NRL Report 6355

# Logarithmic Sweep for Use in Display of Long Pulses in Electrochemical Transient Measurements

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January 5, 1966

U.S. NAVAL RESEARCH LABORATORY
Washington, D.C.

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# Logarithmic Sweep for Use in Display of Long Pulses in Electrochemical Transient Measurements

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The incorporation of a logarithmic sweep in an oscilloscope would be useful in the study of certain time-potential changes occurring at electrode surfaces. High-quality oscilloscope circuitry was modified to accommodate experimental log adapter units. With careful adjustment, the final circuit can provide an accurate one, two, or three decade logarithmic sweep in a display range from 5 to 10,000 μsec. Inherent limitations in the oscilloscope circuitry reduce accuracy in the 1-μsec range of the log sweep. Improved performance at the initiation of the sweep is dependent upon the development of superior horizontal sweep generator and amplifier circuitry.

## INTRODUCTION

The study of electrode reactions by means of constant-current pulses has shown that the time-potential changes occurring at an electrode surface generally proceed in an exponential manner. Such changes represent a combination of events* which, in a simple way, can be considered as a series of parallel capacitive-resistive components. If the time constants of these electrical analogs are dispersed enough, the fastest event may occur within a few microseconds of the application of a pulse, whereas the slower events will take place at much longer time intervals. These fastest events can be examined and analyzed conveniently by means of the usual oscilloscopic display of a relatively short pulse. However, subsequent changes which may occur one or two orders of magnitude later in time require a correspondingly longer pulse and horizontal sweep time. Thus, if the entire long pulse is to be photographed, the display of the initial reactions, using the ordinary linear sweep, will be so effectively compressed that analysis will be difficult, if not impossible.

The usual procedure is to obtain the complete picture to the desired accuracy by taking a succession of photographs at suitable sweep speeds. While this expenditure of time and film may sometimes be necessary, it is clear that the use of a logarithmic sweep would provide in one photograph all of the information ordinarily required. Since no currently available oscilloscope incorporates this feature, experimental work to this end was undertaken.

## EXPERIMENTAL MODELS

### Passive Network Using RC

The use of a simple RC charging circuit as a source of logarithmic horizontal sweep voltage was investigated first, using a Tektronix Type 585 oscilloscope. An RC integrating circuit with several switched values of C was plugged into the +B gate oscilloscope terminal and the output connected to the external horizontal input. In order to eliminate retrace images, A-sweep brightening was used in conjunction with the delay-time multiplier by jumping the A unblanking pulse connection in the horizontal display switch to the external switch positions. By choosing a value of C in the integrating circuit suitable to the pulse length, a fairly good logarithmic sweep and clean presentation were obtained. However, in attempting to calibrate the sweep with standard logarithmic scales, it became evident that the approximation was too rough to meet our needs. Consequently, it was concluded that a passive network would not be adequate for the purpose.

NRL Problems C05-06 and C05-13; Projects SR 007-12-01-0809 and RR 001-01-43-4754. This is an interim report on one phase of the problem; work is continuing on other phases. Manuscript submitted September 17, 1965.

*S. Schuldiner, "Electrode Processes," in "Recent Progress in Surface Science," Vol. 1, J. F. Danielli, K. G. A. Pankhurst, and A. C. Riddiford, editors, New York:Academic Press, p. 180, 1964.

### Log Adapter Unit Using Diodes

When the Tektronix Type O operational amplifier plug-in unit and accessories became available, it appeared that the log adapter unit for converting an operational amplifier from linear to logarithmic response could be useful for the horizontal sweep application. This considerably more elaborate active network consisted of a feedback loop using forward-biased diodes having logarithmic characteristics which was connected into the operational amplifier circuitry. For our purpose the log adapter was plugged into the B operational amplifier and energized from the B-sweep sawtooth in order to preserve the A sweep for trace brightening. This made it necessary to transfer the sawtooth output cathode follower from the A sweep to the B sweep and to make it adjustable by incorporating an amplitude control. A 10-kilohm potentiometer was used for the latter and connected from ground to a 2.7-kilohm resistor which, in turn, was connected to the cathode. This arrangement reduced the maximum available voltage from a nominal 150 v to 100 v, the maximum recommended voltage input to the log adapter unit.

