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Model 200 Pulse Counter

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UNCLASSIFIED
THE MODEL 200 PULSE COUNTER

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ABSTRACT

A complete general purpose electronic pulse counter is described which consists of an amplitude discriminator, scale-of-64, and register driver, and is suitable for use with pulse amplifiers in making nuclear measurements.

INTRODUCTION

For the work of the Los Alamos Laboratory a large number of pulse counters were needed. It was desirable, therefore, that a counter be available which could be used in many different applications, which would be quite reliable, and which could be manufactured easily. The counter to be described was designed to fit these requirements.

The Model 200 Pulse Counter is used for counting (after amplification) the individual pulses from an electrical detector of high-energy particles, i.e., an ionization chamber, proportional counter, or Geiger-Müller tube.

The information contained in the signal of an electrical ionization detector consists, at least in part, of the distribution of amplitudes of the pulses under fixed experimental conditions, or of the variation of the rate of occurrence of pulses with a given magnitude with changes in the experimental set up. The counter is suitable for extracting such information from the amplified electrical signals of a detector.

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Discussion

The counter to be described consists of three principal parts: (1) An amplitude discriminator which selects for counting only those pulses at its input whose amplitude is greater than some chosen magnitude. (2) An electronic tallying circuit or scaler which provides one output pulse for each 64 pulses which it receives. (3) A circuit which operates an electro-mechanical counter, or register, each time the scaler produces an output pulse. Each of these component parts will be discussed in detail.

The Amplitude Discriminator

The amplitude discriminator of the Model 200 Pulse Counter is a trigger circuit which produces a pulse of standard size whenever it receives a pulse whose amplitude is greater than some predetermined value. The discriminator to be described has the following desirable properties: (1) It can discriminate reliably between pulses which differ in amplitude by a small fraction of one volt. (2) The amplitude at which discrimination occurs is stable to a similar extent. (3) The discrimination voltage is easily adjustable from ten to 100 volts. (4) It is capable of accepting pulses whose duration is a few tenths of a microsecond or greater. (5) It will respond to two pulses separated by intervals as small as 0.5 microsecond. (6) It presents a high impedance to the input signal source. Circuits which have been found to possess in practice the above properties are modifications of the Schmitt trigger circuit.1

The particular modification of the Schmitt trigger circuit used in the Model 200 Counter is shown in Fig. 1. It is based on two pentodes since this allows increased speed and greater stability of operation. The operation of the circuit is such that the steady potential at the output

lead can take either of two values depending on the instantaneous potential at the grid of T-1. The components and the supply potential have been chosen such that if the potential at the grid of T-1 is less than about +105 volts with respect to ground, the tube T-2 will be conducting and the tube T-1 will be cut off. Under these conditions the output signal lead is at +265 volts. If the grid of T-1 is above +105 volts, tube T-1 will be conducting, T-2 will be cut off, and the potential of the output signal lead will be +300 volts. The transition from the first state to the second takes place rapidly and irreversibly when the input grid potential reaches some well-defined "triggering" voltage in the vicinity of +105 volts. The value can be made exactly 105 volts by adjustment of the resistor $R_6$. The constancy to which this value is maintained depends on the stability of the +300 volt supply, on the stability of the resistances $R_3$, $R_4$ and $R_6$, and on the variations in the cathode emission and contact potentials in the tubes. Because of the symmetry of the circuit these latter effects are minimized. For variations of ±10% in the heater supply voltage and for normal tube variations, over a period of months the triggering voltage seems to remain stable to about 0.2 volt.

When the input-grid potential is decreasing from values above +105 volts, triggering to the initial state occurs at some value slightly below that at which the initial triggering took place. The difference in the two triggering potentials is called the hysteresis of the discriminator. The hysteresis is determined mainly by the value of the resistance in the plate circuit of T-1. For the components of Fig. 1, the hysteresis is about three volts which seems to be a good compromise for a general purpose instrument. If the hysteresis is made zero, there will be a tendency for the circuit to oscillate when the grid is near the triggering
potential because of the action of $C_1$. Such a condition should be avoided since the discriminator may then produce several output pulses in response to one slow input signal.

