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MULTI-FUNCTION TELEPROTECTION EQUIPMENT

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MULTI-FUNCTION TELEPROTECTION EQUIPMENT

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Introduction

A signaling system for protection of the high voltage power network must meet several conflicting criteria: security, dependability, high speed, and the ability to operate in a high noise environment. Each of these criteria affects the others, and system performance is dependent on numerous internal (and external) factors. Each must be optimized within the overall system operation and performance objectives.

This paper will describe a somewhat novel approach to a protection signaling equipment, the Type 45 MULTI-COM® Teleprotection, and highlight some of its unique features, like on-line system testing.

The main objectives in the design of this new teleprotection equipment were:

- multiple operating modes
- high security against noise
- good dependability in presence of noise
- medium channel speed
- continuous testing of modules and total system
- ease of installation and maintenance

As with any system, the best performance can be expected when all elements, including the transmission media are under the control of the user, e.g. power line carrier, private microwave channels, fiber optics, etc. Reduced performance can be expected if uncontrolled media are used such as leased telephone lines.

Operating Modes

There are numerous types of protection signal equipments. One of the simplest is the ON-OFF type; the most sophisticated is probably the microprocessor-controlled data link. Perhaps the most widely used (and successful) is the FSK (frequency shift keyed) type. The basic FSK equipment can utilize various transmission media such as PLC (power line carrier), leased telephone lines, cable, radio link, fiber optic link, etc. The merits of FSK equipment are generally known, and include: continuous channel supervision (guard signal), efficient spectrum utilization, and good noise immunity.

Type 45 Teleprotection equipment differs from the usual FSK equipment in that it utilizes the basic FSK transmitter approach, but has four separate AM receivers which provide two output functions from a single terminal. Four-frequency operation (guard plus three trip frequencies) enable the two outputs to function independently of each other as well as simultaneously with each other.

The equipment utilizes a frequency bandwidth of 4 kHz or 2.5 kHz, with various operating modes shown in Table 1. Table 2 shows standard tone frequencies for the various operating modes.

Transmitter and Receiver Circuits

A simplified functional block diagram is shown in Figure 1. The transmitter uses a crystal-controlled master oscillator of high stability for the derivation of the four discrete audio tone frequencies generated by the programmable synthesizer. Without any keying inputs the guard signal is transmitted. To remove guard and key a trip signal two actions are required; one or both trip circuits have to be keyed and the start circuit has to be activated.

The start circuit can be keyed by a contact closure (e.g. from the relaying equipment). If this mode is not desirable, a jumper on the transmitter board can be strapped so that any trip keying input simultaneously activates the start circuit (internally).

Signals received from the remote terminal are separated by filters and passed through level detectors into logic circuits for the determination of a valid trip command. A trip output requires the loss of guard and the presence of only one of the three possible trip commands, namely Trip 1, Trip 2, or Trip 1 & 2.

The logic circuit, in addition to signal evaluation, also contains timing circuits for the trip output relays (for improved security) and trip hold timing (for improved dependability).

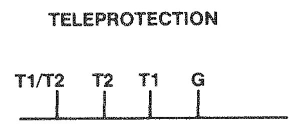
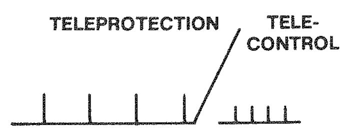
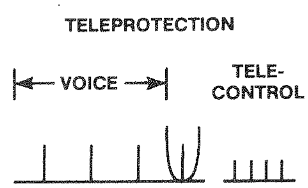
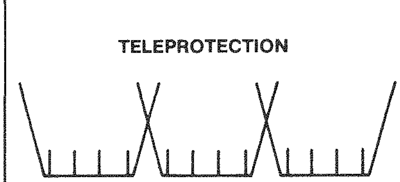
Transmitter and Receiver Salient Characteristics

a) One out of four tones
As mentioned above, four separate signal frequencies are generated in the transmitter: G, T1, T2 and T1/T2. However, only one signal at any one time is in the system. This has the advantage, that the relaying function can command all the power that is alotted to this channel. Conventional FSK systems normally require two transmitters to perform two independent functions, which means that there are always two signals in the system; hence, the channel power has to be shared. A single-signal system can realize a S/N advantage of 6 dB without lessening its performance compared to a dual-signal system.

b) Limiter noise performance
The predominant form of interference affecting security against false trip output usually occurs in the form of short bursts of wideband noise. For improved security, amplitude limiter circuits are used prior to the detection circuit as they provide excellent protection under these conditions. Short noise bursts will lose their amplitude information and be converted into a frequency spectrum. The frequencies are spread out such that an individual frequency detector does not see sufficient noise energy to reach its threshold level. The probability is thus increased that these noise bursts will pass undetected by the trip circuit.

