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Research on Fault Diagnosis of Vehicle-mounted Network Communication Based on CAN Bus

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Abstract. Aiming at the difficulty of vehicle-mounted network communication diagnosis technology and comprehensive working principle of automobile trunk communication, the key technologies of vehicle-mounted network communication diagnosis are extracted. Based on the characteristics of CAN Bus technology, the working principle of CAN Bus is stated. The typical fault diagnosis and key technology analysis and research of CAN Bus network information transmission are carried out. The efficient and feasible diagnosis method is proposed, which has high application and reference value.

1. Introduction

With the development of automotive electronic control technology, there are more and more automotive electrical equipment, from the traditional power system control to the bodywork system control, the development and application of automobile new technology and vehicle-mounted network information communication technology are inseparable, Controller Area Network, referred to as CAN Bus, has become a mainstream vehicle-mounted network trunk and is widely used. Therefore, the research on vehicle-mounted network diagnosis based on CAN bus has market value and practical significance.

2. The Working Principle of CAN Bus

The CAN bus realizes the data trunk transmission, which is a separate system in the in-vehicle electronic device for exchanging information between the connected control units. The important components in its network control units are: CPU, CAN controller and CAN transceiver, in addition to the input / output memory and program memory, as shown in Fig.1.



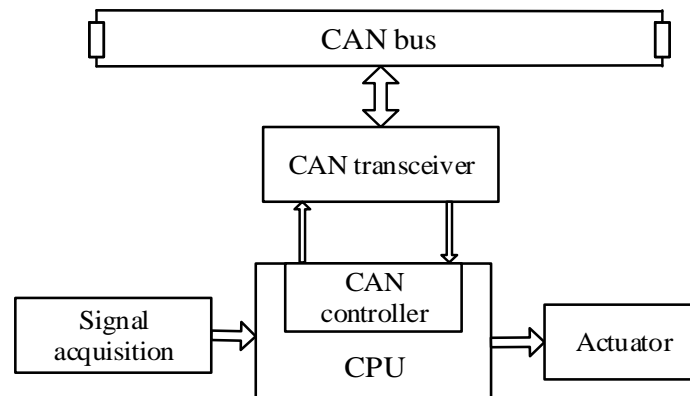


Figure 1. Schematic diagram of the CAN network

The CAN Bus uses twisted pair communication, and the two wires are called CAN-High line and CAN-Low line. All control units of each CAN system are connected in parallel on the CAN data trunk, and the data exchange between the control units is done through these two twisted pairs.

3. The Features of CAN Bus

At present, most of the automobiles use two kinds of CAN Bus, one is low-speed CAN Bus, the transmission rate is about 100 Kb/s; the other one is high-speed CAN Bus, the transmission rate is about 500 Kb/s. Through the gateway, the low-speed CAN Bus can exchange data with the high-speed CAN Bus. The differences in the application states of the two CAN Bus systems are as follows: The high-speed CAN data trunk is cut off by the ignition switch or after a short no-load operation; the low-speed CAN data trunk is powered by the normal fire line and must be kept ready for use. In order to reduce the load on the power supply network as much as possible, after the ignition switch is turned off, if the system no longer needs the low-speed data trunk, the low-speed data trunk enters the so-called sleep mode. When the low-speed CAN data trunk is short-circuited on one of the data lines, or one of the CAN-wires is disconnected, the other line can continue to work. At this time, it will automatically switch to the single-line working mode. The electrical signal of the high-speed CAN data trunk is different from the electrical signal of the low-speed CAN data trunk.

3.1. High-Speed CAN Bus

The main networked control unit of the high-speed CAN data trunk includes an engine control unit, an ABS control unit, an ESP control unit, a transmission control unit, an airbag control unit, a combination meter, and the like. Each control unit exchanges data via the CAN-High line and the CAN-Low line of the high-speed CAN data trunk.