Operation of the discriminator for slow signals is illustrated in the cyclograms which are given in Fig. 2. In all the photographs the sweep voltage is a 2500 cycle per second sine wave of 20 volts peak to peak amplitude (positive to the right) which is also fed to the input of the discriminator. Fig. 2(a) shows the signal at the output of the discriminator. It can be determined from this figure that this particular discriminator has a hysteresis of four volts and that a bias setting of two volts was used. The vertical height of the oscillogram 2(a) is 35 volts. In Fig. 2(b) and 2(c) the vertical deflection sensitivity and horizontal sweep are the same as for Fig. 2(a). In (b) the potential of the plate of $T_1$ is shown and in (c) the common cathode potential. The operation of the discriminator in response to pulses may be deduced from the previous discussion.

As indicated in Fig. 1, the signals are introduced into the discriminator by means of a blocking capacitor and a resistor network for biasing. If the bias potential of the input grid is set by means of $R_9$ at, say +85 volts, any signal less than twenty volts in amplitude will fail to bring the input grid to +105 volts, and will not trigger the discriminator. If a positive signal of amplitude greater than twenty volts, however, is introduced, the discriminator will be triggered to the other state and will remain there so long as the instantaneous signal potential is greater than twenty volts. (The duration of the output signal will depend on the amplitude and duration of the input signal.) If the bias potential of the
input grid is now set to some value greater or less than 85 volts, the amplitude of input signals which will trigger the discriminator will be decreased or increased in that order. The bias setting of the discriminator, or the signal amplitude which is just sufficient to effect the triggering action, is the difference between the triggering potential (+105 volts) and the bias potential of the input grid. The bias setting of the discriminator can be made any value between zero and 100 volts by means of $R_9$. If the dial of $R_9$ is graduated from zero to 100 over 270°, it can be made to read directly the bias setting. This is effected by setting the rheostat $R_7$ until a rotation of 270° of $R_9$ gives a potential change of 100 volts at the input grid and then setting the dial on the shaft of $R_9$ so that the indicator is at zero when the potential is +105 volts with respect to ground. Bias settings less than the hysteresis cannot in general be used. For the sake of stability the resistors $R_3$, $R_4$, $R_6$, $R_7$, $R_8$ and $R_9$ are usually made wire wound. Since $R_1$, $R_2$ and $R_5$ do not directly determine the triggering potential, composition or metallized resistors are used. If some sacrifice in long time stability can be made and if the direct reading bias dial is not desired, an appreciable economy is effected by omitting $R_6$ and $R_7$ and by using carbon resistors throughout.

For a large input pulse having a small rise time, the rise time of the output pulse depends only on the resistance $R_2$ and the parasitic capacitance shunting it. For fast pulses that just trigger the discriminator and for slow input signals, the time of rise of the output pulse is slightly greater. Some decrease in the rise time of the output signal can be achieved by applying shunt compensation to the plate circuits of both tubes. It should be noted that the output signal may never reach its full value if the input signal does not remain above the bias voltage.
for a sufficient length of time. For this reason it is desirable that narrow input pulses should either be rectangular in shape or at least have a sufficiently long flat top. With the present circuit only pulses of duration greater than 0.1 microsecond are counted. The capacitor \( C_1 \) should ideally be chosen to obtain a frequency independent voltage divider from the plate of \( T-1 \) to the grid of \( T-2 \). The value given in Fig. 1 is actually larger than would be required according to the above criterion, but seems to be more suitable in a general purpose instrument.

The maximum permissible duration of the input pulses is determined solely by the time constant of the input coupling network. If slow pulses which are not large compared with noise are being counted it is possible for the discriminator to respond to each of several noise waves on the rise or fall of the pulse, giving many counts for each pulse. This can be avoided either by making the hysteresis at least as large as the noise or by making the resolving time of the conjoining circuit slightly greater than the duration of a single pulse.

