Model 425A
Delay
Operating and Service Manual

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ORTEC® Part No. 733190
Manual Revision F

1202

Advanced Measurement Technology, Inc.

a/k/a/ ORTEC®, a subsidiary of AMETEK®, Inc.

WARRANTY

ORTEC* warrants that the items will be delivered free from defects in material or workmanship. ORTEC makes no other warranties, express or implied, and specifically NO WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

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Quality Control

Before being approved for shipment, each ORTEC instrument must pass a stringent set of quality control tests designed to expose any flaws in materials or workmanship. Permanent records of these tests are maintained for use in warranty repair and as a source of statistical information for design improvements.

Repair Service

If it becomes necessary to return this instrument for repair, it is essential that Customer Services be contacted in advance of its return so that a Return Authorization Number can be assigned to the unit. Also, ORTEC must be informed, either in writing, by telephone [(865) 482-4411] or by facsimile transmission [(865) 483-2133], of the nature of the fault of the instrument being returned and of the model, serial, and revision ("Rev" on rear panel) numbers. Failure to do so may cause unnecessary delays in getting the unit repaired. The ORTEC standard procedure requires that instruments returned for repair pass the same quality control tests that are used for new-production instruments. Instruments that are returned should be packed so that they will withstand normal transit handling and must be shipped PREPAID via Air Parcel Post or United Parcel Service to the designated ORTEC repair center. The address label and the package should include the Return Authorization Number assigned. Instruments being returned that are damaged in transit due to inadequate packing will be repaired at the sender's expense, and it will be the sender's responsibility to make claim with the shipper. Instruments not in warranty should follow the same procedure and ORTEC will provide a quotation.

Damage in Transit

Shipments should be examined immediately upon receipt for evidence of external or concealed damage. The carrier making delivery should be notified immediately of any such damage, since the carrier is normally liable for damage in shipment. Packing materials, waybills, and other such documentation should be preserved in order to establish claims. After such notification to the carrier, please notify ORTEC of the circumstances so that assistance can be provided in making damage claims and in providing replacement equipment, if necessary.

CONTENTS

SAFETY INSTRUCTIONS AND SYMBOLS

This manual contains up to three levels of safety instructions that must be observed in order to avoid personal injury and/or damage to equipment or other property. These are:

DANGER Indicates a hazard that could result in death or serious bodily harm if the safety instruction is not observed.

WARNING Indicates a hazard that could result in bodily harm if the safety instruction is not observed.

CAUTION Indicates a hazard that could result in property damage if the safety instruction is not observed.

Please read all safety instructions carefully and make sure you understand them fully before attempting to use this product.

In addition, the following symbol may appear on the product:

ATTENTION – Refer to Manual

DANGER – High Voltage

Please read all safety instructions carefully and make sure you understand them fully before attempting to use this product.

SAFETY WARNINGS AND CLEANING INSTRUCTIONS

DANGER Opening the cover of this instrument is likely to expose dangerous voltages. Disconnect the instrument from all voltage sources while it is being opened.

WARNING Using this instrument in a manner not specified by the manufacturer may impair the protection provided by the instrument.

Cleaning Instructions

To clean the instrument exterior:

- Unplug the instrument from the ac power supply.
- Remove loose dust on the outside of the instrument with a lint-free cloth.
- Remove remaining dirt with a lint-free cloth dampened in a general-purpose detergent and water solution. Do not use abrasive cleaners.

CAUTION To prevent moisture inside of the instrument during external cleaning, use only enough liquid to dampen the cloth or applicator.

- Allow the instrument to dry completely before reconnecting it to the power source.


ORTEC®
425A
DELAY
50 Ω
1nsec
2nsec
4nsec
8nsec
16nsec
32nsec
50 Ω
DELAY OUT
DELAY IN

ORTEC MODEL 425A DELAY

1. DESCRIPTION

The 425A Delay is a single-width NIM-standard module that provides for signal delays in 1-ns steps from 1.7 to 64.7 ns. This is the basic 1.7-ns instrument delay plus the switch-selected additional delay. Longer delays may be achieved by cascading several 425A modules. Input and output impedances are 50Ω. The delays are accomplished by coaxial cables interconnected by strip-line sections; no power is required. Delay accuracy and definition are discussed in Section 3, "Theory."

2. SPECIFICATIONS

Input 50 Ω impedance, either polarity; 1500 V maximum BNC connector.