Similar operating characteristics are observed with continuous, broad spectrum noise. The RMS value of the limiter output being constant (single frequency or a broad noise spectrum), the white noise spectrum is distributed relatively evenly over the whole receiver channel bandwidth.

Table 1. TYPE 45 OPERATING MODES

CHANNEL MODE OF OPERATION	AUDIO CHANNEL SPECTRUM	FUNCTIONS AND FEATURES
WIDEBAND "SINGLE PURPOSE" Dedicated channel application of teleprotection equipment to a selected channel on a single sideband PLC system. Multi-channel terminals could, of course, have other independent functions (such as voice) on other channels of the same system.		• Permissive or direct trip • Operate time * 10ms back-to-back 12ms with PLC channel • No voice or telecontrol capability • Optional exalt (tone boost) • 4 kHz or 2.5 kHz bandwidth
WIDEBAND "MULTI-PURPOSE" Here the channel is used for the **simultaneous** transmission of tele-control signals in channel space above the teleprotection frequencies.		• Permissive or direct trip • Operate time * 10ms back-to-back 12ms with PLC channel • No interruption of telecontrol or other channels of multi-channel terminal during Type 45 operation. • No optional exalt • 4 kHz bandwidth
WIDEBAND "ALTERNATE PURPOSE" **Both** voice and telecontrol signals share this channel with the teleprotection equipment. However, the voice and telecontrol signals are **blocked** during transmission of any trip signal.		• Permissive • Operate time * 15ms back-to-back 17ms with PLC channel • Voice & telecontrol may be interrupted (blocked) during Type 45 operation. No interruption of other channels on multi-channel terminal. • Optional exalt (tone boost) • Guard can serve as tele. sig. • 4 kHz bandwidth
NARROWBAND "SINGLE PURPOSE" The channel is used for three independent, narrowband Type 45 systems. No voice or telecontrol is applicable to this channel.		• Permissive or direct trip • Operate time * 15ms back-to-back 17ms with PLC channel • No voice or telecontrol capability • Optional exalt (tone boost) • 4 kHz bandwidth
WIDEBAND "SINGLE PURPOSE", DIRECT-TO-LINE Dedicated channel. Uses low cost, single-stage up-converter to line frequencies of 30 to 535 kHz. Also down-converter from line frequency to audio.		• Permissive or direct trip • Operate time * 10ms back-to-back 12ms with PLC channel • No voice or telecontrol capability • Optional exalt (tone boost) • 2.5 kHz bandwidth

*Add 4 milliseconds if 30A relay contacts are used.

Table 2. TYPE 45 STANDARD FREQUENCIES

OUTPUT	WIDE-BAND	NARROW-BAND CH. 1	NARROW-BAND CH. 2	NARROW-BAND CH. 3	DIRECT TO LINE
GUARD	2610 Hz	1140 Hz	2100 Hz	3060 Hz	2100 Hz
TRIP 1	2100 Hz	940 Hz	1900 Hz	2860 Hz	1600 Hz
TRIP 2	1600 Hz	740 Hz	1700 Hz	2660 Hz	1100 Hz
TRIP 1 & 2	1100 Hz	540 Hz	1500 Hz	2460 Hz	600 Hz

Tests have also shown that with wider receiver bandwidth there is a lower probability of noise bursts generating false trip operation. The theory of all these observations is that there is relatively little noise energy left within any individual frequency selector range, therefore decreasing the probability of threshold activation.

In addition, the use of a limiter circuit permits the processing of signals through a 20-dB drop in level from nominal. Beyond this 20-dB margin, a squelch circuit shuts down the receiver to prevent low level noise from capturing the limiters.

c) Receiver logic

Where system requirements direct **high security** operation, the receiver logic can be strapped so that guard has to be present just prior to reception of the trip command. A trip window of 20 milliseconds activated on loss of guard blocks any trip attempt not received within this time period.