Since it is often necessary to count small pulses in the presence of much larger ones, it is important that the discriminator not overload easily. The grid of the tube \( T-1 \) is normally well below its cathode potential. Once the triggering voltage has been exceeded, however, \( T-1 \) acts as a cathode follower and continues to present a high impedance to the signal source. For the circuit values shown in Fig. 1, the tube \( T-1 \) does not draw grid current on slow signals until its grid potential reaches about \( +200 \) volts with respect to ground. Thus if a bias setting of a few volts is used, the circuit will not overload for pulses of 100 volts amplitude. If the input pulses have a rise time of less than 0.1 microsecond and if the capacitance...
to ground of the cathode lead is unduly large, grid current will be
drawn for somewhat smaller signals. Grid current should be avoided
since it alters the charge on the input capacitor and results in a
temporary shift of the bias setting of the discriminator. Although
it might appear desirable to make the input time constant short to
allow a speedy recovery in such cases, other considerations demand that
the time constant be large\(^2\). The value 0.01 second seems to be a
reasonable compromise.

The Scaler

Since it is often either desirable or necessary to take
data at a more or less rapid counting rate, it is convenient to cir-
cumvent the limitations of mechanical registers by the use of scaling
circuits. The Model 200 Counter was developed primarily for counting
pulses which are distributed randomly in time, although it has been used for
counting pulses whose occurrence was neither regular nor random according to
the usual definitions.

Although a quantitative discussion of the errors introduced
by practical apparatus when used for counting random events will be
found in the literature\(^3\), a few remarks may be in order. Any counting
circuit possesses a dead time \(T\) (usually referred to as the resolving time
of the counting circuit) following each pulse it records, during which
time it is incapable of recording another pulse. If the arrival of
pulses to the counter is perfectly random, and the pulses occur at an
average rate of \( \beta \) per second, then the fractional counting loss due to

\(^2\) This time constant is essentially one of the coupling elements of the
preceding pulse amplifier.

\(^3\) W. B. Lewis, *Electrical Counting* (Camb. Univ. Press, 1943)
The dead time of the counting circuit is \( t_d \), so long as \( t_d \ll t \). It is apparent that if one wishes to count random pulses occurring, for instance, at an average rate of 1000 per second with only one percent counting loss, the resolving time of the counter must be ten microseconds. A resolving time of ten microseconds, however, does not necessarily require that the counter be capable of handling \( 10^5 \) regularly spaced pulses per second.

It is only true that a single resolving time completely characterizes a counting circuit if the counter comprises a long chain of identical scaling elements, or if the resolving time of each element in the chain is just sufficient for it to pass along the pulses which it receives when pulses are entering the chain at the maximum regular rate of \( 1/4_1 \), where \( t_1 \) is the resolving time of the first scaling element. In a practical counting circuit, it is not convenient or economical, to meet this requirement in a strict sense. An electronic scaling circuit is terminated ordinarily by an electro-mechanical register which can record \( 10^4 \) or more impulses but whose resolving time may lie in the range 0.1 to 0.01 second. It would be necessary to precede the register by a scale-of-\( 10^4 \) if a counter with an ideal resolving time of ten microseconds were to be achieved. Since it can be shown that when randomly occurring pulses are being counted a considerable "smoothing" effect exists after the counting rate has been reduced by a large scaling factor, it is unnecessary to have the ideal resolving time. A scale-of-\( 10^4 \) seems to be sufficient for most cases although a number of scales-of-256 and greater have been used.

The Model 200 Counter contains a scale-of-\( 64 \) consisting of six scaling stages, each of which is a scale-of-two. The counter is usually used in connection with a register whose resolving time is 0.02 second. The resolving time of the first scaler is five microseconds and the
resolving time of the successive stages is such as to meet the ideal requirement given above. The resolving time of the register does not meet the ideal requirement but, because of the smoothing effect mentioned, the counter can be used to count random pulses at an average rate of $10^5$ per minute with less than one percent counting loss.

The scale-of-two employed in the counter seems to be superior to any yet suggested. It requires no adjustment but operates completely reliably. It is simple and economical to construct, and the checking and servicing can be done by an average technician since failures are usually due to initially defective parts or wiring. The circuit was developed in 1942 by one of the authors (W.A.H.).

Since more than 1000 scales-of-two have been used at Los Alamos, it was found convenient to construct each scale-of-two as a plug-in unit. The type of construction employed is illustrated in Fig. 3. Since it is not necessary that all six units constituting the scale-of-64 be identical to maintain an ideal resolving time throughout the scaler, two different types of unit are used. The basic circuit for both types is shown in Fig. 4.

