Low-Cost Surge Counter

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Significance

Part 5 – Monitoring instruments

This report describes a low-cost, single-threshold surge recorder developed in 1963-64 for acquiring further statistical data on the occurrence of surges in low-voltage AC power distribution systems. Looking over the parts list and costs (last page of the report) induces some nostalgia after 30 years.

After the proliferation of surge-protective devices and switch-mode power supplies, the recording of ***surge voltages*** has become a fallacy – a theme presented in several papers of this part of the anthology – hence a need to characterize the surge environment by monitoring the ***current*** that can be delivered by a surge, not the let-through voltage resulting from "SPDs galore" – see the file "Galore" in this part. Unfortunately, attempts to develop a similar low-cost, single-threshold or waveform-recording instrument (see file "Novel transducer" in this part) have not been successful or undertaken by industry.

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SUMMARY

The purpose of this report is to review the development of a low cost surge counter and to provide operating theory and instructions for their usage. This counter was specifically developed for detecting transient overvoltages on 115 volt AC power systems.

A DIAC-type device provides the threshold function to turn on a Silicon controlled switch, discharging an energy storage capacitor into the solenoid of an electromechanical counter.

Ninety of these have been built for distribution among sponsors of the Transient Overvoltage Pooled Program and will be installed in residences across the country. The results of this broad base statistical investigation will be compiled and serve to give a rough indication of the magnitude of the problem to be expected for transient-sensitive circuits.

KEY WORDS

TRANSIENTS, SURGE RECORDER, SURGES, DIAC, SCS

INFORMATION PREPARED FOR Transient Overvoltage Pooled Program

TESTS MADE BY F.D. Martzloff

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1. Introduction

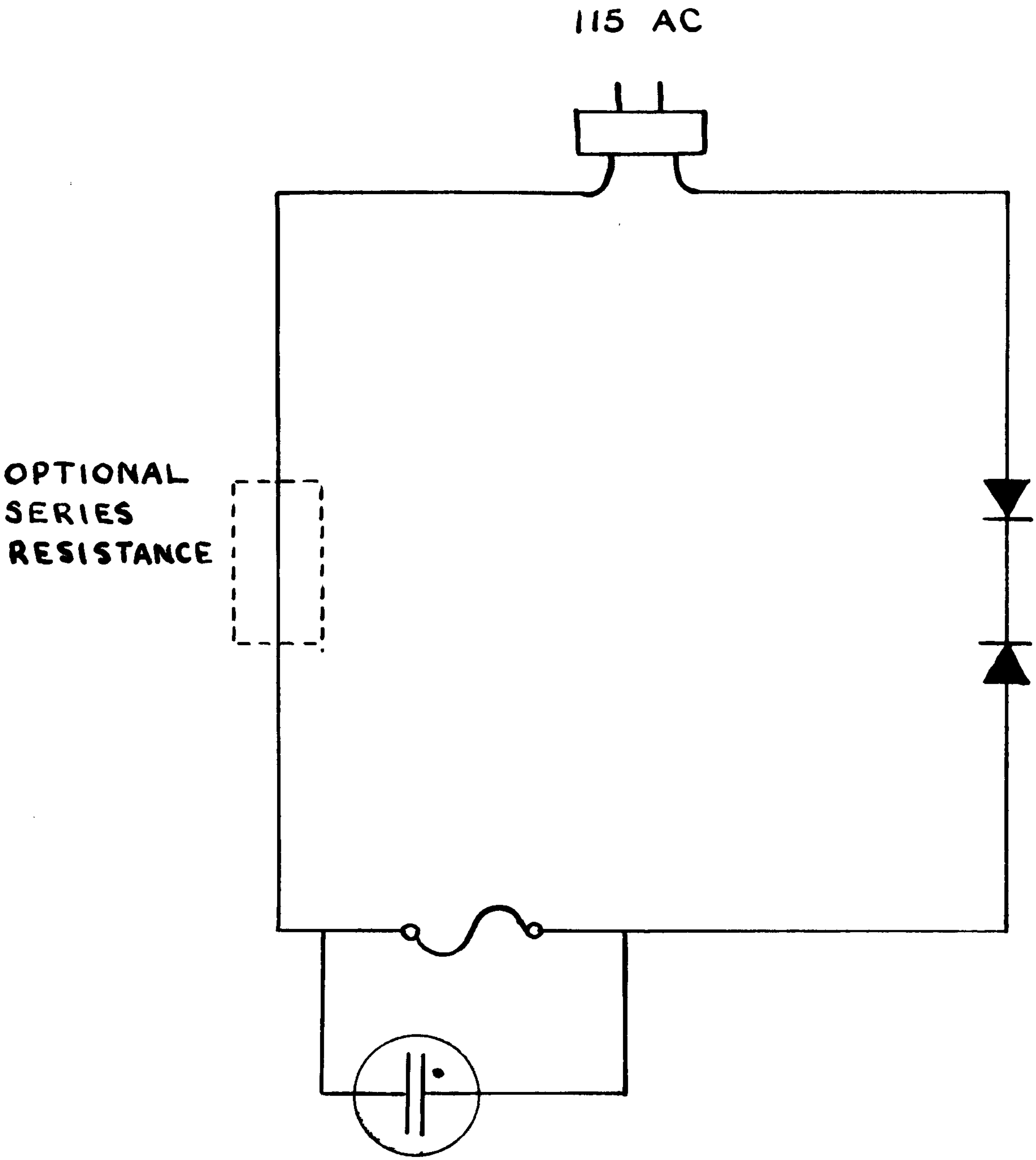
Transient overvoltages on low voltage circuits have been recorded since 1962 with automatic recording oscilloscopes, under a program sponsored by a number of Departments.