Output 50 Ω impedance, delay is the sum of IN switches; BNC connector.

Delay Lengths 1, 2, 4, 8, 16, and 32 ns; may be added in any combination.

Minimum Delay 1.7 ns (all switches OUT).

Delay Accuracy ±100 picosecond or ±1% for each delay section used; whichever is greater.

Cable Type RG-58A/U.

Power Required None.

Dimensions Standard single-width module (1.35 in. wide × 8.714 in. high) per TID-20893 (Rev).

3. THEORY

Pulses transmitted through coaxial cables suffer both attenuation and distortion. In the cable used in the 425A, as in most cables commonly used for pulse work, skin effect losses in the conductor are the predominant losses for frequency components below approximately 1000 MHz. Skin effect losses result in high-frequency attenuation which, expressed in decibels, increases as $(\omega)^{1/2}$.

An ideal step-function pulse impressed on the line appears at the (matched) far end with the shape shown in Fig. 1.

The rise time from 0 to X percent can be expressed as multiples of $\boldsymbol{T}_0$, where $\boldsymbol{T}_0$ is the 0 to 50% rise time. Table 1 presents some rise-time conversion factors; an example of the use of these factors is the following: 10% to 90% rise time = (29.0 ? 0.17) $\boldsymbol{T}_0$ = 28.83 $\boldsymbol{T}_0$.

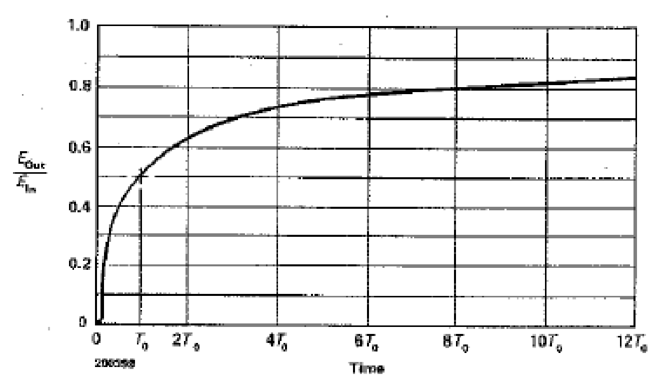

Fig. 1. Step-Function Response of Transmission Lines for Which Decibel Attenuation Varies as the Square Root of Frequency. The time T_0 is defined as the interval measured from the start of the output pulse to the point at which $E_{out} = 0.5\ E_{in}$.

In Fig. 2, T_0 is plotted against the delay length in Nanoseconds

Table 1. Rise Time Conversion Factors

Percent of Pulse Height	Rise Time Factor
10	0.17
20	0.28
50	1.0
70	3.1
80	7.3
90	29.0
95	110.0

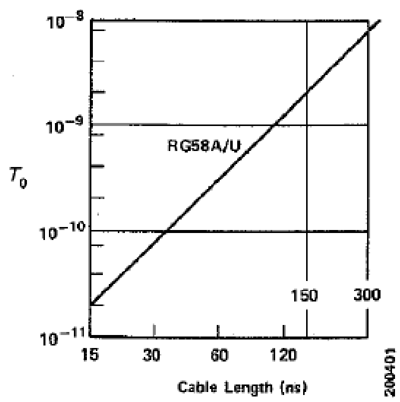

Fig. 2. Calculated Variation of T_0 with Cable Length for RG-58A/U.

For RG-58A/U cable whose decibel attenuation varies as $(\omega)^{1/2}$ for frequencies between 100 MHz and 1000 MHz, it is convenient to calculate T_0 by

$$T_0 = 3.0 \times 10^{-16} A^2 l^2 \text{ s}, \qquad (1)$$

where A is the commonly tabulated attenuation at 1000 MHz expressed in db/100 ft (20 to 24 for RG-58A/U), and l is the length in nanoseconds.

Since the rise time is proportional to the square of the length, if two equal lengths of a given type of cable are cascaded, the rise time of the combination is four times the rise time of either length alone. This is in contrast to the familiar case of amplifiers of Gaussian frequency response, in which the rise time varies as the square root of the number of identical sections. For this reason and also because the characteristic step-function responses of cables and of Gaussian devices are so different, the overall rise time of combinations cannot be calculated from the square root of the sum of squares of individual rise times, either with cables alone or with cables combined with Gaussian elements. Instead, the overall response of a system with cables and other elements may be obtained graphically or with convolution integrals (ref.3)*, using either step or impulse (obtained from the derivative of the function plotted in Fig. 1) function responses.