Suitable values for the circuit components are indicated in the caption for the figure. The first two scale-of-two units in the Model 200 Counter are 6SN7 units and have a resolving time of five microseconds. These are followed by four 6SL7 units which have a resolving time of twenty microseconds.

Both units are constructed in much the same way and have all necessary connections brought out to the pins of an octal plug. Since the 6SL7 units dissipate one half as much power and require one fourth as much current from the...
positive supply source, it is economical to use them in applications
where the shorter resolving time of the 6SN7 units is not needed. The
operation of the two units is quite similar; only the 6SN7 unit will be
discussed in detail.

The scale-of-two circuit, shown in Fig. 4, is based on the
well-known Eccles-Jordan trigger circuit \(^6\) (called here a flip-flop) which
is here symmetrically coupled to a single source of triggering by means of
two diodes. The circuit is capable of being triggered alternately from one
state to the other by successive, identical, negative triggers. The
essential properties of the circuit, in addition to those inherent in
the flip-flop, concern the switching mechanism by which the effect of the
trigger is different on the two halves of the circuit depending upon which
half is conducting; and the choice of operating conditions which give a large
measure of stability. The use of diodes to accomplish a unilateral switching
action in the manner indicated in Fig. 4 is believed to be new \(^7\). In
normal operation the "reset" lead is externally connected to ground,
and the "interpolator" lead goes to a high-impedance indicator.

If the input signal lead has a steady potential of +300
volts, neither of the diodes will be conducting since the potential of
the plates of both diodes is less than their common cathode potential.
Let us assume that the state of the flip-flop is such that tube T-4 is at
first conducting. Its plate will then be at +150 volts, its cathode is at
+20 volts, and its grid will be held at +82 volts by virtue of grid
current flow. The plate of T-3 will be at +280 volts and the grid of

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\(^6\) For operation and theory of the Eccles-Jordan trigger circuit, see
H. J. Reich, Theory and Applications of Electron Tubes, (McGraw-Hill

\(^7\) Subsequent to the development of the circuit shown here, it was
pointed out to the authors that scales-of-two using metallic rectifiers
is described by W. B. Lewis (op. cit.). The mechanism of operation, however,
is somewhat different.
I-3 at +50 volts, thereby cutting off the tube. If the input voltage is slowly decreased, the diode I-2 begins to conduct. Since its resistance is small compared with the resistance \( R_1 \), the plate of I-3 follows the signal. The grid of I-4 does not move in the manner which might at first be expected but drops only slightly in potential so long as grid current is being drawn. A decrease in the grid current takes up the decrease in voltage across \( R_4 \) until the input signal reaches 240 volts. It will be noticed that when the input signal is held fixed at either +300 or at +250 volts the flip-flop can exist quite stably in either of its two possible states. Also, so long as one of the tubes is drawing grid current the circuit has no tendency to be triggered by small fluctuations at the input signal lead. In fact, when the input signal lead was at +250 volts in the above discussion a small variation at that point appears as a much smaller signal at the output lead. This fact is of importance since part of the simplicity of this circuit lies in the possibility of connecting an indefinite number of such circuits directly together with no resulting instability. The self-biasing arrangement in the cathode circuit of I-3 and I-4 adds greatly to the stability of the flip-flop.

Let us suppose now that the input signal voltage is brought suddenly from +300 volts to +250 volts. The potential of the grid of the conducting tube I-3 immediately goes negatively by about 30 volts, an amount which is determined by the ratio of \( C_1 \) to the static parasitic capacitance at the grid of I-4. Immediately following the input signal, the plate potential of I-4 starts to rise rapidly and the grid of I-3 moves