The most comprehensive data available in this field has been reported in TIS 63GL144, listing 30 locations where such recordings were made.

However, the selection of these locations was rather arbitrary, either these were homes or businesses in the Schenectady area where permission to install a recorder was obtained, or they were areas where equipment failures occurred and were brought to our attention so that a recorded could then be installed. In both cases, this selection is far from the statistician's ideal. In an attempt to cover a broader base for the locations of the homes where recordings should be made, the sponsors of the program agreed to underwrite the development of a low-cost recorder which could be readily installed in the homes of the engineers of those departments, and thus provide this broader base for a more valid estimate of the transient's frequency of occurrence.

The purpose of this survey could be accomplished if two or three levels of surges were investigated, in the range where semiconductor failures are most likely to occur.

It would also be desirable to design the recorders so that they may trigger at different levels and operate at other than 115 AC supply voltages.



ONE-SHOT SURGE INDICATOR

2. Initial Approaches

Some very simple ideas towards meeting the basic requirement of at least a one-shot surge recorder included various schemes. For instance, the failure of a diode can be used as a calibrated voltage sensor, or turning on the AC power by a surge-triggered DIAC-type device into a fuse which would then blow, or blowing a fuse by the reverse current in controlled avalanche diode, etc.

2.1 One-shot diode recorder

The one-shot diode circuit would only have required two back-to-back diodes and a fuse. Tests have shown that the failure of the 1N679, for instance, under reverse transient voltage is very consistent, so that this failure level could be used as threshold. Following failure of one diode, in a first approach the second diode would have failed on excess forward current, causing the fuse to blow (see sketch). In a second approach, the high forward current in the remaining diode would then cause the fuse to blow first. In the second case, examination of which diode had failed would indicate the polarity of the surge. In each case, a neon lamp across the fuse would have indicated the failure, i.e. the occurrence of a surge exceeding the threshold level. Resetting of the indicator would then require one or two diodes to be replaced, in addition to the fuse.

The advantage of this is the low initial cost (under $2) offset, however, by the replacement costs for each resetting (about 75¢). The other disadvantage is the need to examine the diode for polarity discrimination, and the limited number of threshold levels existing in available diodes.

2.2 Controlled avalanche diode recorder

In this circuit, the high current following diode failure would be replaced by the avalanche current above the knee of the diode characteristic. Again, two diodes would be mounted back-to-back with a fuse in series and with a neon lamp in parallel to indicate a blown fuse.

However, the energy available during avalanche is likely to be small and too sensitive a fuse might be required. Furthermore, the leakage current in the diode might not be sufficient to fire the indicating neon lamp across the blown fuse.

2.3 DIAC-type recorder

A slight modification of the controlled avalanche diode appeared possible, by using a DIAC-type switch, which would be turned on by a surge above the threshold of the device, while the follow-current from the AC line would then supply the necessary energy to blow the fuse. Resetting would then only require a fuse replacement.

