Fault Detector and Length Measurement of Electric Cables Based on Frequency Waves

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Abstract: This research presents an approach to simultaneously detect the faults and measure the length of the electric cables. This approach is easy to use and inexpensive. Moreover, it can be applied to any kinds and sizes of the electric cable. This paper uses 750V 4x4 Sq.mm. cables. The concept is to send the 2 kHz pulse into the electric cable. When the pulse bumps into the fault, it bounces back. Then, the total time the pulse travels back and forth and the shape of the pulse after bumping are inspected using the pulse detector and pulse converter. Next, the signal obtained is modulated with 10 MHz carrier pulse to segregate into several small pulses before sending to 8-bit counter. The length of the electric cable can be obtained using microcontroller and the location of the faults can be seen on the LCD screen. This approach can be used to inspect the electric cables with the length of at least 15 m.

Keywords: Pulse, Pulse detector, Electric cable, Frequency, Signal, Carrier, Fault

1. INTRODUCTION

From traveling wave theory, there are two approaches to analyze the location and the type of the faults on the electric cables; one is open circuit and the other is short circuit. The type of the fault can be categorized using the relationship between the equivalent resistance of the fault (R_f) as well as the surge impedance of the cable (Z_0) and the size of the reflective pulse. The reflective pulse is positive if the fault is open circuit and it is negative if otherwise. The location of fault can be found from Eq. 1.

$$d = \frac{Tv}{2\sqrt{\varepsilon_r}} \qquad (1)$$

Where d is the distance that the fault occurs
T is the total time the pulse travels
v is the velocity of the pulse
ε_r is the permittivity of the cable

2. DESIGN OF THE SYSTEM

The system is mainly comprised of the Pulse Generator, Pulse Detector, Pulse Summing, Pulse Converter, Pulse Amplitude Modulation (PAM), 8-bit Counter, and the computation.

2.1 Pulse Generator

A pulse generator used is the 74LS123, a Dual Retriggerable Monostable Multivibrator with Clear, to generate 2 kHz narrow-width pulse in order to locate the faults on the electric cables. Fig. 1 illustrates the signal generated from this pulse generator.

The pulse width is the crucial factor and it must be chosen properly since the pulse can be overlapped when travelling back and forth causing the analysis impossible. Fig. 2 (a) and (b) displays the overlapping of the pulses. The proper width for the size and length of the electric cables used in this experiment is 1.5 nS. The width can be modified by adjusting the resistance at the 15th pin of 74LS123 (R_{ext}) as shown in Eq. (2) and Fig. 3.

$$PW = 0.3RC\left[1+\frac{0.7}{R}\right] \qquad (2)$$

Where PW is the pulse width

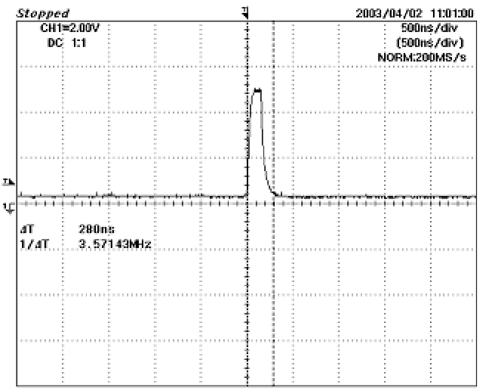
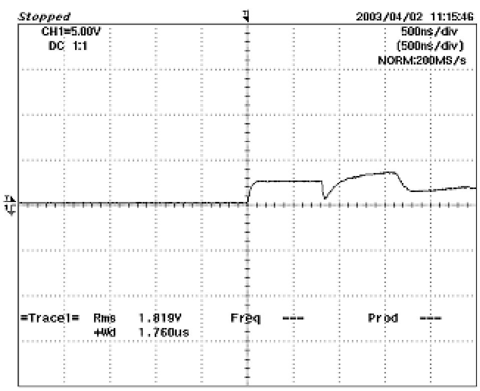
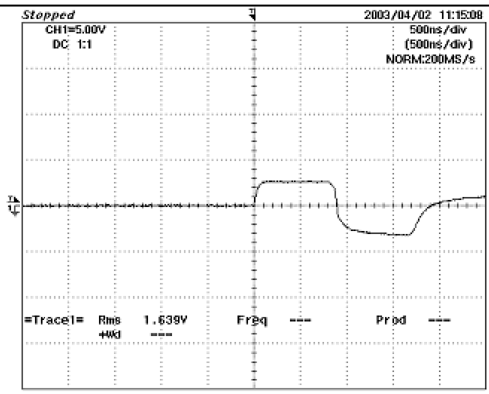


