N69 29431

IX. Electronic Parts Engineering

ENGINEERING MECHANICS DIVISION

A. MOSFET Screening Methodology, *R. A. Summers*

1. Introduction

The metal oxide semiconductor field effect transistor (MOSFET) is a recent development in the transistor field. Its significant features include: (1) a high input impedance comparable to vacuum tubes, and (2) operation at very low power levels. Its use tends to simplify transistor circuitry, and it is somewhat simpler to manufacture.

Because of the significant difference in operating principles and design between MOSFET and conventional bipolar transistors, the method of screening will be different. Two vendors, Fairchild and Siliconix, were selected to develop new screening methods.

Although the approaches by the two vendors were somewhat different, the investigations included:

(1) Gate voltage stresses in the breakdown region.

(2) High-temperature bias tests.

(3) Noise measurement.

(4) Oxide purity tests.

(5) Temperature cycling effects.

(6) Characterization at low temperatures.

(7) Life test to determine degrading effects of various stresses.

The transistors at Siliconix are single enhancement–depletion mode, N-channel units similar to the 2N3631. The Fairchild units are dual enhancement mode, P-channel units similar to the FI0049.

2. Test Results

The test at Siliconix has been concluded. Accidental damage to the high-temperature reverse bias test group invalidated the test sample integrity. However, the following test results were obtained:

Thermal shock. The transistors were tested for resistance to thermal shock by immersing them alternately in boiling water and boiling liquid nitrogen. This test is a screen for marginal internal lead bonds and defective chip-to-header bonds. There were no failures.

Oxide stress test. The absolute maximum rating of the gate to channel voltage is ±60 V. The devices had actual destructive breakdown voltages of 105 to 120 V, which shows adequate safety margin. There was some parameter shift before oxide rupture, but it was too close to breakdown to be useful.

Low-temperature performance. Over the temperature range of +25 to −196°C the MOSFET exhibited the following characteristics:

(1) Gain doubled.

(2) Pinch-off voltage decreased linearly by 8%.

(3) Drain-source breakdown voltage decreased 15%.

(4) No deterioration in input resistance.

(5) Input capacitance was stable.

(6) Drain-source on resistance decreased by 50%.

At Fairchild all the screening tests have been completed, and the parts are in life test. Analysis of data will await completion of the life test. Completion is estimated for March 1969.

B. Power Pulse Method of Screening Resistors,

K. C. Evans

The feasibility of a screening method for resistors is being investigated wherein a short duration power pulse is applied to the part and the resistance variation is monitored during the pulse period. If successful, this method will replace current methods and effect significant savings in screening time and cost.

The current method used for most screening tests is to apply a high-level stress to the part being evaluated with the anticipation that the stress will provide an indication of any defect or weakness in the part. In the past a permanent change in the resistance value has been the indication of defectiveness. By measuring the resistance before and after the screening test, it could be determined that a permanent resistance shift occurred as a result of the high-level stress.

The power pulse method of screening resistors consists of monitoring the resistance change of the test component while it is being subjected to a controlled pulse of maximum nondestructive power. The maximum nondestructive power is defined as that power level which during the test period will bring the temperature of the resistance element up to a specified maximum just below the point where it will cause damage to the resistive material. Generally 5 to 20 times the rated power is applied to the element for a period of 5 s or less. Since the temperature rise in the resistance element is effected over such a short time period, the resulting differential expansion will create stresses in the test unit beyond what would be encountered under normal operating conditions. The effect of these stress conditions on the resistance of the test component is continuously recorded.

The contracted portion of this investigation has been completed. The work included a comparison evaluation on selected resistor types of the power pulse method versus the currently used screening method. The feasibility study has demonstrated that the power pulse method is highly effective. The power pulse screen detected 54 parts of a total 3900 as being abnormal, whereas the conventional screen detected 9 parts of a total 3900. The life test indicated that the power pulse screen detected an additional 15 abnormal parts for a total of 68. In the conventionally screened lot, 30 additional parts were detected for a total 39. This indicates the power pulse method to be about six times more effective in detecting abnormal parts.

