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AUTOMATED MONITORING OF THIN FILM
CAPACITORS FOR ELECTRICAL BREAKDOWN

By R. T. Horn

Published January 1979

Topical Report
D. D. Smith, Project Leader

Prepared for the United States Department of Energy
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**Kansas City
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A long term automated test system was constructed to provide full time monitoring of thin film capacitors for electrical breakdowns. System sensitivity was investigated to relate electrical background noise to electrical breakdowns.

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**A prime contractor with the United States
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SUMMARY

A long term automated test system and one test station with 15 part test capability were constructed to monitor thin film capacitors for electrical breakdowns. When a breakdown event occurs (one or more detectors sense breakdown pulses at the same time), the system will record the time of day for each breakdown onto a separate file in a disc memory system. This information is accessible for statistical analysis and printout.

The system also incorporates the following features.

- The test stations are electrically isolated from the recording and control section.
- The test stations are on battery backup power. In the event of a general power failure, this power is capable of maintaining the supply voltage to the parts under test for up to 8 hours.
- The programmable calculator, included in the system, can be used for normal operations while the parts are being monitored.
- The calculator, in a power-up condition, automatically checks for breakdown events.

Four typical parts (approximately 4 μ F each) were monitored for breakdown events over a 4-month period. These parts were held at 73.9°C (165°F) and 20 V potential. During this period, 35 breakdown events occurred. Of these, 33 occurred on normal working days. During nine of the events, breakdowns were recorded at part locations where the test leads were shorted together. The results of preliminary data analysis reveal the majority of breakdown events occur during the middle of the day and in the middle of the week with a high probability of false triggering from electrical background noise.

Future studies will involve Sandia Laboratories Albuquerque (SLA) detector designs, connecting the system to a non-interruptible power line, possible expansion of the data recorded at breakdown to include immediate breakdown time and oven temperature, and the fabrication of four more test stations.

DISCUSSION

SCOPE AND PURPOSE

The purpose of this work was to develop a continuous monitoring system for detecting breakdowns of thin film capacitors undergoing long term storage tests. This activity involved designing and constructing a breakdown pulse detector and interfacing it with a programmable, calculator-controlled system to record when breakdowns occur.

PRIOR WORK

Since the early development of thin film capacitors, long term testing of parts subjected to thermal and electrical stress has been required. Data obtained from periodic monitoring of part capacitance and leakage current has aided process characterization since 1974. Also, data obtained on part breakdowns indicated continuous monitoring for such events would prove invaluable.

After a literature search showed there was no system available in industry for performing the desired monitoring function, it was decided to design and construct a breakdown pulse detector and interface it with a programmable controlled calculator.

ACTIVITY

A test system has been constructed that is capable of continuously monitoring for electrical breakdowns in thin film capacitors. When a breakdown occurs, a record of the time of the breakdown (within 2 seconds) is made by the system. The system contains one test station, but is expandable to 36 test stations. Each test station contains up to 16 parts. In addition, each test station can be separate from all others in supply voltage level and temperature at which its respective parts are maintained.

System Description

The master test station (Figure 1) continuously checks each test station for a breakdown signal. When a breakdown signal is detected, the master test station signals the programmable calculator. The calculator (which could have been working on another program at the time) immediately goes to the floppy disc memory and retrieves a program which controls the data recording operation. The correct time of each breakdown is determined, and a printer is available to list out pertinent data at the programmer's request.

Figure 1. Long Term Automated Test System Diagram

The description of the electrical schematics and operational flow of the system is divided into three main sections: the test station, consisting of the detector and its interface; the master test station; and the programmable calculator. The complete electrical schematics of the circuits for the test station, master test station, and interface connections to the programmable calculator are available at Bendix Kansas City.

System Operation

Detector Circuit

The detector circuit (Figure 2) is connected to the part under test by the twisted leads. The breakdown detector input is a pulse transformer with a torus type core. It has three windings. Two of the windings are connected in phase series and form the primary. The primary is connected across a 1 k Ω resistor (RB) (for impedance matching) and a 0.1 μ F capacitor (CA) in series with the part under test.