According to the trunk working state, the signal voltage on the high-speed CAN data trunk can be divided into two states: dominant (working) and recessive (idle). In the dominant state, the voltage on the CAN-High line is raised by a predetermined value, which is at least 1 V; and the voltage on the CAN-Low line is reduced by a value of the same magnitude. Therefore, on the high-speed CAN data trunk, the CAN-High line is active, its voltage is not lower than 3.5 V ($2.5\text{ V} + 1\text{ V} = 3.5\text{ V}$), and the voltage value on the CAN-Low line can be reduced to 1.5 V ($2.5\text{ V} - 1\text{ V} = 1.5\text{ V}$). In the recessive state, the voltage difference between the CAN-High line and the CAN-Low line is 0 V, and in the dominant state, the voltage difference is at least 2 V, as shown in Fig.2.

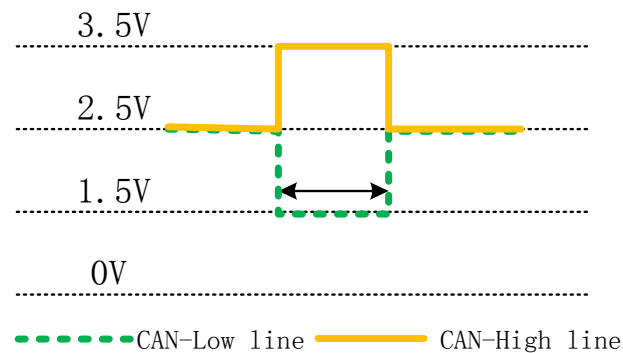


Figure 2. Signal voltage variation of the high-speed CAN Bus

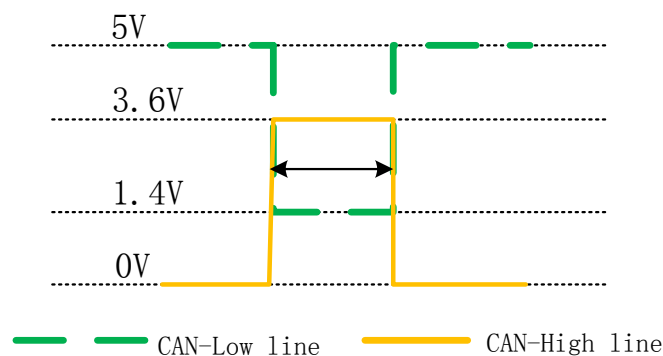


Figure 3. Signal voltage variation of the low-speed CAN Bus

3.2. Low-Speed CAN Bus

The main networked control unit of the low-speed CAN data trunk includes the vehicle-mounted power grid control unit, the car door control unit, the automatic air-conditioning control unit, and the instrument control unit to realize window lift, interior light on/off, door lock control, and vehicle positioning (GPS) and other functions. Each control unit exchanges data via the CAN-High line and the CAN-Low line of the low-speed CAN data trunk. Compared with the high-speed CAN data trunk communication characteristics, when a low-speed CAN data trunk is short-circuited on a certain data line or a CAN line is disconnected, another data conductor that works normally can still be used for communication to ensure normal network communication and record the point of failure.

The working signal voltage on the low-speed CAN data trunk is divided into the dominant and recessive states as well as the high-speed CAN data trunk. In the recessive state, the CAN-High signal is 0 V. In the dominant state, the CAN-High signal is greater than or equal to 3.6 V; for the CAN-Low signal, the recessive level is 5 V, and the dominant level is less than or equal to 1.4 V, as shown in Fig.3.

4. Typical Fault Diagnosis

The fault type of CAN Bus system can be summarized into three categories: vehicle network transmission system failure, node failure and link failure caused by vehicle power system failure. The commonly used diagnostic tool for trunk communication faults is the oscilloscope. The paper uses the oscilloscope to detect the waveform of the CAN data trunk, and uses the channel CH1 to measure the CAN-High voltage. The channel CH2 measures the CAN-Low voltage. By comparing the signal waveforms of the normal working level of the CAN data trunk, the fault waveforms are analyzed to summarize typical fault diagnosis ideas and methods.

4.1. Analysis of typical fault waveform of high-speed CAN Bus

The normal level signal of the high-speed CAN Bus is as shown in Fig.4. The CAN-High (yellow waveform) signal has a voltage of approximately 2.5 V when the trunk is idle. The voltage on the trunk will have a high frequency fluctuation between 3.5 V and 2.5 V when there is signal transmission on the trunk. The CAN-Low (green waveform) signal has a voltage of approximately 2.5 V when the trunk is idle. When the signal is transmitted on the trunk, the voltage on the trunk fluctuates between 1.5 V and 2.5 V.

