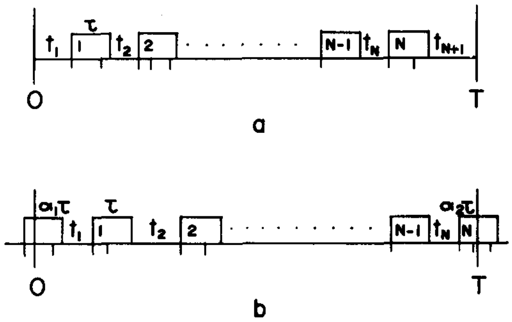

FIG. 1. Tick marks below the line represent actual events. Rectangles above the line, which represent system dead times of length τ, occur after each recorded count. Intervening live times are labeled by $t_1, t_2, \cdots$, and α_1, α_2 denote fractions of dead times occurring inside the counting interval. In general, $0 \leq \alpha_1, \alpha_2 \leq 1$. (a) Ideal case; (b) less ideal case.

a one-dimensional random walk, for which the statistical properties are well known. The essential idea behind this approach can best be seen in Eq. (2) where the individual $t_i + \tau$ terms in the sum on the left represent steps in a unidirectional random walk, the walk being terminated when the value T is reached. A detailed treatment (facilitated by the definition of the l_i given above) shows that the number of steps required to do this is, on the average, $N_0 = T/(\bar{t} + \tau)$, as expected, and is subject to one-σ statistical variations given by

$$\Delta N = N_0^{\frac{1}{2}}/(1 + R\tau), \tag{4}$$

(*not* $\Delta N = N_0^{\frac{1}{2}}$), the only approximation involved (except for high count rates) being the rather mild one that $N_0 \gtrsim 10$. These results derive from the sum $\sum_{i=1}^{N} l_i$ being, on average, zero, with rms variations of $\pm N_0^{1/2}\bar{t}$.

For high count rates, when $\bar{t} < \tau$ (for very high count rates, $\bar{t} \ll \tau$), most of the counting interval is taken up by dead times and there is very little live time left. Under these circumstances, lack of knowledge of what happens at the beginning and end of the counting interval may contribute significantly to uncertainties in the total live time, i.e., the last two terms in the numerator of Ex. (3) may be comparable to statistical variations in the value of $\sum_{i=1}^{N} l_i$. Since for high counting rates t_{N+1} is not likely to be larger than τ, we have

$$|(\alpha_1 + \alpha_2 - 1)\tau + t_{N+1}| \sim \tau$$

and, as mentioned above, $(\sum_{i=1}^{N} l_i)\text{rms} = N^{1/2}\bar{t}$, so we require that

$$N^{1/2}\bar{t} \gg \tau,$$

or

$$N^{1/2}/R\tau \gg 1 \tag{5}$$

in order for Eq. (4) to be accurate. This is a new result.

The statistical error in R can now be found from Eqs. (1) and (4),

$$\Delta R = \frac{\partial R}{\partial N}\Delta N = R\,\frac{1 + R\tau}{N}\,\Delta N = \frac{R}{N^{1/2}}, \tag{6}$$

subject to the validity restriction, Eq. (5), which says that if, to take a fairly extreme case, ten events are lost for every one counted ($R\tau = 10$), we need $N \approx 10^4$ for Eq. (6) to hold with good accuracy.

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Fast, high-current pulse generator with variable amplitude and width

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A simple pulse generator, providing continuous variation of current amplitude (0.1–35 A) and pulse width (100–700 nsec) is described. This pulser has been used for operating injection lasers at repetition rates up to 5 kHz.

In a recent publication[1] we described a simple pulse generator that was used for testing injection lasers. This pulser has recently been improved, so that now it allows continuous variation of both amplitude and width of the current pulses, and it can be operated at high repetition rates.

The circuit, which may be tailored to suit individual requirements, is shown in Fig. 1. The width of the out-