Where system requirements direct **high dependability** operation, the receive logic can be strapped so that guard is not required just prior to a valid trip command, e.g. after noise squelch or loss of signal.

In many applications, it is also desirable to provide a timed, unblocking type output when not receiving any signal. The use of an additional logic module can provide this output, dependent upon operating conditions, i.e. loss of signal, with or without extreme noise on the channel, and their respective durations.

In any application, the detection of more than one tone causes the logic to block trip output.

d) Trip output relay driver security

An added measure of security is provided by the trip output relay driver design in that **two** transistors have to turn on simultaneously to energize the relay. Loss-of-guard turns on one transistor and receipt of trip turns on a second transistor. Since the relay is connected between the two collectors, turning on only **one** transistor leaves the other end of the relay at a very high impedance and thus no current can flow through the relay coil.

Testing and Monitoring Circuits

The system status is both monitored and reported. Visual indication is shown via an LED on the front of shelf, with remote indication via a normally energized relay such that malfunction or removal of any module in the system, including the power supply, is reported.

a) Local loop test (automatic)

In a bi-directional system (both transmitter and receiver in the same shelf and of the same frequency) a test can be performed to check all active circuits with the exception of the trip output relays. The premise is that this test is performed periodically and automatically and that it does not hinder a real trip command.

A functional block diagram of the test operation is shown in Figure 2. Following is a description of how the test is accomplished with the (optional) test module.

The test module consists of a clock circuit, a sequencer, a logic and evaluation circuit, and a relay to alarm an unsuccessful test sequence. The test module can only be applied in a bi-directional shelf (transmitter and receiver in the same shelf). However, all necessary connections to and from the modules with the test module are already provided in the standard shelf. Therefore, the test module is operational by simply inserting it into the shelf.

The test module tests all active components in a shelf with the exception of the trip relays. The system remains fully operational during a test cycle. If a relaying function is called for, the test sequence is interrupted (aborted), and the trip is accurately executed with a penalty of less than 3 ms additional channel time. This test is called Local Loop Test (automatic, timed) because the far end of the system is not involved in the test sequence.

The clock serves two functions: to provide the test sequence pulses and to count down the time for the test interval. This interval is selectable from 3 hours to 24 hours between tests by means of a movable jumper.

The test sequence simulates all the relaying functions of the system. However, to prevent a trip from the transmitter reaching the far end of the system, an artificial guard is switched to the transmitter output during the test sequence.

The transmitter is then keyed by the test module to produce all the trip frequencies (sequentially). These frequencies are switched directly into the receiver and turn on the appropriate outputs. In the output module, each event turns on **one** driver transistor. The test module receives the confirmation of the turned on transistor and declares this as a successful test of this event.

Since **two** transistors have to turn on to pull up a trip relay, the test sequence does not constitute a trip output (the trip relays will not activate).

The test consists of four sequence events:

1. Test Guard Circuits - Suppression of guard in the receiver to turn on the guard transistor in the output module.
2. Test Trip 1/Trip 2 Circuits - Keying Trip 1 and Trip 2 in the transmitter to turn on Trip 1 and Trip 2 transistors in the output module (but not the guard transistor).
3. Test Trip 2 Circuits - Keying Trip 2 in the transmitter to turn on Trip 2 transistor in the output module.
4. Test Trip 1 Circuits - Keying Trip 1 in the transmitter to turn on Trip 1 transistor in the output module.

The test sequence is aborted when a relaying function is called for. In the transmitter, the abort command is derived from the keyed "start" signal. In the receiver, a loss-of-received guard (from the remote station) causes the test sequence to abort, since the loss-of-guard is taken as an attempt to trip.

The channel time is delayed by less than 3 ms to assure that any unwanted residual test signal has time to decay.

b) Remote loop-back test (manual)

A remote loop-back test sequence can also be performed with the aid of test switches located on the front of the transmitter module (Figure 3). The spring-loaded switches, Trip 1, Trip 2, or both, can be closed thereby causing the respective trip frequency to be sent to the remote end. The remote receiver, responding to the trip signal from the master end, keys its own transmitter and provides loop-back to the master station. However, since the remote and master terminals both receive valid trip signals, the trip output relays will operate.

c) Alarms

Visual indication of normal operation is shown with a normally "ON" LED on the front of the shelf.