The test pulse level for this effort was arbitrarily established at the level necessary to produce a 0.02% permanent change in resistance. Because of differences in rating criteria by manufacturers, as well as differences in configuration and materials, the actual pulse level used ranged from 7 to 70 times rated power for the various types tested. The power pulse method of screening will effect a substantial saving in both time and money. Based on 1,000 resistors to be screened, the power pulse method can be accomplished in one fifth the time and cost of the previous method. Both the potential time and cost savings has prompted further investigation into the use of power pulse screening of resistors.

JPL is purchasing a machine that will screen resistors by the power pulse method. This equipment will provide a maximum of 200 W for resistors up to 20,000 Ω and a maximum of 2,000 V for resistors between 20,000 and 2.0 MΩ. After the proper power level and pulse duration are set up, the machine automatically plots the change in resistance during the power pulse. The resistance monitoring device can indicate resistance fluctuations of as little as 0.001%, so that deviation from the expected change in resistance trace can easily be identified and evaluated to determine if they indicate a nonhomogeneous part. The amount of resistance change or the variation from a normal trace which can be allowed before a part is considered defective varies depending upon the type of resistance element and the degree of the discrimination which is required.

Before the power pulse method can be incorporated into a project screening operation, it will be necessary to establish optimum pulse levels for all types of resistors on the JPL preferred parts list. Testing will be performed and procedures written so that the equipment can be used for project screening.

C. High-Impact Survival of Electronic Parts,

K. R. Bilodeau and K. C. Evans

1. Purpose of Test

Spacecraft electronic equipment capable of withstanding high shock accelerations can benefit the lunar and planetary exploration programs in several ways. The use of such equipment in capsules intended to survive high velocity landings will generally ease design constraints and lead toward increased overall efficiency of the capsule system. Another use is in soft landers, where a hard core could survive an abnormal landing and provide valuable diagnostic information. In other applications, increased reliability of performance after exposure to the normal ground handling and flight environments may be realized (Ref. 1).

The development of such equipment involves two problems on the component part level: (1) ensuring that the component parts used are, by themselves, capable of withstanding high shock accelerations, and (2) ensuring that these parts and their structures are protected by proper mounting and packaging. This test program was initiated to solve the first problem.

2. Test Program

The test program involved rigidly mounting various resistors, capacitors, transistors, diodes, thermistors, relays, fuses, and inductors selected from the Jet Propulsion Laboratory preferred parts list. Various electrical parameter measurements of the mounted parts were then made. After initial measurement, the total number of parts of each part type was divided into three subgroups. Each of the subgroups was subjected to a 2,000 $g \pm 10\%$ square wave with a pulse time of 0.5 to 1.5×10^{-3} s with each subgroup mounted in one of the three distinct axes of the part. Electrical parameter measurements were again made and recorded. The mounted parts were then subjected to a 5,000 g shock with each subgroup mounted in the same axis as before. The parameters were again measured and recorded. The parts were subject to a 10,000-g shock, and final parameter measurements were made and recorded. Those parts which failed by excessive parameter change and those which failed catastrophically were removed from the mounting board, disassembled, and visually inspected.

3. Shock Testing

It is insufficient to define an impact shock by g-level alone. Additional information is required in the form of duration and pulse shape. There are numerous ways in which the damage potential of a shock pulse or the sensitivity to damage of a component may be presented. A concept that is easy to understand was originated at the Naval Ordnance Laboratory (Ref. 2).

According to this concept, the conditions under which a specimen will or will not be damaged may be presented graphically on a plot of velocity change versus acceleration. The shape and location of the curve separating the region of damage and no damage is dependent on the mechanical properties of the specimen and on the shape of the applied shock pulse. Quantitatively, for a given shock pulse shape and direction of loading, there are two ways in which the specimen may escape damage. The peak acceleration may be so low that the component could withstand its steady application, or the velocity change may be so small that the maximum energy that can be supplied to the component is insufficient to produce damaging stresses. In the latter case, the applied acceleration could be extremely high without causing damage.

The remaining factor to consider is pulse shape. Kornhauser (Ref. 2) derives curves that show that a square-wave input provides the greatest amplification factor. Amplification factor is the ratio of maximum dynamic deflection of a system to the maximum static deflection. It can then be concluded that to conduct a severe test, it is best to use a high-level square-wave shock pulse of as long a duration as possible.