However, the unavailability of DIACs (or SSS switches) with a high threshold required the use of a voltage divider in order to trigger at surge voltages above 300 volts, which is the case here. It then became difficult to provide a divider with sufficiently high impedance to avoid loading the circuit under test and still with low enough impedance to provide holding current during the remaining part of the 60 cps half wave following the surge.

Furthermore, it was also found that turn-off of this device occurred very fast, so that if the surge was a damped oscillation, the switch could be turned on by the first loop, but promptly turned-off as the surge oscillated into the next loop of reverse polarity with insufficient amplitude to turn it on. Thus, the 60 cps follow current could not occur.

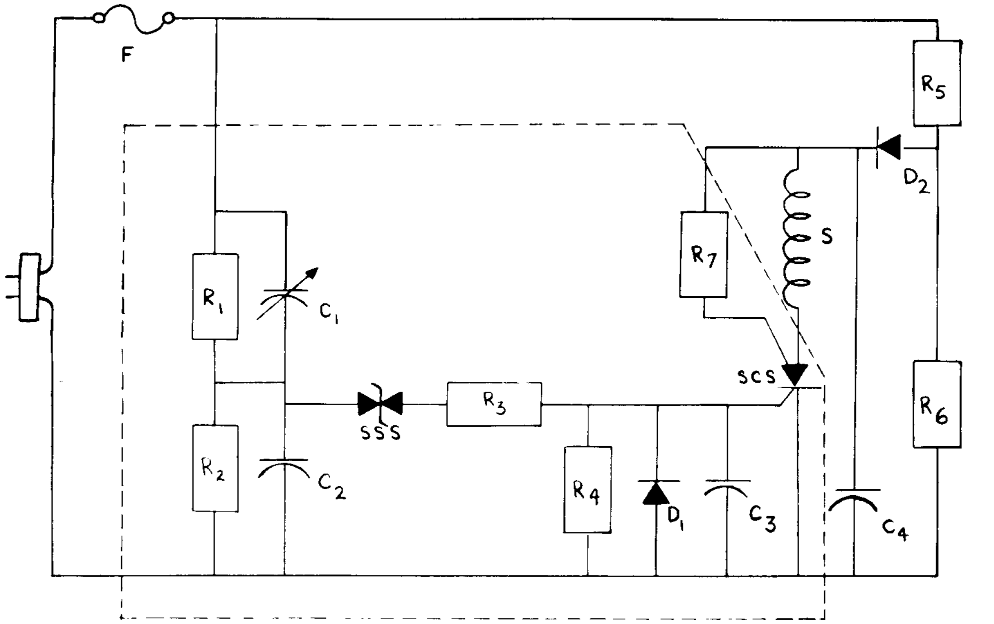
After reviewing and trying some of these three approaches, it became apparent that some latching had to be provided by some form of stored energy, with the surge supplying only the trigger pulse. As soon as the concession was made, against the initial concept of minimum circuitry, to provide stored energy, it seemed that using this stored energy to drive a counter would produce more interesting results than just to blow a one-shot fuse. This led to the development of the recorder described in the following section.