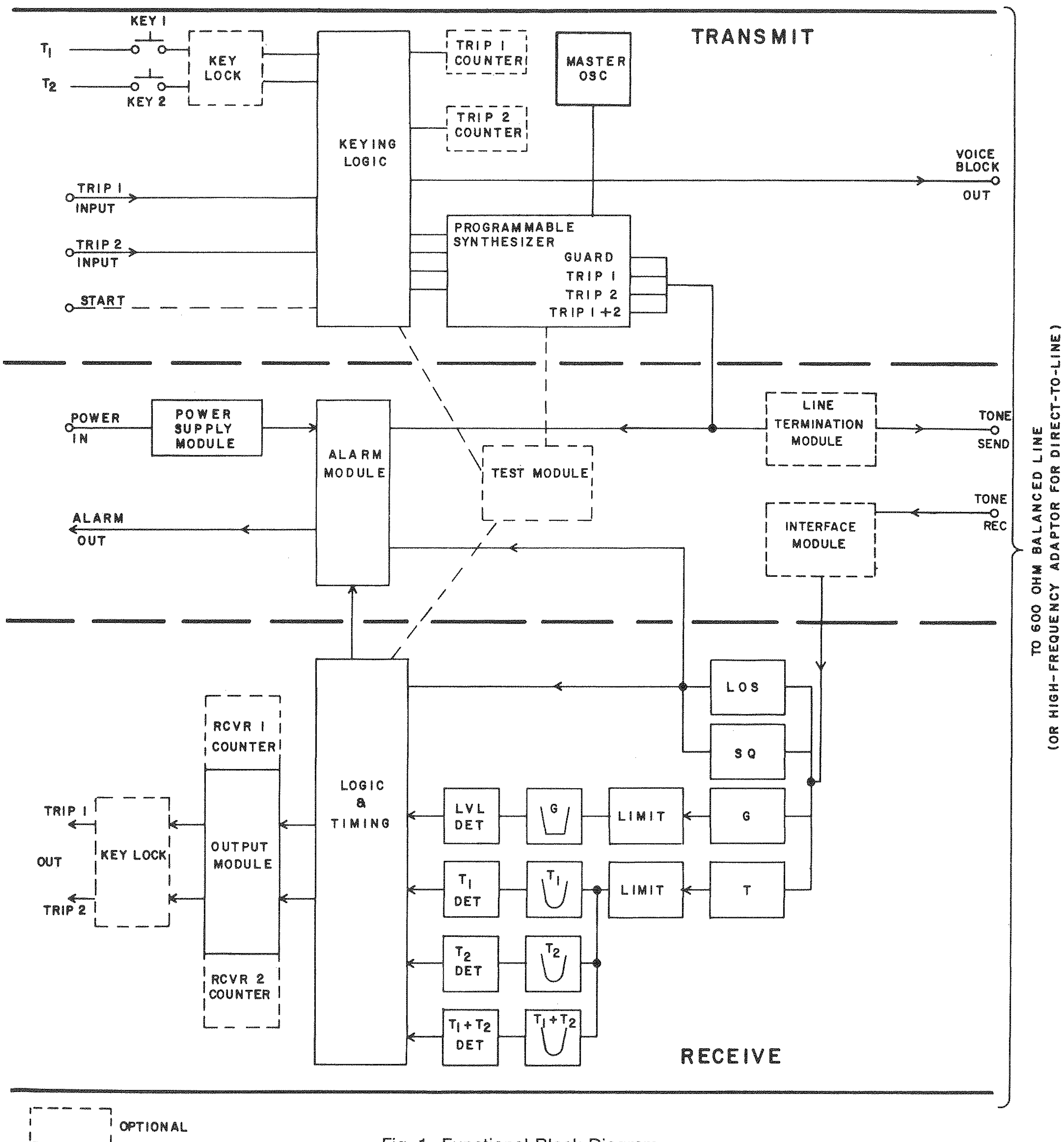


Fig. 1. Functional Block Diagram

To facilitate fault isolation within the equipment, alarms have been incorporated in several key locations. By remotely supervising the alarm contacts, a malfunction can be easily tracked down (often to a particular module). The five alarm functions are:

- Loss-of-power
- Transmitter alarm
- Receiver alarm
- General alarm
- Test alarm (if used)

For example: a loss-of-power alarm activates **all** alarms. A loss-of-signal in the receiver activates the general alarm and the receiver alarm.