4. Equipment

The main piece of equipment is the sling-shot type shock tester (Fig. 1). The tester consists of a pair of guide rails (I-beams), a pretensioning mechanism, a winch, a release mechanism, a test carriage, a copper target, and an impact block. The test carriage travels between the guide rails. It uses a 40-ft long shock-absorber (bungee) cord. The bungee cord is loaded to a small pretension, and the test carriage is pulled by the winch against the tension of the bungee cord to a selected length for desired shock pulse duration. Various bungee cords, each with different diameters, are used to achieve selected impact velocity. Tension force varies linearly with a displacement of up to about 80% elongation. The impact tool is mounted in front of the carriage. Test shocks are produced by impacting the carriage nose against an annealed copper block (target), which is mounted in the impact block. The

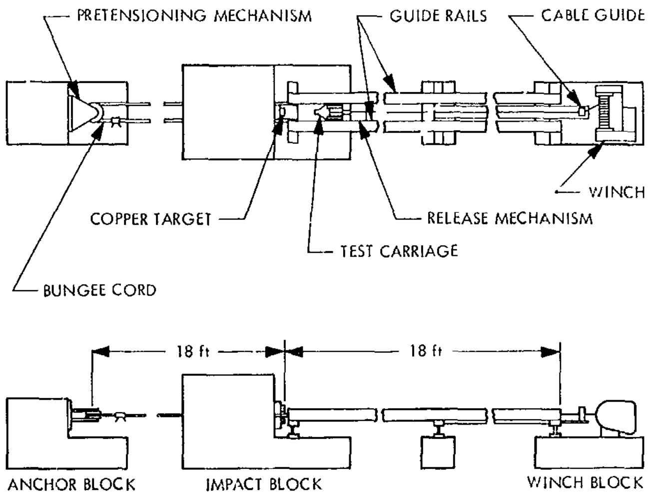

Fig. 1. Sling-shot shock tester configuration

acceleration level is determined mainly by the impact material and the diameter of the impact tool (Ref. 3). The length of the shock is determined by the velocity of impact. The velocity of the test specimen could be increased until depth of penetration in the target is so deep that near plastic deformation of the target is no longer possible, or until the 200 ft/s limit of the tester is obtained.

5. Instrumentation

Two methods of measuring the acceleration level produced by the test were used, and the results were recorded. The first method employed a piezo-electric shock accelerometer. The output was displayed on a memory oscilloscope and simultaneously FM-recorded on 0.5-in. magnetic tape at a speed of 120 in./s, which enabled a frequency response of dc to 100 kHz. Figure 2 shows typical shock curves.

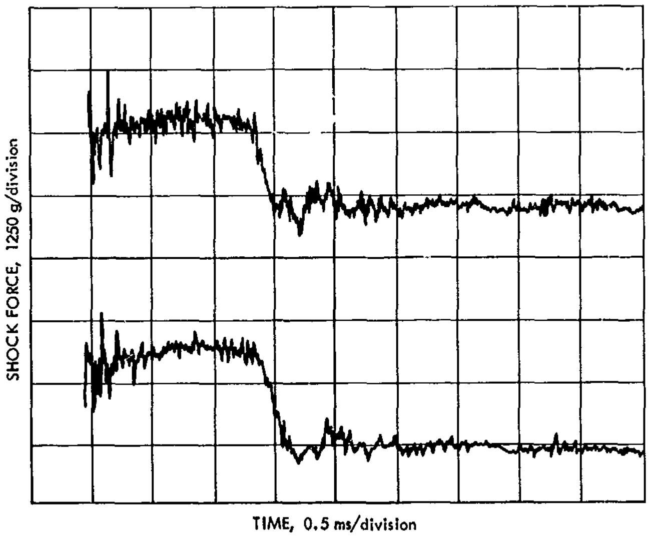

Fig. 2. Typical shock curves

The second method measures the impact velocity v with a set of timing lights placed a few inches in front of the target, and measures the depth d which the impact tool penetrates into the target. Knowing these two quantities and assuming the pulse to be reasonably rectangular, the acceleration level can be calculated from the basic equation for uniformly accelerated motion, $v^2 = 2ad$.