\[ 8 \) as many as twenty stages have been used in one continuous chain. \]
positively a proportionate amount determined by the ratio of $C_2$ to the parasitic capacitance at the grid. The tube $T-3$ begins to conduct and regeneration causes the circuit to proceed toward its other equilibrium state. Before the state equivalent to the original state is reached, however, the plate of $T-4$ is "caught" by the diode $T-1$ and the circuit assumes a stable state with the plate of $T-4$ at +250 volts. If now the input voltage is returned either quickly or slowly to +300 volts, there is no effect on the trigger circuit other than causing it to assume the stable state which is the exact mirror image of the original state described. The application of a second trigger similar to the first causes the circuit to pass through a similar cycle of operations in which the role of $T-3$ is now replaced by that of $T-4$ and vice versa. It should be noticed that the diodes provide a switching action in that an application of the triggering signal a potential change is transmitted to only one grid, and that no signal appears at the opposite grid to counteract the effect of the trigger. Also as soon as the triggering action has begun the negatively moving plate " disconnects" itself from the input lead and the "flip-over" process proceeds unhampered. Because of this, triggering can be effected by a short signal (as is done in the first stage of the counter) or by a rectangular signal (as is done when a stage is triggered by the preceding one). The reliability of the circuit rests in the switching action of the diodes. The capacitive portion of the couplings employed in the flip-flop not only allows rapid operation of the circuit but is an essential part of the triggering mechanism as described above. The output connection of the scale-of-two alternates in potential between +200 and +250 volts during the operation. This
signal has the correct d-c level, and the correct amplitude, for triggering
the next scale-of-two unit to which it is direct-coupled (to pin 4). Evi-
dently any number \( n \) of the scale-of-two units can be direct-coupled in a
chain to form a scale-of-two\(^n\). The use of diodes as automatic switching
devices as shown here is also very useful in many other types of circuit\(^9\).

Since a finite time is required for the flip-over action, and
since an additional recovery time must elapse after flip-over before static
conditions again prevail, the scale-of-two circuit will respond to a second
input signal only after a certain time has elapsed following a previous
signal. The resolving times given above were achieved by striking a com-
promise between these two effects and the required reliability of the
circuit. Similar scales-of-two with varying degrees of reliability have
been made with resolving times down to 0.2 microsecond.

Pulse forms which appear in a chain of scaling units are shown in
Fig. 5. In all the photographs the vertical scale is the same (positive
upwards) and in all but (f) the same linear horizontal sweep was used.
Double positive pulses with an amplitude of fifty volts are being fed
to the input of the discriminator. The pulses are five microseconds
apart and are repeated 1000 times a second. In Fig. 5(a) the input pulses
are shown. The signals which appear at the input to the first scaling stage
are shown in (b), and the output of that stage (input to the second stage)
is shown in (c). Figure 5(d) shows the signal between stages two and
three. The signal between stages three and four is shown in (e). The
same signal is shown in (f) but here with a total horizontal sweep time of
11 milliseconds.

\(^{9}\) A diode switching arrangement has been used to convert a scale-of-16
into a decade (scale-of-ten) scaler which operates completely satisfactorily.
The scale-of-ten circuit will be described at some later date.
The interpolation indicator for the scale-of-two is a 1/25 watt neon lamp connected to the plate of T-3 through a 1-megohm resistor. As soon as T-3 is conducting and its plate potential has dropped to ±150 volts, the lamp will fire and carry a current of 100 microamperes. A neon lamp so operated gives sufficient light to serve as an effective indicator for normal visual purposes and has a negligible effect on the operation of the scale-of-two. The interpolation lamps are, of course, not necessary when a large number of counts occur in each observation but they are useful at slow counting rates and serve as a visual indication of the proper operation of the circuit.

The Register Driving Circuit

Since economy dictates the use of an electro-mechanical impulse register to terminate a scaling circuit, the final function of a counter circuit is the production of signals for operating a register. Most registers consist of a ratchet-operated mechanism which involves a dial or a wheel counter, indicating one digit for each electrical impulse received. The limiting speed at which a register will record impulses faithfully is dependent on the mechanical inertia of the mechanism, and on the amount of power which can be supplied to affect the necessary mechanical motion. Energy is supplied to a register by means of current through a coil which has a large inductance. Evidently the rate at which a register can operate depends in part on the driving voltage, the maximum value of which is limited by the break-down voltage of the insulation used in the register windings. Also, if the mechanical inertia of the register mechanism is to be the limiting factor in the speed of operation, it is necessary that the resistance of the driving source be high enough that the time constant L/R of the register associated circuit will be short compared with the time for mechanical motion.
reason the register is best operated in the plate circuit of a pentode
and with a plate supply having the highest voltage conveniently available.

Registers are commercially available which have been designed
specifically for use with electronic counters. Registers of this type made
by the Cyclotron Specialties Company of Moraga, California, are used with the
Model 200 Counter. They have a minimum operating current of 10 ma, an inductance
of 3.3 henrys and a d-c resistance of 1000 ohms. A register of this
type can be operated at continuous counting rates of fifty impulses
per second with the circuit shown in Fig. 6.