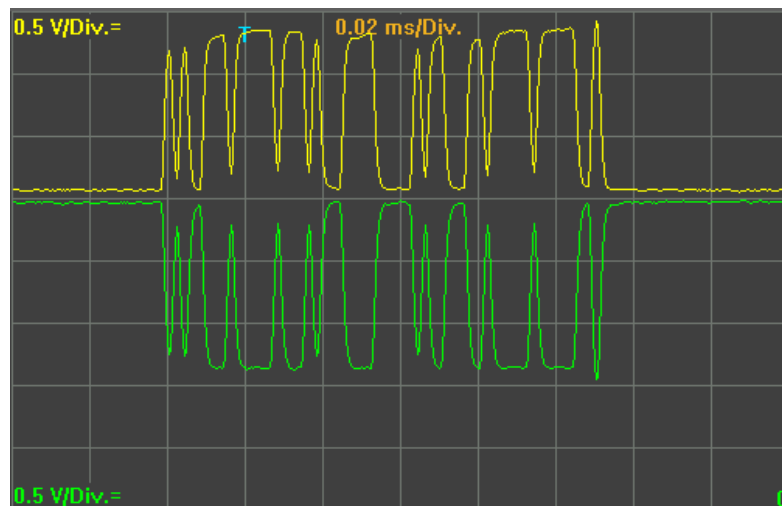


Figure 4. Level signal waveform when the high-speed CAN Bus is normally working

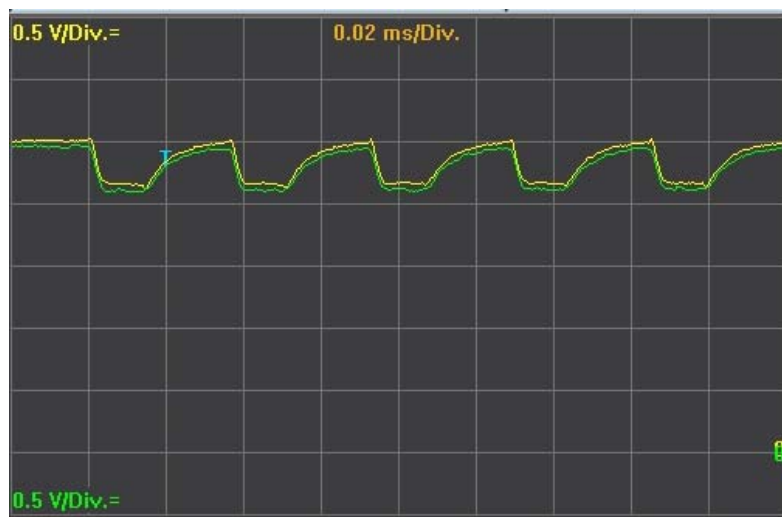


Figure 5. Waveform of high-speed CAN-High and high-speed CAN-Low short-circuit fault

(1) Fault waveform 1—the short-circuit waveform of CAN-High and CAN-Low is as shown in Fig.5. The CAN-High line and the CAN-Low line behave in the same waveform, and the voltage potential is placed at a recessive voltage value (approximately 1.5 V). From this, it can be inferred that the CAN-High line and the CAN-Low line are short-circuited. By plugging and unplugging the control unit on the high-speed CAN Bus, it can be judged whether it is a short circuit caused by the control unit or a short circuit caused by the CAN-High and CAN-Low line connections. When it is caused by short circuit, you need to take the CAN-High line and CAN-Low line from the line node in turn, and pay attention to

the waveform of the digital oscilloscope. When the fault line group is removed, the waveform of the digital oscilloscope should return to normal.

(2) Fault waveform 2—the waveform of CAN-High short-circuit to the positive pole is as shown in Fig.6. The voltage potential of the CAN-High line is placed at 12 V, so it can be inferred that the CAN-High line is shorted to the positive terminal. Due to the internal connection of CAN-High and CAN-Low in the control unit transceiver, the recessive voltage of the CAN-Low line is also pulled high to approximately 12 V.