6. Procedure

Parts of known reliability, including resistors (carbon, metal film, wirewound, and trimming), capacitors, diodes, transistors, thermistors, relays, fuses, inductors, and microcircuits, were purchased directly from the manufacturer to assure that the latest manufacturing techniques were used.

All parts except transistors, microcircuits, six diodes and one inductor were mounted by epoxy to aluminum test fixture plates. If the shear stress would be greater than 500 psi, or the tensile stress greater than 750 psi at 10,000 g, a 0.018-in. stainless steel strap was placed over the part. The part was then covered with a coating of polyurethane conformal coating (Solithane 113/300).

The transistors and diodes were mounted separately in a fixture containing holes, into which the transistor or diode can fit. The leads were potted in polyethylene glycol. Power diodes were mounted by their studs in a tapped aluminum fixture and tightened to the specified torque limits.

The inductors were mounted to an aluminum plate, through existing holes, with a strap and two bolts. The microcircuits were mounted to an aluminum plate with adhesive tape.

After mounting, initial parameter measurements were made; then the parts were subjected to 2,000-, 5,000-, and 10,000-g shocks. Parameter measurements were made between each shock level and after the 10,000-g shocks.

7. Test Results

Because of the small sample size tested (15 parts per part type), care was taken to ensure that test samples reflected normal distributions. The following statistics were calculated following each test level on all parameters: mean, median, standard deviation, F test (statistical test of significance of parameter variability), skewness and kurtosis. Histograms were also plotted.

a. Fixed resistors. No catastrophic failures were noted in any of the fixed resistors tested.The mean, median, and standard deviation changed less than 1% as a result of the three levels of shock testing. In all cases the distribution passed the F test at $F_{(0.80)}$. Skewness and kurtosis values were close to normal distributions.

b. Variable trimming resistors. Three parametric failures were noted in the voltage ratio parameter:

(1) One decrease of 81.5% from initial to post 10,000 g.

(2) One increase of 66.8% from initial to post 10,000 g.

(3) One increase of 66.4% from initial to post 10,000 g.

All failures occurred in parts shocked in a direction parallel to the plane of the resistive element. Visual examination yielded no reason for these failures.

The change in the mean of the voltage ratios and resistance of the remaining parts was less than 1%.

The shapes of the distributions were generally normal in skewness but not in kurtosis; however, these values remained constant throughout the tests. The F test was passed at $F_{(0.80)}$.

c. Capacitors. The capacitance and dissipation factor of all parts, with the exception of a few catastrophic failures, changed less than 3%. Two large increases in dissipation factor of 126.6% occurred due to cracking of the glass body on one type tested. One failure occurred at 5,000 g and one at 10,000 g, but both were in shock axes which were perpendicular to the largest surface of the part.

The dissipation of one of the tantalum slug capacitors increased 95% after 10,000-g shock. X-ray analysis revealed that the slug had shifted.

Five catastrophic failures occurred out of the 30 rolled foil capacitors tested. Visual examination revealed that the foil roll shifted when shocked in a direction parallel to the leads causing the internal connecting lead to pierce an insulating wafer and short the capacitor.

d. Transistors. None of the transistors tested failed to the point that the case or the chip was broken or the bonds lifted. Several parts did, however, experience parameter shifts, some of which appeared quite serious. The parameters which did exhibit this change (50% to as high as 1500%) were consistently current measurements. Visual examination, however, failed to reveal the cause.

e. Diodes. Three types of catastrophic failures occurred among the diodes tested. Seven (5 at 2,000 g and 2 at 10,000 g) of the stud-mounted varactors failed when the ceramic spacer on the terminal sheared. One chip of a can-mounted diode cracked at 2,000 g when shocked in an axis perpendicular to the face of the chip. One small diode showed a particularly large increase in forward voltage drop V_F and reverse leakage current I_R measurements. Microscopic examination revealed that the gold ball contact to the chip had shifted.

f. Thermistors. No catastrophic or parametric failures were noted. In the worst case the mean resistance of any part changed less than 4%.

g. Relays. The relays are typically rated for 200 g shock maximum. Some survived the 10,000 g shock pulse. The samples were not tested for contact bounce during the shock pulse. The only requirement was that the relay remained in one contact state before and after the shock pulse and that it was able to function as a relay. Relays by design are basically quite fragile, and are packaged in a very small space. The sample size of this test was too small to make statistically conclusive statements; however, because of the amount of damage sustained it seems unlikely that relays of the types or construction tested can be used at these shock levels.