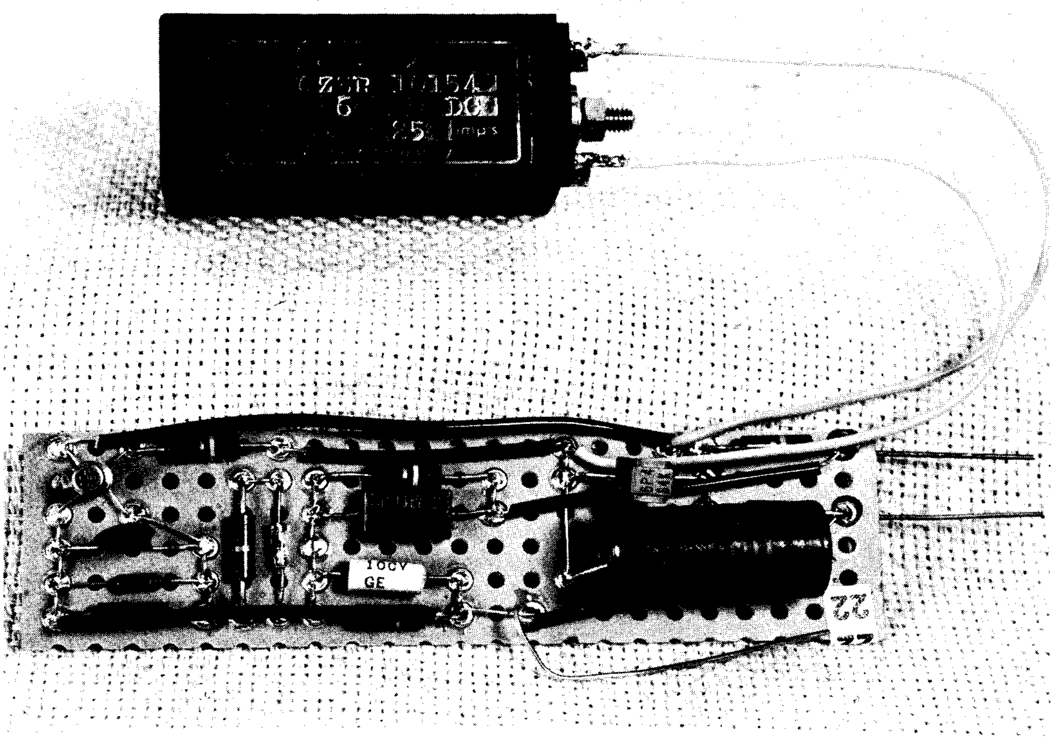
3. Counter-output Recorder

The device shown on the opposite page was developed as the result of the experimentation and considerations discussed above. It is capable of triggering for surges as short as 0.5 μs in excess of the design threshold level, for one polarity. The threshold level is determined by the combined parameters of an input attenuator and SSS switch. Reverse polarity is recorded by reversing the connection, i.e., the plug in the outlet.

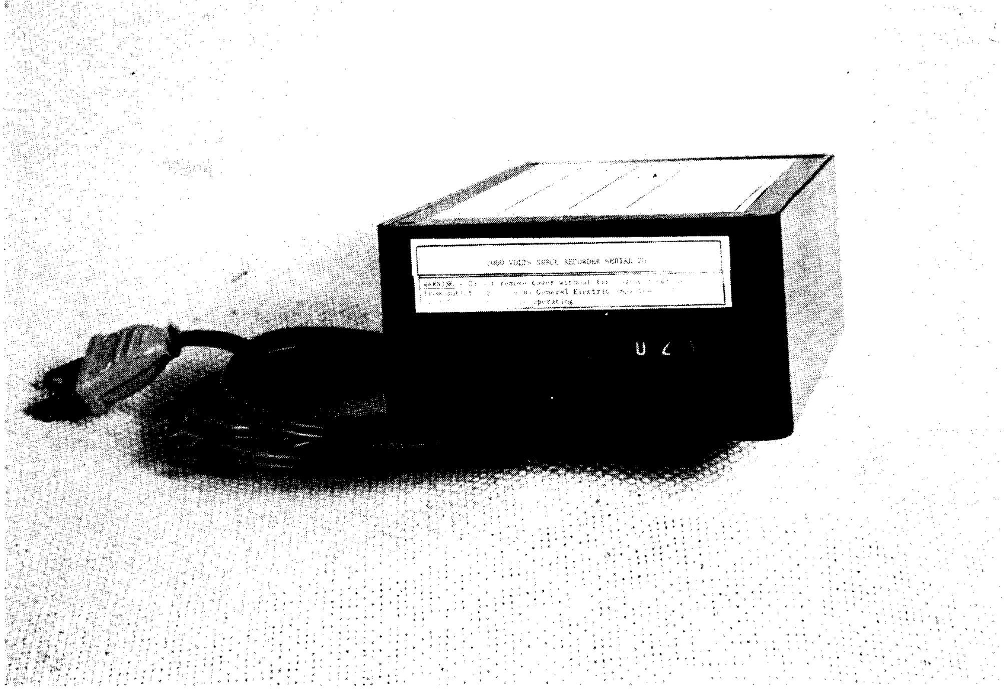
In contrast with available commercial recorders which generally use a coaxial input lead, with attenuators sometimes built in the probe, this recorder is connected to the circuit to be measured by a standard appliance cord. This provides an easy method of connection, with the added feature that the recording takes place at the end of 6 feet of lamp cord, where an appliance would normally be connected. Fast surges (less than 0.1 μs rise time) would obviously be distorted by such a crude connection, but this is not the point here where the expected surges will have 0.5 μs rise time or more, as demonstrated by a number of oscilloscope recordings.