The stress voltage is applied through two 100 k Ω resistors (RA, RC) and across capacitor CA. This voltage will charge both CA and the part through the transformer primary. The part under test is essentially in parallel with capacitor CA.

Figure 2. Detector Circuit Schematic

If the part under test breaks down, the part and capacitor CA will discharge through the transformer primary, generating a voltage/current pulse in the secondary. A $510\ \Omega$ resistor (RG) is paralleled with the secondary for impedance matching purposes. The secondary pulse is applied to the emitter and base of a transistor and will therefore pulse the transistor on. The collector is tied to the clock input of a flip-flop used as a latch.

The remainder of the detector circuit consists of another $100\ \text{k}\Omega$ resistor (RD) in series with a shut-off transistor QA. This $100\ \text{k}\Omega$ resistor is used for leakage current viewing ($100\ \text{mV} = 1\ \mu\text{A}$).

The function of QA, which is used as a switch, is to remove voltage from the part under test following a breakdown. The base of QA is tied through a $1\ \text{k}\Omega$ current limiting resistor (RF) to signal SO (shut-off). This signal is generated by the flip-flop when it latches. A $51\ \text{k}\Omega$ shunt resistor (RE) is tied from the collector of QA to the positive bias line. It provides a low impedance to effectively remove the voltage on the part when transistor QA is off.

Preliminary investigations indicate the detector latch will set with at least a $1\ \mu\text{s}$ pulse resulting in a 1-V change in the primary of the transformer. Shorter pulses of smaller amplitudes have not been evaluated.

A flow chart illustrating the basic operation of the detector system is shown in Figure 3. Once a breakdown occurs, a particular latch associated with the part is set. When it becomes set, it also turns off the power to that part. With the setting of the part latch, a service request latch is set which transmits a service request signal to the interface board.

Interface Board

Each test station contains an interface board (Figure 4) which interprets commands from the master test station or the calculator to assist in determining which part broke down. Its first operation is to output the service request to the master station. It then waits until a signal from the master station "unlocks" its part counter. This counter is held at "0" in a "locked" state to prevent false triggering from noise. On the first clock pulse from the calculator, the service request latch is reset. This action permits the setting of the latch by a subsequent breakdown while the test station is being polled. The counter is incremented by one with each clock pulse from the calculator. If the part latch corresponding to the counter value is set, a signal is sent to the calculator. The system then waits until the next clock

Figure 3. Diagram of Operational Flow of Breakdown Detector

pulse from the calculator to increment the counter for the next part latch. If the part latch is not set, the system bypasses the output signal to the calculator. When the counter value exceeds the number of part stations, a signal from the master station resets the part counter and "locks" it up.

Figure 4. Diagram of Operational Flow of Interface Board

Master Test Station

The master test station (Figure 5) acts as the interface between the calculator and up to 36 test stations. It is electrically separated from the test stations by opto-isolators. Its function is to consecutively examine each service request line from each test station. When it finds one that is set, it places the identification number of that test station on an identification (ID) bus (a multiconductor cable to the calculator), issues a signal to unlock the counter in the test station, and issues an interrupt to the calculator. Once the calculator responds and reads the test station ID, the master test station has no other function but to wait for a signal from the calculator to reset and lock the counter in the test station and resume normal operation.

Programmable Calculator

The overall system is constructed so the programmable calculator can be utilized in its normal manner on other programs until an interrupt signal is received from the master test station (Figure 6). At that time, current operation is suspended. Normal operation resumes after the interrupt is serviced with no loss of information.

Figure 5. Diagram of Operational Flow of Master Test Station

When the interrupt is serviced by the calculator, it first requests the master test station for the test station ID. It then opens the corresponding file in disc memory and issues a clock pulse to the corresponding test station to check the first part latch.

If a signal is returned, then the part latch is set and the calculator checks to see if it has already recorded that at a previous time. If so, the system continues by sending the next clock pulse. If not, the time of day is read from a battery powered clock and written to the file of the part latch that was set. When all the parts have been examined, a signal is sent to master test station to reset and continue. The calculator then returns to normal operation.