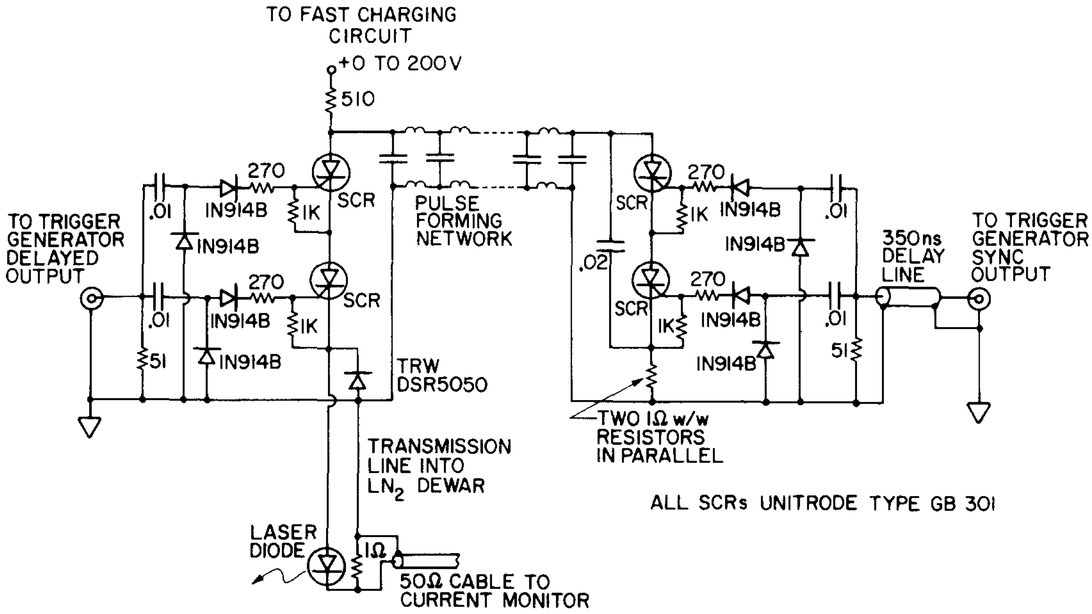

FIG. 1. Pulse generator circuit.

put pulse is controlled by terminating both ends of the pulse-forming network (PFN) with an appropriate relative time interval.

Thus, if the PFN has an electrical length of τ seconds, switching on the control termination τ seconds before the output load produces an output pulse of zero length. Switching the control termination τ seconds after the output produces a pulse of duration 2τ. Output pulse durations between 0 and 2τ can be obtained by varying the switching delay between the two limits indicated above.

For the switches, a fast silicon-controlled rectifier (Unitrode GB301) has proved invaluable, since it offers an acceptably short turn-on time, high gate sensitivity, and adequate current rating, and can be cascaded for increased operating voltage.

The pulse-forming network was made as follows. Two coils of 25 turns No. 20 wire, 1 cm i.d. and 15 cm long were prepared, and supported side by side, 1.5 cm apart. One hundred 0.001-μF ceramic disc capacitors were then soldered between the coils in pairs, with ½ turn spacing. The resulting assembly produces pulses ~700-nsec wide, at an estimated impedance level of ~3 Ω.

One drawback of such a network is a rather long fall time which limits the minimum pulse width obtainable (~100 nsec in this case). This can be reduced by judicious adjustment of the resistive and reactive loading at each end.

A delay line of electrical length greater than that of the PFN is inserted in the trigger input of the width-control switch to provide the necessary range of relative trigger timing (when using an ordinary trigger generator with sync and delayed output), and also to isolate this end of the circuit from ground.

Two SCRs in cascade may be triggered simultaneously without difficulty, and allow the PFN to be charged to 200 V, at which level the current pulse amplitude is ~35 A. The circuit operates satisfactorily down to an amplitude of ~0.1 A.

If the PFN is charged simply through a resistor, the resistance must be high enough that the SCR holding current is not exceeded, and the repetition rate is then limited. For some applications, it is preferable to use a fast charging system, which closes the circuit to the voltage source after the SCRs have turned off, and opens it before the next pulse is triggered.

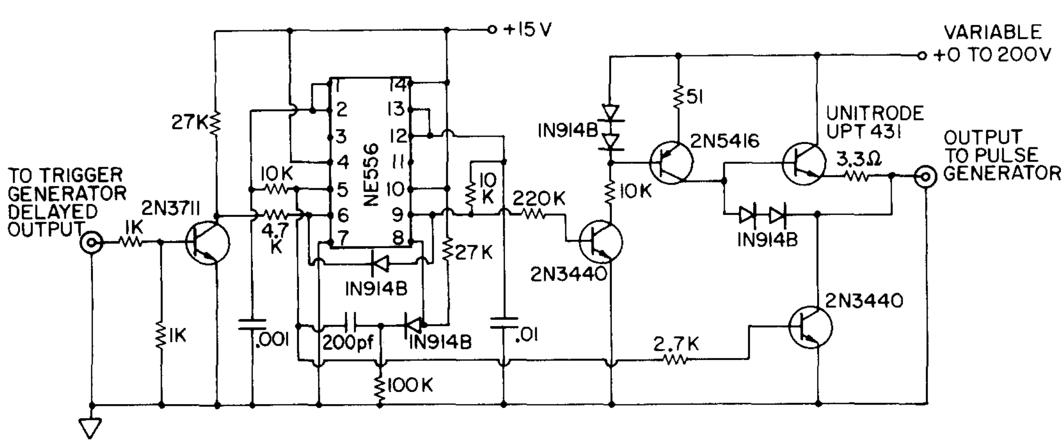

FIG. 2. Fast charging circuit for the pulse generator.