The alarm relays are energized in the non-alarm condition, so that an alarm de-energizes them. Removal of any module also causes an alarm to indicate that system integrity has been breached.

SUMMARY

The Type 45 MULTI-COM Teleprotection equipment design has been presented to show how a teleprotection system can perform with the security and dependability of a dual-channel system, but with the added flexibility of multiple trip output which can be operated independently or simultaneously. The integrity of this new system is improved by the built-in test feature.

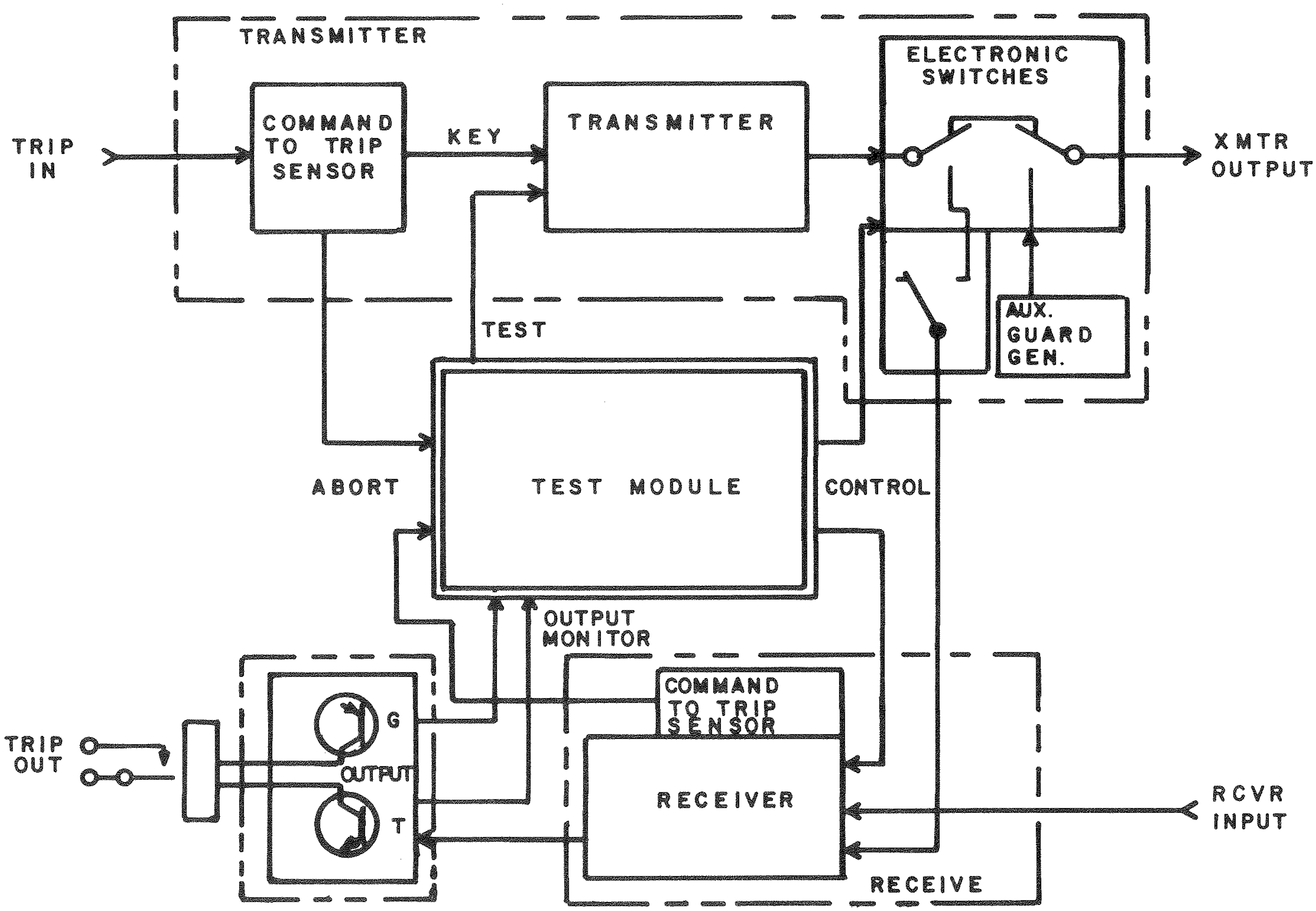


Fig. 2. Block Diagram of Type 45 Equipment and Test Module

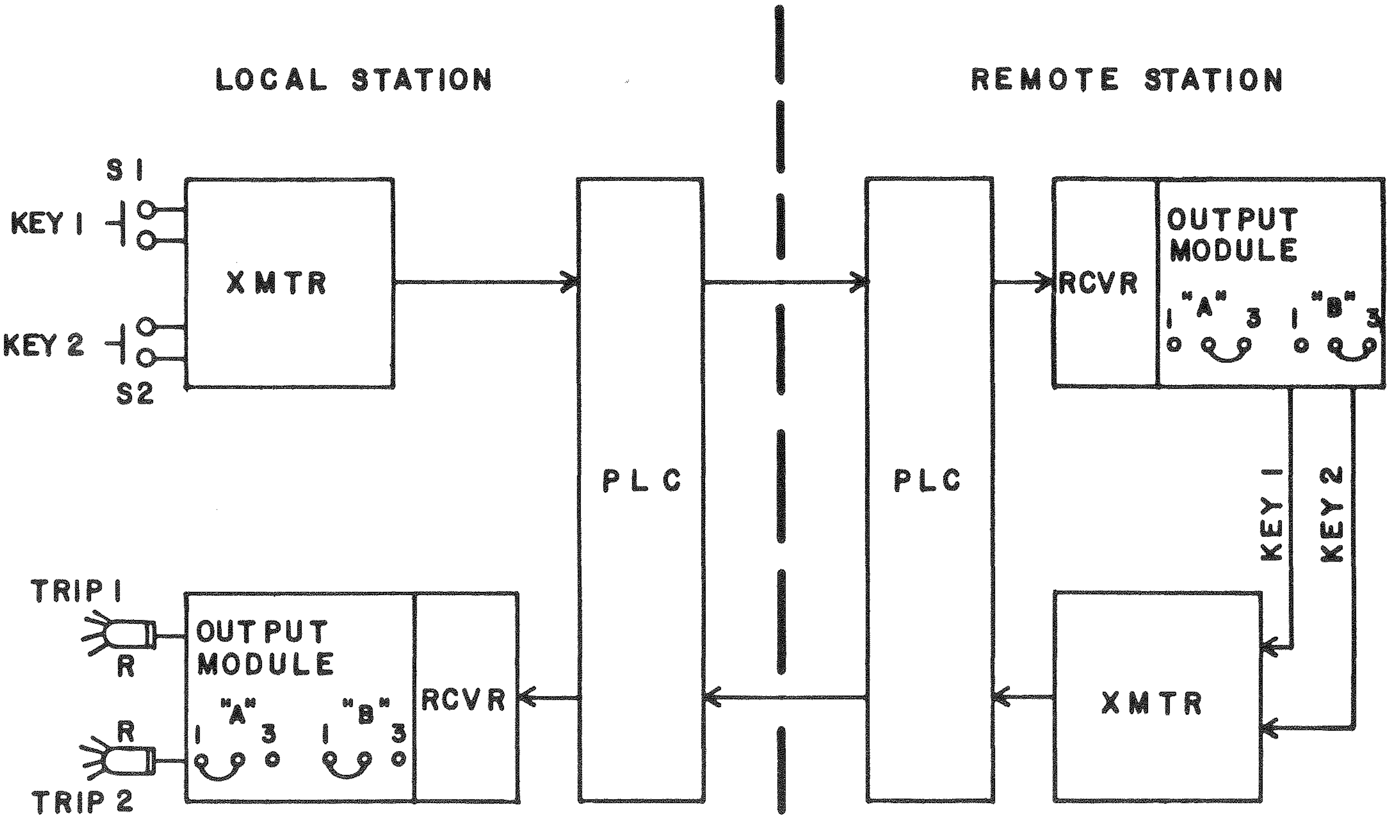


Fig. 3. Manual System Test with Remote Loop-Back

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