The threshold level is stable within $\pm$10% of the nominal value for a temperature variation of $\pm$25%^{o}C, which is more than what can be found between hot attics or cold basements.

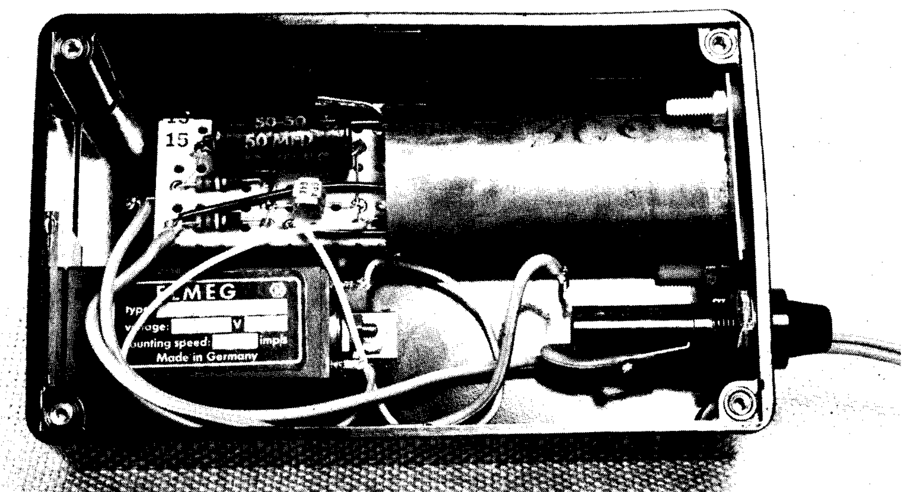




Surge counter - Active circuit and counter . The left side of the circuit, shielded by tubing shown in preceding photograph, is visible here.
(ATL Photo No. 833103)



Surge counter - connecting cord is only accessible part, with non-reset counter behind window.



Surge counter - cover removed.

1964-vintage surge counter mentioned in the "*Where do we go from here?*" article
(See GE TIS Report "Low-Cost Surge Counter" in Part 5 of the Anthology)

The level of each individual unit has also been set within 10% of nominal value by matching the SSS switch with the input divider ratio.

Two levels were selected for the threshold: 1200 volts, corresponding to a value where, for instance, low cost appliance half-wave rectifier circuits feeding a capacitor or a battery will begin to fail; the other level is 2000 volts, where most half-wave rectifier circuits will not survive, and where appliances with an input transformer may start failing. Thus, the results of the survey will yield statistics at these two levels.

3.1 Principle of operation

An incoming positive surge is attenuated in the R_1-C_1/R_2-C_2 divider. If the voltage across R_2-C_2 exceeds the turn-on voltage of the DIAC-type SSS, this voltage is applied through the divider $R_3R_4C_3$ to the gate of the SCS. Excessive gate current is prevented by this $R_3R_4C_3$ network, while the diode D_1 protects the gate against negative pulses. C_3 also helps to reduce firing of the SCS by spurious noise and attenuates the signal leaking through the junction capacitance of the SCS at levels below the threshold.

With the SCS turned on by the gate signal, the capacitor C_4 will discharge through the coil of the counter which indexes for one count. The anode gate resistor R_7 stabilizes the turn-on of the SCS and prevents any possible rate effect. With the 60 cps supply to the rectifier, the latter is not very likely; a resistor in the anode circuit would further reduce the possibility of rate effect, but was found unnecessary in this case.

The capacitor C_4 is charged to a fraction of the line voltage through the divider R_5-R_6 and the diode D_2. The diode D_2 is a selenium rectifier in order to withstand the incoming negative surges which are implicitly expected in this application, and which would promptly cause failure of an unprotected silicon diode in this half-wave circuit.

The values of the divider R_5-R_4 are high in order to reduce the follow-current through R_5, D_2 ,S and SCS below the holding current of the SCS. The gate resistance R_4 contributes to making this holding current relatively high so that the resistance R_5 is held low enough to allow recharging the capacitor in a reasonable time.

The input attenuator is enclosed in a shield in order to eliminate the variable stray capacitances which would affect the divider ratio. The gate circuit of the SCS and the SCS are enclosed in the same shield in order to eliminate noise radiation into the gate circuit.