Figure 6. Diagram of Operational Flow of Programmable Calculator Response to Test Station

System Study

Four dummy parts, approximately 4 μ F each, were attached to the first four sets of test leads in one test station. The parts were in an oven maintained at 73.9°C (165°F) and had a constant applied voltage of 20 V. The other eleven sets of test leads were shorted in their respective pairs. After each breakdown, the time of the breakdown was printed out and the part file in the memory was reset. Voltage was then restored to the parts that exhibited breakdowns to allow more breakdowns to occur.

The study lasted 4 months and the results are listed in Table 1. As can be seen, breakdown pulses were detected even at the locations where the leads were shorted together. This indicates sufficient background noise was present to falsely trigger the part latches. Of the 35 separate breakdown events listed, nine contained breakdown counts on shorted leads. Figure 7 is a histogram of data shown in Table 1. The horizontal axis is scaled in hours and the vertical axis is scaled in the days of the week. The data is plotted as the number of breakdowns that occurred during a particular hour on a particular day of the week. The frequency of breakdowns according to the day of week is shown to the right of the graph. The majority of breakdown events occurred in the middle of the week and the median of the events lies on Wednesday. The frequency of events according to the hour of the day is shown at the bottom of the graph. The median lies at 12:00 a.m. and it can be seen that the majority of events occurred around the middle of the day.

ACCOMPLISHMENTS

A long term automated test system was constructed to monitor thin film capacitors for electrical breakdowns. The parts are subjected to various levels of temperature and electrical stress during testing. The system contains one test station, but is readily expandable to 36 test stations capable of handling 15 parts each. The programmable calculator included in the system can also be utilized for other functions without reducing the system's monitoring capability.

Four test parts were monitored during a 4-month period and only 35 breakdown events were recorded. Because of the small number of parts tested, a detailed statistical analysis was not possible. Information was revealed, however, that the majority of breakdown events occurred during the middle of the day and in the middle of the week. Also, the absence of a random pattern of breakdown events indicates the true breakdowns, if they occurred, were probably masked by the background noise either from the regulated power supply lines or background electromagnetic radiation.

FUTURE WORK

Results from this endeavor indicate improved shielding and power line regulation might be needed as well as adjustments to the sensitivity of the breakdown detector. Tests will be conducted to evaluate sensitivity to noise spikes in the power lines and filters will be added as needed. Shielding will be utilized to try to limit the influence of electromagnetic radiation. To assist in deciding which adjustments will be the most valuable, a

Table 1. Breakdown Events

Date	Time*	Test Leads**														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1/23	1536	X	X													
1/24	1413	X	X													
1/25	1259	X	X													
1/27	0929		X													
1/27	2332	X														
1/31	1036	X														
1/31	1235	X														
1/31	1345	X														
1/31	1700	X														
2/1	1331	X														
2/2	0947	X														
2/2	1115	X														
2/3	0042		X					X	X						X	
2/15	2230		X		X											
2/27	0852				X											
3/7	1159														X	
3/8	0911	X														
3/8	0923		X													
3/16	1333	X	X	X	X	X	X	X	X							
3/18	2147	X	X													
3/24	0123	X	X													
3/26	0852			X	X			X	X	X	X	X	X	X	X	X
3/30	1416	X														

Table 1 Continued. Breakdown Events

Date	Time*	Test Leads**														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
4/10	1846	X	X													
4/12	1411													X		X
4/13	0933		X									X	X	X	X	X
4/13	2307	X	X													
4/19	1510				X					X		X	X	X	X	X
5/3	1006				X					X	X	X	X	X	X	X
5/16	0316	X	X													
5/19	0659	X	X													
5/19	1124	X	X													
5/19	1503													X		X
5/22	0009	X	X													
5/23	1928	X	X													

*24-hour clock.

**Parts installed on first four sets of test leads, remaining 11 leads shorted; oven temperature was 73.9°C.

Figure 7. Histogram of Breakdown Data in Table 1

breakdown simulator will be designed and constructed. This simulator will be used as a reference for other detector circuits as required.

Most test stations will be fabricated with adjusted detectors installed and several types of parts will undergo long term test. The increased data obtained from having more stations and therefore more parts under test will aid in the evaluation of the sensitivity of the detectors and the efficiency of the system.

Future studies will involve considerations of SLA detector designs, and possible expansion of the data recorded at breakdown to include the part temperature.

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