The plate voltage for the output stage of the driver circuit
is secured from the unstabilized part of the power supply. This arrangement
prevents transients, which arise when the register is actuated, from inter-
acting with other parts of the counter and causing spurious counts. The higher
supply voltage is also advantageous. The driver stage shown does not load
the final scaler stage to such an extent that the scaling operation
becomes unreliable. The impedance inserted across the register winding is
sufficient to prevent the production of voltage surges large enough to damage
the insulation. The circuit operation consists essentially of placing a suffi-
ciently high voltage across the register until it closes, and then of re-
moving this voltage to enable the register to recover in preparation for the
next count. If the square voltage pulse is too long, the maximum permissible
counting rate is reduced, whereas if it is too short, the register may
occasionally miss. In the present circuit the signal which is applied
to the grid of the driver tube is a very nearly rectangular, positive
voltage pulse of ten milliseconds duration. This seems to be sufficient
for reliable operation of the registers.
The tube T-1 of Fig. 6 and its associated components serve as a device for producing the requisite pulse shape. The negative step pulse which appears at the output terminal of the last scaling stage is converted into a triangular pulse at the grid of T-1 by the resistance-capacitance network in the grid and the mechanism of grid current. This triangular wave cuts off the plate current in T-1 for ten milliseconds. The plate of T-1 would rise to the positive supply potential during this ten milliseconds were it not that the grid of T-2 will always be driven at least to the cathode potential and held there for the ten millisecond period of operation of the register. The circuit shown also insures that operation of the register is reliable at rates from the slowest to the maximum permissible (about fifty per second). The register can be put directly in the plate circuit of T-2, but for the safety of personnel as well as the register insulation one side of the register is grounded and the operating current is supplied through the blocking capacitor C5.

This driver circuit can be used for any register which does not require more than forty milliamperes or 300 volts. For the optimum speed of operation of any register the time constant in the grid circuit of T-1 should be suitably chosen. The time constant in the grid of T-2 is not critical and need only be sufficiently large.

The Complete Counter

The circuit diagram of the complete Model 200 Counter is given in Fig. 7. In addition to the circuit elements already described it contains a coupling stage between the discriminator and the scaler, a regulated power supply, and an output stage to an external counting rate meter. A photograph of a completed counter containing plug-in units is shown in Fig. 8.
In Fig. 7, tubes T-1 and T-2 comprise the discriminator. The additional components in the grid circuit permit the input to be connected and disconnected at the beginning and end of a measurement without introducing spurious switching counts at the same time.

The positive signals from the discriminator are converted into sharp pulses, inverted, and amplified by the tube T-3A and its associated components. The 65 volt negative signal thus produced then goes to the first scale-of-two. The wiring diagram to the sockets for plug-in units is shown in the figure. The numbers which appear correspond to those shown in Fig. 4. The first two plug-in units are 6SK7 units, the last four, 6SL7 units. The reset leads are connected together and to ground through a normally closed push-button switch. When this switch is opened momentarily the potential of the reset line rises about fifty volts and returns all the flip-flops to the starting state. The resistor across the switch is necessary to prevent the reset line from going too far positive when the connection to ground is broken. If the reset line goes much more than fifty volts positive the cathode potential of the flip-flops changes so much that the circuits are momentarily unstable when the switch is closed again and resetting is not accomplished. The interpolation indicator circuit (neon lamps and 1-megohm resistors) is shown. The lamps are extinguished in the starting position. They are labelled "1", "2", "4", "8", "16" and "32". The sum of the numbers corresponding to the lamps which are lighted shows the number of pulses received after the last multiple of 64. The tube T-3B is a cathode follower which couples the output of the first scaling stage to an external counting rate meter. The signal which appears at this point has a shape suitable for operating a very simple meter which can be used for
checking bias curves or operating conditions with given discriminator settings. The output of the sixth scaling stage is coupled directly to the register circuit described above.