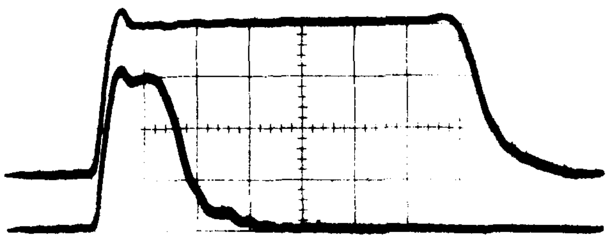

FIG. 3. Two typical current pulses measured through an RCA 2003 laser diode. Vertical scale—10 A/div; horizontal scale—100 nsec/div.

A satisfactory fast charging circuit is shown in Fig. 2. The first half of the NE556, acting as a monostable multivibrator, is triggered simultaneously with the laser pulse generator, and produces a 15-μsec pulse. The trailing edge of the 15-μsec pulse triggers the second half, which produces a 150-μsec pulse. During the 15-μsec pulse, the output of the charging circuit is connected to ground to prevent any leakage through the power transistor from keeping the SCRs in conduction. During the 150-μsec pulse, the power transistor is switched on, allowing the PFN to charge. By this means, repetition rates above 5 kHz are achievable. Figure 3 shows two typical pulses through a laser diode, with widths of ~150 nsec and ~700 nsec, as measured across a 1 Ω resistor.

Both the pulse generator and the fast charging circuit described above may be used with the measuring system described in Ref. 1. This has the advantage of permitting observation of heating effects in the injection laser as the pulse width and the repetition rate are increased.

The authors are grateful to Dr. Amnon Fisher for very helpful discussions.

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Tidal gravimeter employing magnetic suspension

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A magnetic suspension consisting of a small Kovar cylinder constrained to float in the fringing field of a permanent magnet was used to monitor the semidiurnal components of the earth's gravity field caused by the sun and the moon. No methodical drift of the equilibrium level of the cylinder for nongravitational reasons was ever observed. It appears that this apparatus has considerable potential for long-term uninterrupted gravitational observations.

A new long-term gravimeter[1-4] is an interesting and challenging consideration because of the smallness of the forces to be measured. The well-known sensitivity of magnetic suspensions to small force changes,[5] and particularly the inherent stability of suspensions employing permanent magnets,[6] suggested that this concept, i.e., magnetic suspension, would be useful in long-term gravitation experiments.[7] After an extensive developmental period, we have for the past several years, on periodic occasions, maintained a 6-g, open ended, cylindrical shell of 0.5-mm Kovar in magnetic suspension with sufficient sensitivity to monitor the tidal fluctuations in local gravitation, thus demonstrating the feasibility of the idea. The main problem has been identified as effective temperature control. We confidently expect that with several obvious modifications in the new apparatus under construction at the University Observatory at Beltsville, MD, removed from the vibrations of the city, we will be able to more effectively utilize the stability of the permanent magnet, now estimated to drift at less than one part in 10^8 per year.

The basic apparatus, already described in detail,[6] was subjected to several essential modifications. The principal difficulty was as previously mentioned, temperature control, as the ambient must be of the order of $\pm 0.001\,°C$ because of the well-known temperature dependence of magnetization. For this reason the suspension system, consisting of the Kovar cylindrical shell and a Pyrex constraining fiber, was hermetically sealed into a 6×40-cm Pyrex capsule. The capsule was subsequently positioned in an adjustable manner in the fringing field of a well stabilized and aged 20-kg magnetron magnet,[6] and enclosed in a huge insulated masonry oven mounted on a major seismic pier in the basement of the physics building. Vertical motions of the cylindrical shell were monitored with a 6-m external optical system that employed a high-quality lens of 31-cm focal length and 10-cm diameter to focus the filament of a 14-V flashlight bulb onto the edge of a slit in a thin tantulum aperture in the end of the cylinder, thence onto a cadmium-sulfide photoresistor. The bulb, fed by 8.5 V of Zener regulated dc, had a nominal lifetime