Fig. 1 The signal generated from pulse generator



(a) The open circuit case



(b) The short circuit case

Fig. 2 Overlapping of the pulses

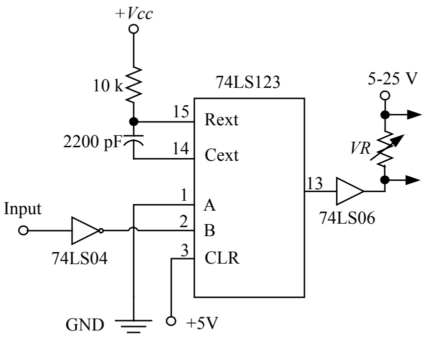
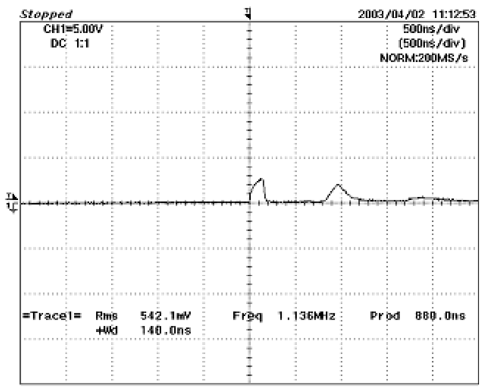


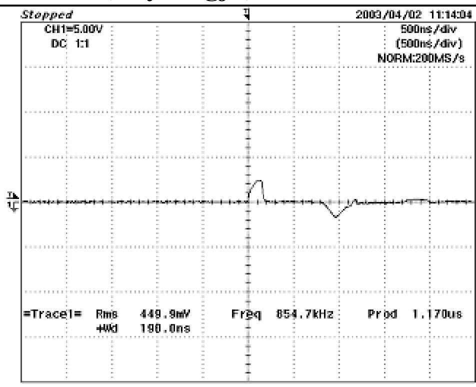
Fig. 3 Pulse generator circuit

2.2 Pulse Detector

The Op-Amp LM710 is used to compare between the positive and negative pulses by detecting both sending and receiving pulse signals as well as the reflective signal. Fig 4 (a) and (b) illustrate, respectively, the positive and negative reflective signals used as the input for the pulse detector.



(a) Positive reflective signal in case of open circuit fault



(b) Negative reflective signal in case of short circuit fault

Fig. 4 Reflective signals

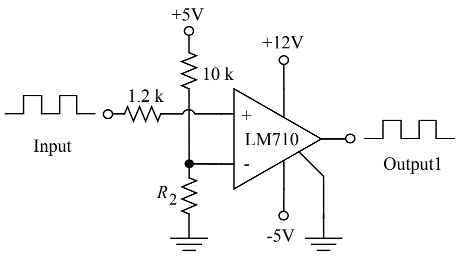
2.2.1 Positive Pulse Detector

The lowest amplitude of the positive reflective signal, which is 0.5 V, is used as the reference voltage (V_{ref}). The calculation can be found from the voltage divider equation as shown in Eq. (3)

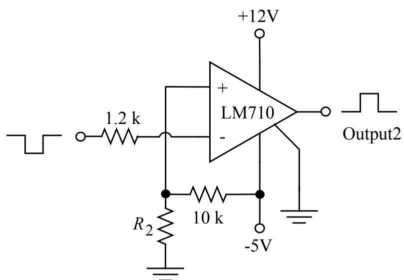
$$V_{ref} = \frac{V_{cc} R_2}{R_1 + R_2} \tag{3}$$

2.2.2 Negative Pulse Detector

The reference voltage used is –1 V, which provides the best amplitude of the negative reflective signal. Fig. 5 (a) and (b), respectively, display the positive pulse detector and negative pulse detector used with the designed instrument.