3.2 Limitations

The threshold is obviously fixed for a given unit. It could just as obviously have been possible to provide an attenuator with several levels and a selector switch. However, it was decided to limit each unit to a single level in order to avoid possible confusion in the records on the position of the selector, as well as to avoid bringing a metal shaft out of the insulating box and out of the attenuator shield.

The recorder triggers on one polarity only, reducing in half the number of random surges likely to be recorded in a given period. On the other hand, this allows discrimination, where desirable, of the surge polarity. If it is necessary to record both polarities at the same time, two recorders with the plugs reversed (the plugs are marked) can be used.

The resetting time of the recorder is determined by the charging cycle of the energy storage capacitor. We saw why this had to be long. However, this is no problem in the case of the erratic surges which are expected to be recorded in homes. On the other hand, it is conceivable

INSTRUCTION AND RECORD SHEET FOR USER

1200 VOLTS SURGE RECORDER SERIAL 12

DATE	COUNTER READING	LOCATION	REMARKS (Lightning, power outage, etc.)

__INSTRUCTIONS__ - Plug in any 110 volt outlet where occurrence of surges is to be recorded. Enter date, counter reading and location (city) in appropriate column. Also show in remark column if any unusual activity occurred during recording period.

__WARNING__ - Do not remove cover without first disconnecting cord from outlet. For use by General Electric employees only! Read TIS 64GL166 before operating.

INSTRUCTION AND RECORD SHEET FOR USER

2000 VOLTS SURGE RECORDER SERIAL 12

DATE	COUNTER READING	LOCATION	REMARKS (Lightning, power outage, etc.)

__INSTRUCTIONS__ - Plug in any 110 volt outlet where occurrence of surges is to be recorded. Enter date, counter reading and location (city) in appropriate column. Also show in remark column if any unusual activity occurred during recording period.

__WARNING__ - Do not remove cover without first disconnecting cord from outlet. For use by General Electric employees only! Read TIS 64GL166 before operating.

that if the recorder were connected to a circuit where surges would occur at the rate of several per minute, the SCS would be continuously triggered, so that the capacitor would never reach a sufficient charge to actuate the counter.

4. Recording Procedure

Previous recordings performed with oscilloscope-camera combinations have shown that one week is more than sufficient to determine the pattern of household switching surge occurrence. On the other hand, surges due to power system switching and lightning are quite erratic, but tend to involve all the homes in the area.

Therefore, the following procedure is suggested: a 1200 volt recorder should be installed in a selected home, and left for one week. Enter start and finish date and counter readings at these dates, and install the recorder in the next available home. From previous oscilloscope recordings, we would expect about a 70% probability that very few or no surges will be indicated, in which case there is no point in installing the 2000 volt recorder. In those homes where the 1200 recorder will have indicated surges, the 2000 volt recorder should be installed next in order to determine the number of the surges in excess of 1200 volts which even exceed 2000 volts. Of course, the two recorders could be installed simultaneously at the same location, but this would require two units. With a split of 3 units at 1200 volts and 1 at 2000 volts, more of those 70% locations where little surge activity is to be found can be covered in a given period of time.

As soon as the peel-off data sheet secured to the recorder is filled, (see opposite page), it should be returned to ATL for compilation of the statistics. Spare sheets have been provided with each counter.

5. Acknowledgments

The author wishes to acknowledge the encouragements and valuable suggestions received during the circuit development from Messrs. J.D. Harnden and H.F. Storm of ATL and R. Muth of SPD.

The contributions of Messrs. Deiber, Travis and Young in packaging the experimental circuit into a number of units are also acknowledged.

PARTS LIST

R_1	200 K (2000 volts)	
	120 K (1200 volts)	
R_2	12 K	
R_3	2 K	
R_4	2 K	
R_5	68 K	
R_6	68 K	
R_7	51 K	

all ½ watt carbon

C_1	150 pF 500V mica nominal (2000 volts)
	250 pF 500V mica nominal (1200 volts)
C_2	.01 μF 100V mylar
C_3	.001 μF 500V ceramic
C_4	50 μF 50V

F	½ amp fuse
SSS	Hunt Electronics "logic device"
SCS	3N85
D_1	1N457
D_2	6RS6PH4RAD1
S	Elmeg counter 0Z3R10154
Casing:	Lafayette Cat. #19G2001
Cover:	Lafayette Cat. #19G3701

Total Parts cost (in quantities of 100)	$18.00
Counter only	$10.00