OPTOELECTRONIC TIMING SYSTEM

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DEVELOPMENT DIVISION

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*Normal Process Development
Endeavor No. 231*

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ABSTRACT

An optoelectronic timing system is being developed for the measurement of detonation front arrival times in an initiation sensitivity test currently in use at Pantex(1,2,3,4,5,6). The primary goal this quarter was the design, construction, and testing of a photodiode circuit which would have a two-nanosecond rise time response proportional to light intensity and which would have an adequate voltage output for the level of light intensity encountered in the sensitivity test. The results were satisfactory.

DISCUSSION

A test currently in use at Pantex(1,2,3,4,5,6) for determination of the sensitivity to initiation of a relatively large diameter acceptor pellet by a small diameter confined donor (such as MDF) incorporates the use of the detonation electric effect(7) for measurement of detonation front arrival times at various interfaces in the explosive train. The explosive train typically consists of a detonator, several 6.35 and 12.70 mm MDF segments separated by sub-mil air gaps, and an acceptor pellet stack. The detonation wave arrival times at the air gaps and at the center of the pellet output face are monitored. The air gaps are necessary in order to produce the detonation electric effect signals.

The degree to which the air gaps perturb the propagation of the detonation wave is acceptable for compacted HNS MDF of moderate size(2,3,6). However, for lower density cores and smaller core loadings, problems due to non-propagation of the detonation wave are significant(5). The air gap size has been reduced with success to 5 μ m in previous work(6). The MDF segments must remain electrically isolated for the detonation electric effect signals to be received; therefore, in order to reduce the air gaps to essentially zero, a method other than the detonation electric effect technique must be used to monitor times of arrival at the air gaps. For this purpose an optoelectronic system seemed a possible solution.

EXPERIMENTAL TECHNIQUE AND RESULTS

The optoelectronic system for monitoring the detonation front arrival at each interface is being developed. Light is coupled from each interface to a photodiode via a fiber optic light guide. The circuit presently being tested is shown in Fig. 1. The circuit allows for multiple inputs with a single output. The number of inputs can be increased as necessary; however, the rise time of the output signal will be degraded due to the increased capacitive loading on the output. The single output obviates the necessity of signal cable length considerations; therefore, only differences in the fiber optic light guide lengths need be considered.

Components for the system were selected after a market survey was conducted. The Spectronics SPX 2232-2 silicon PIN photodiode was chosen because of the following desired characteristics: the 10 to 90% rise time is 1.1 ns for a reverse voltage of 100 V; the slow tail response is eliminated

Fig. 1. Photodiode Circuit

by complete depletion of the wafer at a reverse voltage of 90 V which allows fall times on the same order as rise times; the detector element is isolated from the case which allows the case to be grounded for EMI shielding; the package has a lens which focuses more light upon the active element; and the photodiode is in a TO-46 package which allows it to be mounted in a commercially available adapter which is designed to hold the fiber optic light guide at the optimum distance from the photodiode lens for maximizing the light intensity on the active element. This photodiode has a peak spectral responsivity at about 870 nm and 50% relative responsivity at approximately 550 and 1000 nm.

The filter is an Erie ceramic EMI suppression type. The resistors are Allen-Bradley cermet film type and were chosen primarily for their low noise generation level. The capacitors are American Technical Ceramics UHF/microwave porcelain capacitors, which were selected for their high-Q properties. The fiber optic light guides are a synthetic polymer manufactured by Poly-Optics Inc. Their spectral transmission is approximately matched to the spectral responsivity of the photodiode. The fiber used in all work to date is 1.02 mm diameter with an opaque black jacket.

The circuit is relatively simple. When not illuminated, the photodiode has a high reverse resistance to current flow, which is about $0.1 \text{ T}\Omega$. The capacitors charge through the $100 \text{ K}\Omega$ resistors to 90 VDC with a time constant of $48 \text{ }\mu\text{s}$. When illuminated, the photodiode becomes conductive due to free carriers produced in the intrinsic region by photon absorption. The capacitors discharge through the series combination of the photodiode and the $51 \text{ }\Omega$ signal cable load. The time constant of the discharge circuit and the current amplitude are both dependent upon the illumination intensity; therefore, the voltage output is a function of light intensity. For a given illumination intensity, the discharge circuit time constant can be controlled by changing the value of capacitance. The initial response of each photodiode channel is somewhat proportional to the light intensity. The voltage output of the total circuit is proportional to the sum of currents through the photodiodes.

The response of the circuit was first tested repeatedly with an Abtronics model 1101 light source. The light pulse is a high intensity point source of approximately 50 ns duration with a 10 to 90% rise time of 10 ns. The rise time and amplitude of the circuit response were typically less than 10 ns and greater than 1.5 V as shown in Fig. 2. A preliminary investigation of the light amplitude produced in air gaps between HNS MDF segments has been conducted. The amplitude of the circuit response is lower than that obtained with the Abtronics light source. The signal shapes are more complex as seen in Figs. 3 through 5.

CONCLUSIONS

The output voltage of the photodiode circuit is satisfactory for the illumination intensity expected. The rise time is probably within the 2 ns desired.

Sweep Speed = 20 ns/cm
 Vertical Sensitivity = 2.3 V/cm
 Magnification = 1.01
 10% to 90% Rise Time = 6.3 ns

Fig. 2. Photodiode Circuit Response to Abtronics Model 1101 Light Source (Which Has a 10% to 90% Rise Time Specification of 10 ns)

Sweep Speed = 1 μ s/cm
 Vertical Sensitivity = 0.2 V/cm
 Magnification = 0.55

Fig. 3. Photodiode Circuit Response to Light Obtained From 13 μ m Air Gaps Between HNS MDF Segments

Sweep Speed = $1 \mu\text{s}/\text{cm}$
Vertical Sensitivity = $0.2 \text{ V}/\text{cm}$
Magnification = 0.55

Fig. 4. Photodiode Circuit Response to Light Obtained From $6 \mu\text{m}$ Air Gaps Between HNS MDF Segments

Sweep Speed = $0.5 \mu\text{s}/\text{cm}$
Vertical Sensitivity = $0.2 \text{ V}/\text{cm}$
Magnification = 0.55

Fig. 5. Photodiode Circuit Response to Light Obtained From $0 \mu\text{m}$ Air Gaps Between HNS MDF Segments

FUTURE WORK

The rise time of the photodiode circuit will be measured. The complex waveforms obtained with the HNS MDF—air gap type light source will be time correlated to air gap signals obtained via the detonation electric effect technique.

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