(a) Positive pulse detector



(b) Negative pulse detector

Fig. 5 Pulse detector

2.3 Pulse Summing

The positive and negative signals from the output of the pulse detector are combined using OR Gate. This width of this combined signal is proportion to the length of the investigated electric cable. The block diagram of the pulse summing can be found from Fig. 6 and Fig. 7 displays the comparison between the input and output signals when summing.

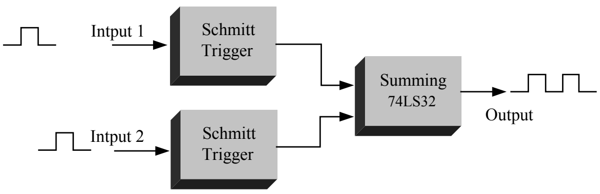


Fig. 6 Block Diagram of the Pulse Summing

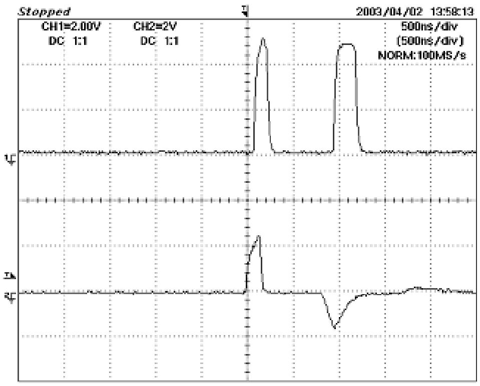


Fig. 7 Comparison between the input and output signals when summing

2.4 Pulse Converter

Pulse converter converts the distance between the sending pulse and the reflective pulse into a new pulse which has the width equal to the distance between the sending pulse and the reflective pulse as shown in Fig. 8. The D-F/F(1) receives the input signal from the output of the pulse summing whereas the D-F/F(2) receives its input signal from the negative pulse detector to detect the type of the fault whether it is open circuit or negative circuit one. In case of short circuit, the reflective pulse is negative and a 5 V pulse is generated from Op-Amp (LM710) and sent to the D-F/F(2) (Logic ‘1’). On the other hand, if the fault is open circuit, the reflective pulse is positive and no output at the Op-Amp causing the voltage at the output of the D-F/F(2) is 0V (Logic ‘0’). The output of the D-F/F(2) (either Logic ‘0’ or ‘1’) is then transferred to be computed at the Microcontroller. Fig. 9 (a) and (b) illustrate the comparison between the input and output signals of D-F/F, respectively.

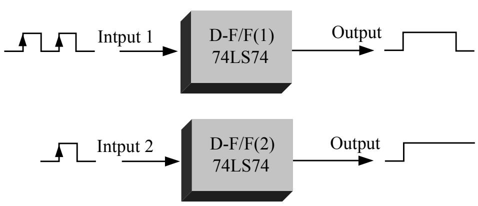
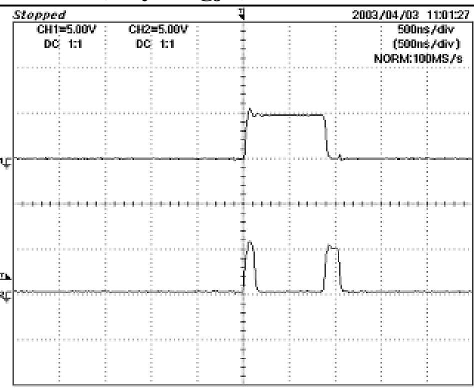
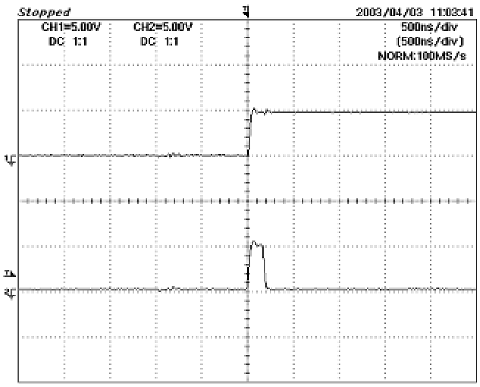


Fig. 8 Block diagram of Pulse converter



(a) Signals from D-F/F(1)



(b) Signals from D-F/F(2)

Fig. 9 Comparison between the input and output signals

2.5 Pulse Amplitude Modulation (PAM)

The signal from D-F/F(1) is later on modulated with 10 MHz carrier pulse using AND Gate as shown in Fig. 10 PAM then segregates the input pulse into several small pulses at every 10 MHz reflective Pulse’s width as shown in Fig. 11. The reflection time is somehow related to the distance the pulse travels.