Figure 6. Waveform of high-speed CAN-High short-circuit fault to positive pole



Figure 7. Waveform of high-speed CAN-High shortcircuit to ground

(3) Fault waveform 3—the waveform of CAN-High short circuit to ground is as shown in Fig.7. The CAN-High voltage is at 0 V, which can be inferred for CAN-High short to ground. Due to the internal connection of CAN-High and CAN-Low in the transceiver of the control unit, the voltage at the recessive state of CAN-Low is also lowered at 0 V, but slight voltage change can be seen on the CAN-Low line during the dominant period, inferred that the CAN-Low line is normal.

(4) Fault waveform 4—the waveform of CAN-Low short circuit to ground is as shown in Fig.8. The CAN-Low line has a signal voltage of 0 V in both dominant and recessive states. When the CAN-High line is dominant, the ripple voltage rises by 2V ($>1V$), which can infer the CAN-Low short-circuit to ground. Due to the internal connection of CAN-High and CAN-Low in the transceiver of the control unit, the recessive voltage of CAN-High is also reduced to 0 V.

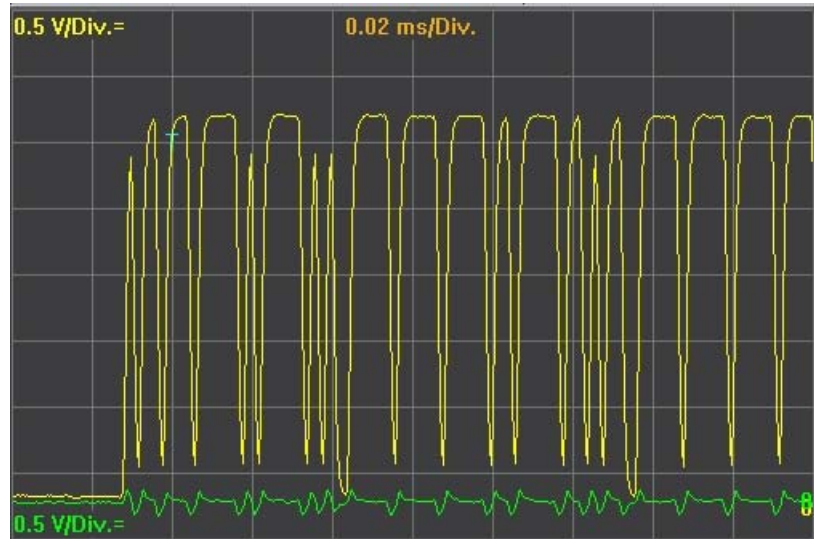


Figure 8. Waveform of high-speed CAN-Low short circuit to ground

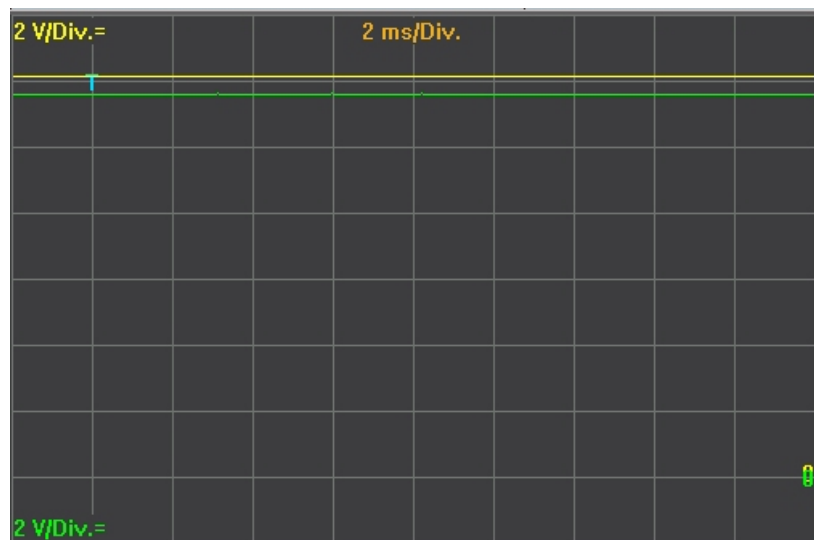


Figure 9. Waveform of high-speed CAN-Low short-circuit fault to positive pole

(5) Fault waveform 5—the waveform of CAN-Low short circuit to the positive pole is as shown in Fig.9. The voltage on both trunk is approximately 12 V.