The above discussion makes it clear that the delay of a cable cannot be specified unless the point on the response function is specified. For the 425A Delay, an operational definition is chosen. When the required delay has been selected by any one of the IN switches, the 50% amplitude point will be delayed by an amount equal to the delay that would be effected by lossless delay line. One example will serve to explain the sense in which this definition is operational. Two counters (scintillation) detect prompt coincidence gamma rays from a radioactive source. The source is moved 120 cm away from one counter and 120 cm closer to the other. If the cable delay from one counter is changed by 8 ns by use of the 425A, the two counters will be properly time-realigned if the discriminators associated with each counter are operated at 50% amplitude. In practice, the experimenter cannot readily operate at 50% amplitude just to have the cable calibrations meaningful, but, using Eq. (1), it can be seen that the timing difference between 0% and 50% amplitude is less than 20 ps for a 10-ns length of RG-58A/U. It is in this range of operation that discriminators are usually used. If the discriminator is to be used at a large percentage of full amplitude or if long delays are to be achieved at settings other than 50%, corrections can be made by using Fig. 1 or Table 1 as a reference. For the above example, a delay error of 0.26 ns would result if the discriminator were operated at the 90% level.

Figure 3 shows the block diagram of the apparatus used in testing the delay cables of the 425A.

A fast-rising pulse is split into two branches, one of which is the 425A Delay. The other consists of sections of high-quality rigid air lines with one adjustable section. The delays between the

*See Section 5, "Bibliography."

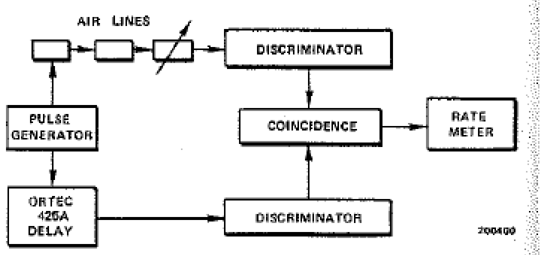

Fig. 3. Block Diagram of Apparatus Used in Production Testing.

discriminators and the coincidence circuit are adjusted to the middle of the edge of the decay curve, i.e., 50% count rate. The width of this edge is about 20 ps; that is, changing the adjustable air line by 20 ps can change the output counting rate from 100% to 0%. When a delay is switched into the 425A branch, the equivalent length of air line is introduced into the other branch. If the delay cable has the correct length, the count rate will again be 50%; if not, the amount of required readjustment of the variable air line gives the error directly. Both discriminators operate at 50% amplitude for this test.

The termination of the cable at any realizable discriminator input is not exactly 50 Ω. Commonly used circuits include the shunt capacity of a tunnel diode or the base of a fast transistor plus stray inductances and capacitances. This slight deviation from perfect termination does not affect the delay definition appreciably because it is the same in both branches. Finite test pulse rise time (~1 ns) also affects both branches equally, and so it introduces only second-order errors. Also, the air cables are not exactly lossless, but the T_0 is almost 2 orders of magnitude shorter than for RG-58A/U, so it can be neglected.

If a transmission line system were to introduce no reflections, it would have to have a uniform impedance throughout. Since $Z_0 = \sqrt{L/C}$, the ratio of inductance to capacitance at each point would have to be a constant. This cannot be achieved even for the cable itself, and further deviations occur when cables must be interconnected and the pulses routed through switches. At points of interconnection where excess inductance is encountered, some small capacitance has been purposely added, so that the ratio of *L/C* averaged over the connection is correct. Likewise, the switches have been mounted so that averaged over the switch gives 50 Ω, even though from point to point there are deviations. Thus reflections occur when the magnitude of the deviations and the distance over which they extend become appreciable when compared to the distance traversed by a pulse during its rise time (ref. 8) For most pulses used in data acquisition systems in the physics laboratory in which the rise time is equal to or greater than 1 ns, the reflection introduced at each end of the each delay cable will be comparable in size to that incurred when two cables are connected together by BNC connectors and a BNC union.

The temperature coefficient of the delay of the cables used in the 425A is about 150 ppm/°C within 20° of room temperature.

4. MAINTENANCE

The assembly procedures peculiar to the 425A Delay are considered virtually irreversible; therefore, any warranty problems will be resolved by replacement of the module.

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