h. Fuses. No catastrophic failures or appreciable parameter shift occurred.

i. Inductors and transformers. All transformers and inductors that survived behaved in a normal manner. The major problem was providing adequate mounting for the heavier parts. One suggestion would be to completely encapsulate them into a test fixture.

j. Microcircuits. All parts with metal lids to the flat pack failed at 10,000 g when mounted with their faces perpendicular to the shock axis. The failures were caused by the lifting of the metal lid and cracking of the ceramic case. In actual circuit use, the parts would probably be fastened to circuit boards by their leads and conformal coating. This type of mounting could prove to be adequate if it were tested.

8. Conclusions

The best technique of testing electronic components for high-impact survival appears to be to subject the part to a square wave shock of long duration and high magnitude. Components which must withstand up to a 10,000-g shock must be mounted in such a way as to assure that no movement is possible. Component parts selected for high-impact survival must not be constructed in a manner that will allow internal movement of material. Neither can the part be made from fragile materials such as glass, for the mounting of such parts to ensure that there is no movement is difficult without cracking the glass.

References

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X. Advanced Projects Development

ENGINEERING MECHANICS DIVISION

A. Parachute and Deployment Mortar Jettison Mechanisms, *T. H. Mack*

Mechanisms for jettisoning a parachute and its associated deployment mortar from a planetary landing capsule are under development. The current effort is directed toward a Martian rough-landing mission, but other planetary landing missions are expected to have similar requirements.

For this class of mission, it is necessary to jettison the parachute at impact in such a way that it does not envelop the landed payload and thus interfere with subsequent experiments. The deployment mortar, which is required to deploy the parachute through the wake of the entry body, must be jettisoned so that it does not present a landing hazard for the payload and does not interfere with post-landing antenna patterns.

The conceptual approach that has been taken to provide these functions is as follows:

(1) The deployment mortar is released soon after the peak parachute deceleration loads have passed. The system is at sufficient altitude at this time to ensure that aerodynamic dispersions will separate the mortar and payload impact points sufficiently (Fig. 1a).

(2) At the same time that the mortar is jettisoned, the heavy three-legged parachute bridle (required to carry peak loads) is released. The lander is then attached to the parachute by means of a single line (Fig. 1a).

(3) The parachute is equipped with elastic "jumpers" on some of its suspension lines. The effect is that these lines become shorter than the others when high loads have passed. The parachute/lander system then "glides" at an angle to the vertical, with the parachute leading the lander (Fig. 1b).

(4) At lander impact, the single lander suspension line is severed. By virtue of the gliding geometry, the parachute canopy descends to the surface beyond the lander (Fig. 1c).

Several mechanizations for the mortar and bridle release function have been considered; a prototype of the