(6) Fault waveform 6—the waveform of the CAN-High open circuit is shown in Fig.10. Since the current can no longer flow to the central termination resistor to pass the CAN-Low line, the voltage of all two conductors is close to 1 V. If there are other control units in operation, the level shown in the Fig. will change with the normal voltage on the CAN-High line.

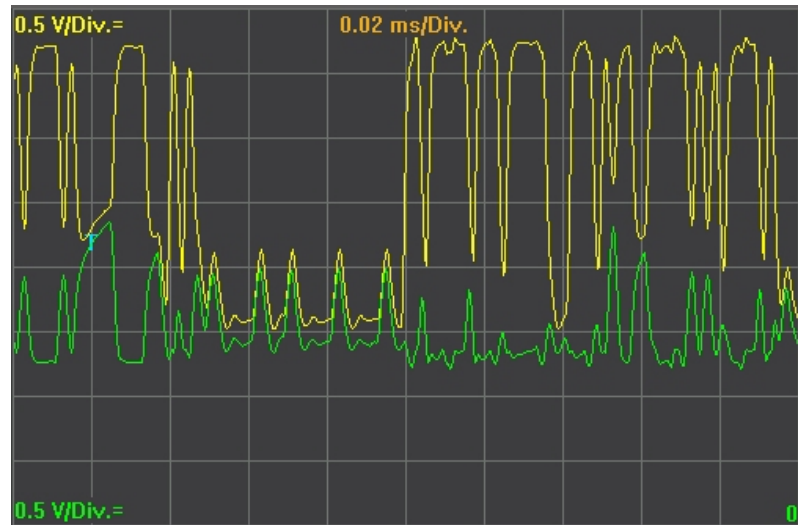


Figure 10. Waveform of high-speed CAN-High to open circuit fault



Figure 11. Waveform of high-speed CAN-Low to open circuit fault

(7) Fault waveform 7—the waveform of the CAN-Low open circuit is as shown in Fig.11. Since the current can no longer flow to the central termination resistor to pass the CAN-High line, both conductor voltages are close to 5 V. As with fault 6, if there are other control units in operation, the level shown in the Fig.will change with the normal voltage on the CAN-Low line.

4.2. The typical fault waveform analysis of Low-speed CAN Bus

The level signal of the normal communication of the low-speed CAN Bus is as shown in Fig.12. The CAN-High signal has a voltage of about 0 V when the trunk is idle. When the signal is transmitted on the trunk, the CAN-High voltage fluctuates between 0 V and 5 V. The CAN-Low signal has a voltage of about 5 V when the trunk is idle. When the signal is transmitted on the trunk, the voltage on the trunk fluctuates between 5 V and 0 V.