The minimum voltage or operating level applied to the log adapter unit is very important because it determines the small-signal (maximum) gain. In terms of sweep time, this critically determines the speed of the start of the logarithmic sweep when a linear sawtooth is applied. This adjustment was provided by the use of a 5-kilohm "zero level" coarse control and a 100-ohm fine control connected in series with a 1.5-kilohm limiting resistor and a 68-kilohm, 2-w bleeder resistor between the B-sweep generator output and the −150-v line. The fine control was panel mounted. This particular combination was neatly tailored to cover the required operating range when the desired output was taken from the movable arm of the fine control as indicated in the connection diagram (Fig. 1). (This "takeoff" circuit shunts the B-sweep generator output circuit incorporating the length control.)

The amplitude of the linear sawtooth applied to the log adapter unit affects the compression of the latter portion of the logarithmic sweep. Since the output of the log adapter/operational amplifier combination approximates 1 v, the remaining A operational amplifier was connected in and adjusted as a linear amplifier for a gain of 10, which proved necessary in order to obtain the required horizontal deflection on the graticule. By manipulating the zero level and amplitude controls it proved possible to spot the sweep on ×10 and ×100 logarithmic scales that were placed over the graticule, to the degree of accuracy claimed for the log adapter unit. In fact, it was possible to reproduce an accurate scale up to about ×300. However, the ×1000 scale could not be reproduced from 1 μsec to 1000 μsec because the initial rise could not be expanded sufficiently. This limitation was apparently due

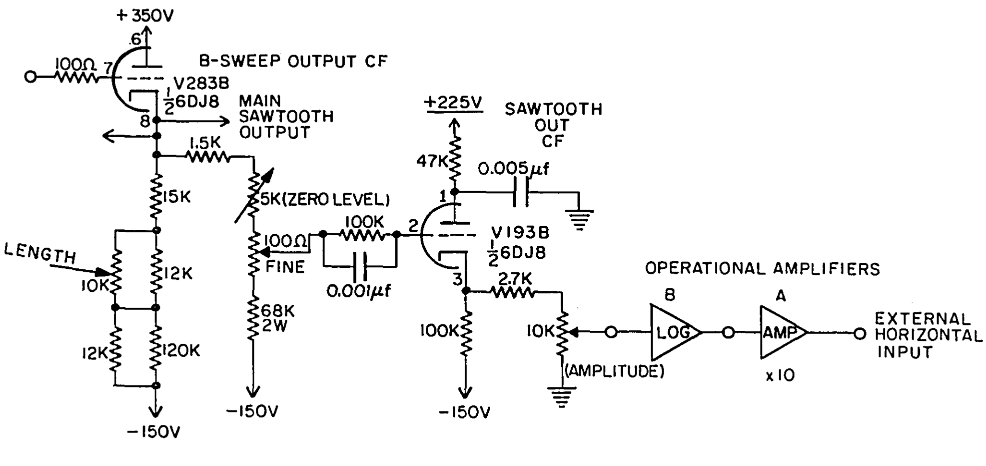


Fig. 1 — External modifications to Tektronix Type 585 scope for logarithmic sweep application

to the shunting effect of the resistors connected across the feedback diodes, limiting the maximum gain.

Adjustments to the sweep were made by observation of time marker pulses fed to the vertical oscilloscope input. These were obtained from a Tektronix Type 181 time-mark generator.

Although recurrent pulses were used in setting up the logarithmic sweep, single-pulse or "one-shot" operation could be used in making the desired measurements. This is ordinarily done by means of the one-shot pushbutton on the pulse generator that is furnishing the test pulses. In the arrangement herein described, the synchronizing pulse output from the marker generator is fed to the B-sweep external trigger input.

The log adapter unit is an extremely compact device which does not lend itself readily to alteration for experimental purposes. Consequently, in order to explore the limitations of these circuits, it was left intact for general use and a revised circuit was designed.

### Active Network Using Diodes

The revised circuit set up in a small plug-in minibox was a variation of the simpler circuit (No. 12) given in the Tektronix Type O plug-in instruction manual, using GE Type 1N3605 stabistors. The minibox was wired as shown in Fig. 2.

The variable condensers provide high-frequency compensation. The 10-megohm rheostat limits the maximum gain and, thus, the initial sweep speed. The 3-kilohm rheostat is an amplitude control which also affects the curve shape.