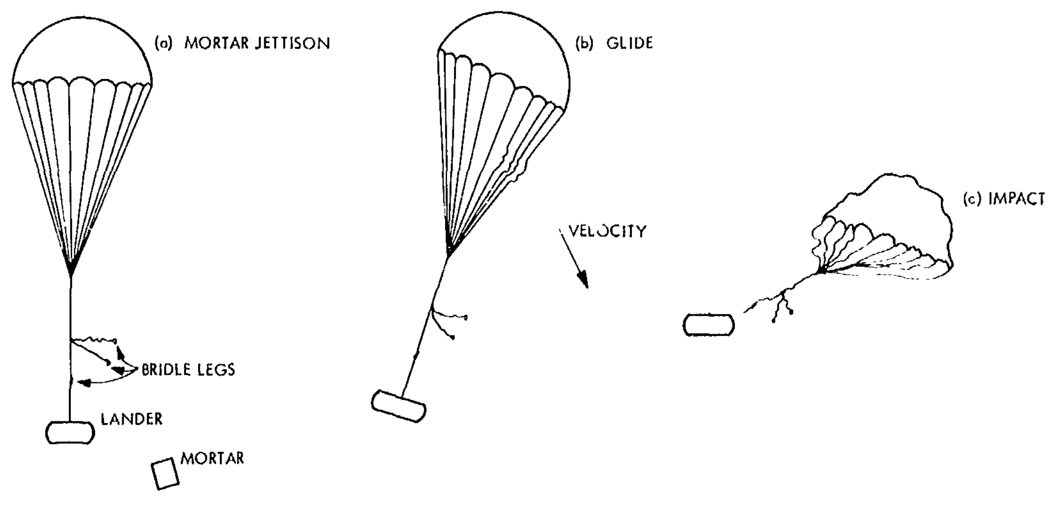

Fig. 1. Parachute and mortar jettison sequence

one selected is shown in Fig. 2. In operation, a pyrotechnic cable cutter would sever a cable passing around the three mortar/bridle clamps about 10 s after parachute deployment. The clamps would then free the mortar as well as the bridle legs. A single line leading from one of the bridle loops to the center of the lander

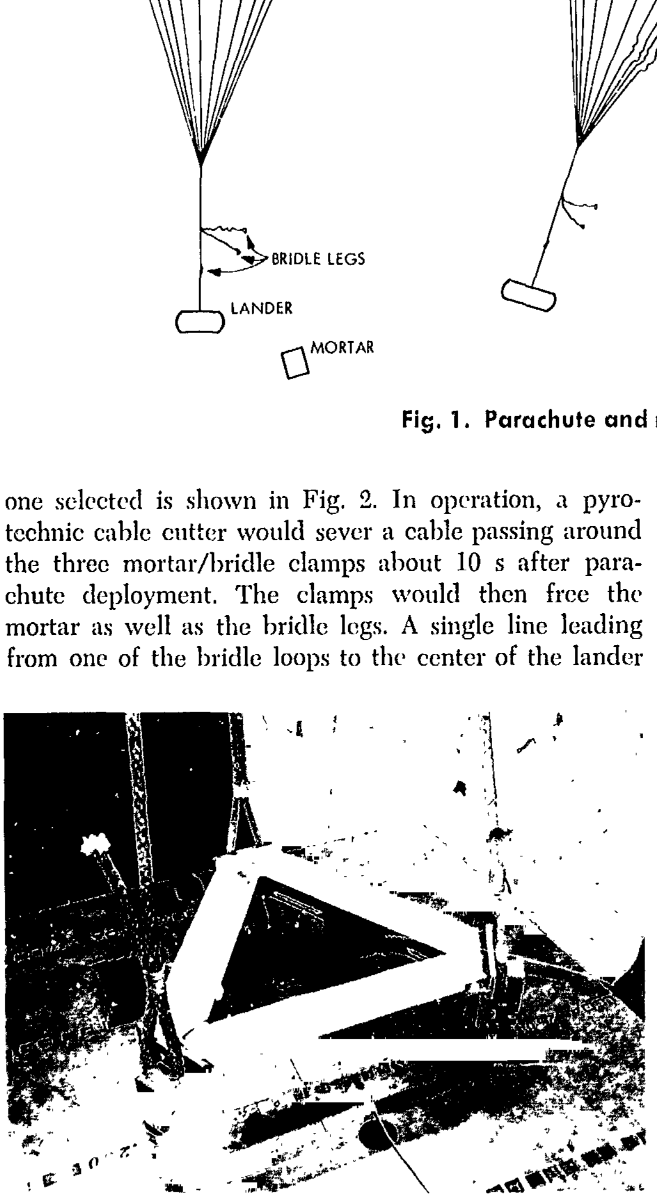

Fig. 2. Prototype mortar and bridle release mechanism

would then become taut, causing the mortar to be thrown off to one side.

The mechanization envisioned for the parachute gliding feature is to "jumper" several of the suspension lines with lengths of elastic shock absorber (bungee) cord. Under high load, these jumpers will stretch sufficiently to allow the suspension lines to take substantially all of the load. At low load, they will effectively shorten the lines and provide the gliding feature.

The final parachute release will be accomplished by using an impact switch to trigger the firing of a pyrotechnic cutter. Much of this hardware was developed during the Capsule System Advanced Development program and will be re-used.

Future plans include performing gliding tests as well as a drop test demonstration of the whole jettison system. This demonstration will employ a parachute typical of the type that might be used in such a mission and a live deployment mortar. The test system will be dropped from a helicopter and allowed to go through the entire functional sequence.