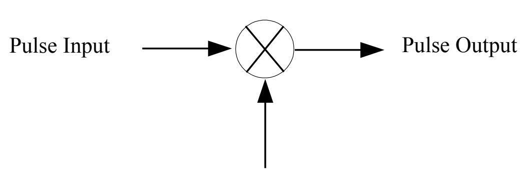


Fig. 10 Frequency modulation

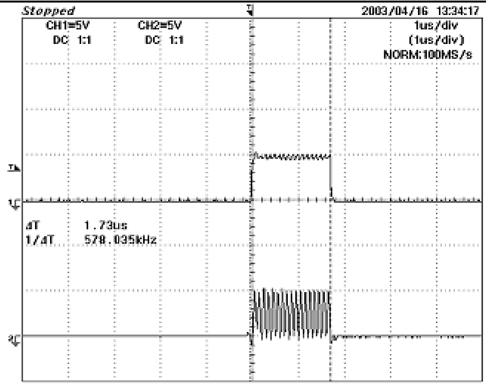


Fig. 11 Input and output of PAM

2.6 8-bit Counter

8-bit counter uses IC TTL to count the number of small pulses generated by the PAM. The counter counts every a period of signal modulating, that is, every time there is gap between the sending pulse and the reflective pulse. The count starts only when the input pulse is Logic '1'. This pulse is also used as an on/off counter signal for the 8-bit Counter.

3. SYSTEM TESTING

The procedure starts by pressing the key test. The pregram then tests whether the fault is open circuit or short circuit by detecting the signal obtained from D-F/F(2). The signal received from 8-bit counter is also used to count, calculate, compute, and display the results on the LCD screen to report the location and the type of the fault. This experiment uses 750 V 4x4 Sq.mm. electric cables and the results comparing between the open circuit and short circuit cases are shown in Table 1 and graphically shown in Fig. 12.

Table 1 Test result of 750V 4x4 Sq.mm. electric cable.

Length (m)	Open Circuit		Short Circuit	
	Display (m)	Error (%)	Display (m)	Error (%)
15.0	15.0	0.0	15.0	0.0
30.0	30.0	0.0	30.0	0.0
50.5	52.5	3.9	52.5	3.9
52.5	52.5	0.0	52.5	0.0
67.5	65.5	2.9	65.5	2.9
101.0	97.5	3.4	97.5	3.4
105.0	105.0	0.0	105.0	0.0
135.0	130.5	3.3	130.5	3.3

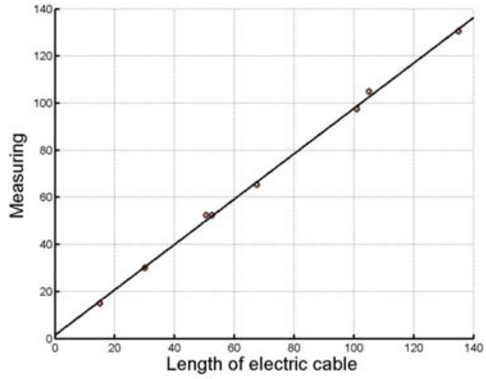


Fig. 12 Comparison between the open circuit and short circuit cases

4. CONCLUSIONS

The length of the electric cables used in the experiment is 135 m. The error occurred as shown in Table 1 is less than 3.9% and the cause is the impedance at the joint of the cables. To reduce the error, the differential voltage of the pulse detector must be adjusted properly according to the length tested. Moreover, the frequency of the carrier pulse should be greater than 10 MHz in order to detect longer cables and obtain higher accuracy.

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