Since a constant plate supply potential is needed for the discriminator, it is nearly as economical and somewhat more reliable to operate the complete counter from a stabilized plate supply. The supply shown in Fig. 7 is of the degenerative type. This supply provides 55 milliamperes at 300 volts and an additional 5 milliamperes at 450 volts. The 200 volt supply is stable for input line voltages of from 95 to 135 volts. It has a stabilization factor\(^{10}\) of 700, an output resistance of 2 ohms, and has less than 3 millivolts of 120 cycle per second ripple at its output.

Several Model 200 Counters or their equivalent have been made and are in use at the Los Alamos Laboratory. Satisfactory operation has always been obtained. Failures which have occurred are usually due to either: (1) Poor mechanical construction in the scaler units (i.e., bad solder joints, etc.) (2) Resistors which were more than twenty percent outside of the rated values, particularly in the symmetric parts of the circuit. No trouble has been experienced when five per cent tolerance or matched resistors were used. (3) Failures or extreme unbalance in tubes. All tubes are operated within rated dissipations and voltages, but, since such equipment is usually kept operating 24 hours a day, weak tubes soon show up. Many counters, however, have been operating for over a year with no servicing.

Acknowledgements

The authors are greatly indebted to the many individuals contact with whom has made the development of the Model 200 Counter possible. One

\(^{10}\) Ratio of fractional change in input voltage to fractional change in output voltage.
of us owes much to the ideas exchanged with those of the Radiation Laboratory of the Massachusetts Institute of Technology. Also, much credit is due to those members of the Los Alamos Laboratory who gave valuable suggestions during the developmental work and aided in preparing this paper. In particular to D. K. Froman, W. C. Elmore and R. J. Watts.
Captions for figures included in the report on the Model 200 Pulse Counter

Fig. 1. Circuit diagram of the amplitude discriminator.

Fig. 2. Cyclograms of the discriminator operation. The time base is a 2500 cps sine wave with a peak to peak amplitude of twenty volts.

(a) Waveform appearing at the plate of tube T-1

(b) Waveform appearing at the plate of tube T-2

(c) Waveform appearing at the common cathode.

Fig. 3. Photograph of the plug-in scale-of-two.

Fig. 4. Basic circuit of the scale-of-two.

For 6SN7 unit: T-1 and T-2 - 6H6; T-3 and T-4 - 6SN7;

* R₁ = 20k; R₂ = 5k; R₃ = 15k; R₄ and R₅ = 200k; R₆
and R₈ = 100k; R₇ = 10k; C₁ and C₂ = 50 μf; C₃ = 0.01.

For 6SL7 unit: T-1 and T-2 - 6H6; T-3 and T-4 - 6SL7;

* R₁ = 100k; R₂ = 25k; R₃ = 75k; R₄ and R₅ = 200k; R₆
and R₈ = 500k; R₇ = 40k; C₁ and C₂ = 40 μf; C₃ = 0.01.
Fig. 5. Pulse forms which appear in the pulse counter with a linear time base.

(a) Input pulses of fifty volts amplitude separated by five microseconds.
(b) Input to the first scale-of-two
(c) Output of the first scale-of-two
(d) Output of the second scale-of-two
(e) Output of the third scale-of-two
(f) Output of the third scale-of-two with the linear time base eleven microseconds in length.

Fig. 6. Diagram of the register driving circuit

Fig. 7. Circuit diagram of the complete pulse counter

Fig. 8. Photograph of the completed counter showing the plug-in scale-of-two.
FIG. 1

AMPLITUDE DISCRIMINATOR
Fig. 2. Cyclograms of the discriminator operation. The time base is a 2500-cps sine wave with a peak-to-peak amplitude of twenty volts.

(a) Wave form appearing at the plate of tube T-1.
(b) Wave form appearing at the plate of tube T-2.
(c) Wave form appearing at the common cathode.
FIG. 4

BASIC CIRCUIT OF THE SCALE-OF-TWO
Fig. 5. Pulse forms which appear in the pulse counter (linear time base).
(a) Input pulses of fifty volts' amplitude separated by five microseconds.
(b) Input to the first scale-of-two.
(c) Output of the first scale-of-two.
(d) Output of the second scale-of-two.
(e) Output of the third scale-of-two.
(f) Output of the third scale-of-two with the linear time base eleven microseconds in length.
FIG. 6

REGISTER DRIVING CIRCUIT
Fig. 8

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