With the aid of these adjustments plus the zero level and sawtooth amplitude controls which were added to the scope circuitry, it was possible to improve somewhat upon the performance of the log adapter unit and obtain a good, reproducible logarithmic sweep in a display range from 5 μsec to 1000 μsec or more. The difficulty of fitting the trace to the log curve between 1 and 5 μsec, already encountered with the log adapter unit, still persisted. This limitation may well be due to the inherent characteristics of the Type 585 scope. In particular, this instrument shows a deviation from linearity at the start of the B-sweep sawtooth used in this investigation. Furthermore, the specified 240-kc (−3-db) response of the external horizontal sweep amplifier in itself constitutes a basic limitation to the log sweep speed below approximately 2 μsec. There were also other complicating factors, such as the minimum delay required by the delayed A-sweep trigger and the maximum negative voltage available at the horizontal positioning controls to hold the trace on the screen at high sweep gain. A revision of the scope circuitry with these specific problems in mind would in all probability extend the true logarithmic response to 1 μsec or better. However, it was decided not to undertake such basic changes in the instrument at hand since it is needed for other fast-pulse studies and cannot be spared for a long, complicated experimental modification.

## RESULTS AND RECOMMENDATIONS

The current investigation of the possibility of using the Tektronix Type 585 or other equivalent type of oscilloscope as a source instrument for the incorporation of logarithmic sweep circuitry has determined that an accurate one, two, or three decade log sweep can be obtained for a pulse range from 5 μsec to 10,000 μsec.

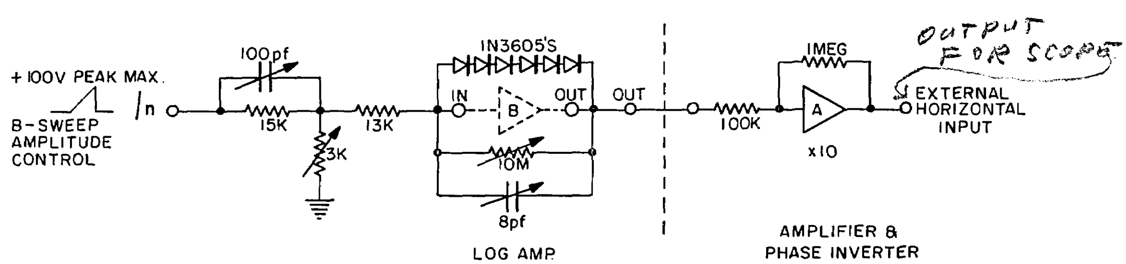


Fig. 2 — Log sweep unit

This capability should be very useful in the "one-shot" display of medium and long pulses used in electrochemical transient measurements.

This experience with the Type 585 scope emphasizes the fact that the production of extended-range, logarithmic sweeps demands state-of-the-art equipment if good accuracy is required at sweep speeds greater than 10 $\mu$sec/cm. It also highlights the desirability of modular equipment including plug-in horizontal sweep units, one of which could be specifically designed for this application and used for further experimental studies.

Further pursuit of this investigation is dependent upon the acquisition of improved equipment having certain desirable features indicated by the present study or capable of being conveniently modified so as to provide them.

Security Classification

**DOCUMENT CONTROL DATA - R&D**

*(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)*

| | |
|---|---|
| 1. ORIGINATING ACTIVITY *(Corporate author)*<br>U.S. Naval Research Laboratory<br>Washington, D.C. 20390 | 2a. REPORT SECURITY CLASSIFICATION<br>Unclassified<br>2b. GROUP |

3. REPORT TITLE

LOGARITHMIC SWEEP FOR USE IN DISPLAY OF LONG PULSES IN ELECTROCHEMICAL TRANSIENT MEASUREMENTS

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

An interim report on one phase of the problem.

5. AUTHOR(S) *(Last name, first name, initial)*

Presbrey, C.H., Jr.

| | | |
|---|---|---|
| 6. REPORT DATE<br>January 5, 1966 | 7a. TOTAL NO. OF PAGES<br>6 | 7b. NO. OF REFS |

| | |
|---|---|
| 8a. CONTRACT OR GRANT NO.<br>NRL Problems C05-06 and C05-13<br>b. PROJECT NO.<br>SR 007-12-01-0809<br>c. RR 001-01-43-4754<br>d. | 9a. ORIGINATOR'S REPORT NUMBER(S)<br>NRL Report 6355<br>9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)* |

10. AVAILABILITY/LIMITATION NOTICES

Distribution of this document is unlimited.

| | |
|---|---|
| 11. SUPPLEMENTARY NOTES | 12. SPONSORING MILITARY ACTIVITY<br>Dept. of the Navy (Office of Naval Research and Bureau of Ships) |

13. ABSTRACT

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