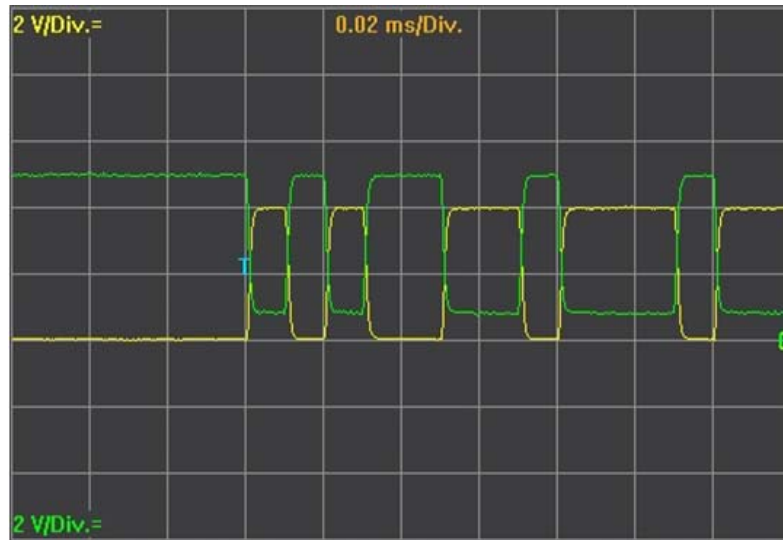


Figure 12. Low-level CAN Bus normal level signal waveform

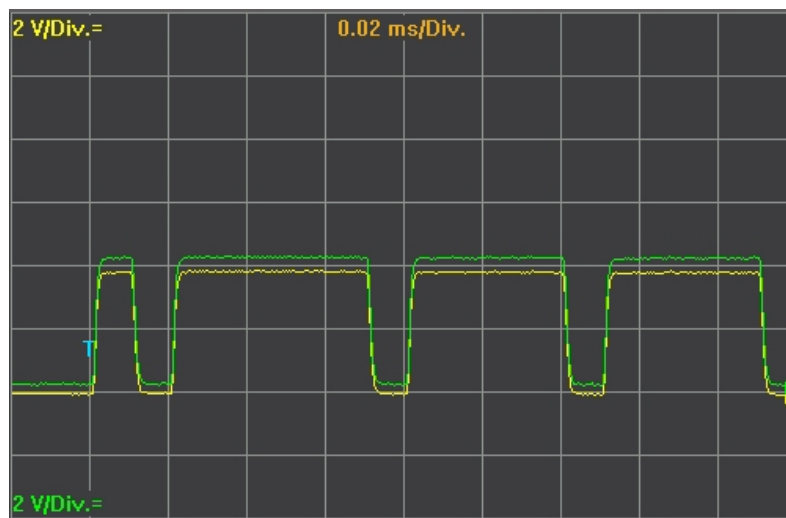


Figure 13. Short-circuit fault waveform between CAN-High and CAN-Low

(1) Fault waveform 1 - Short circuit waveform between CAN-High and CAN-Low is as shown in Fig.13. The CAN-High and CAN-Low of the CAN Bus exhibit the same level signal waveform change, and it can be inferred that the two lines are short-circuited. Since the low-speed CAN Bus has a "single-line operation" mode, when the trunk fails, the CAN Bus communicates with another data conductor that uses normal operation to ensure normal network communication.

(2) Fault waveform 2—the waveform of CAN-High short circuit to ground is as shown in Fig.14. The voltage of CAN-High is set to 0 V, and the voltage potential of CAN-Low is normal. Therefore, the low-speed CAN enters the single-line working mode. As can be seen from the waveform, the fault is caused by the CAN-High short circuit to ground.

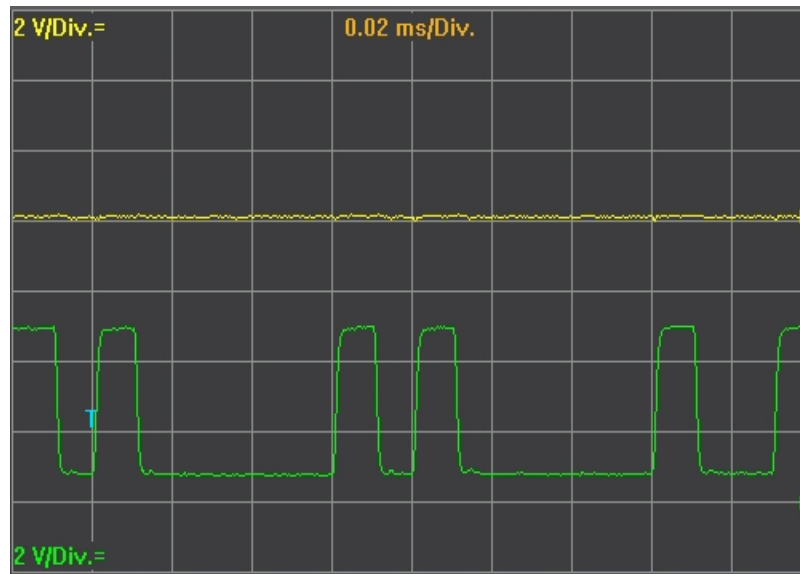


Figure 14. Waveform of CAN-High short circuit to ground

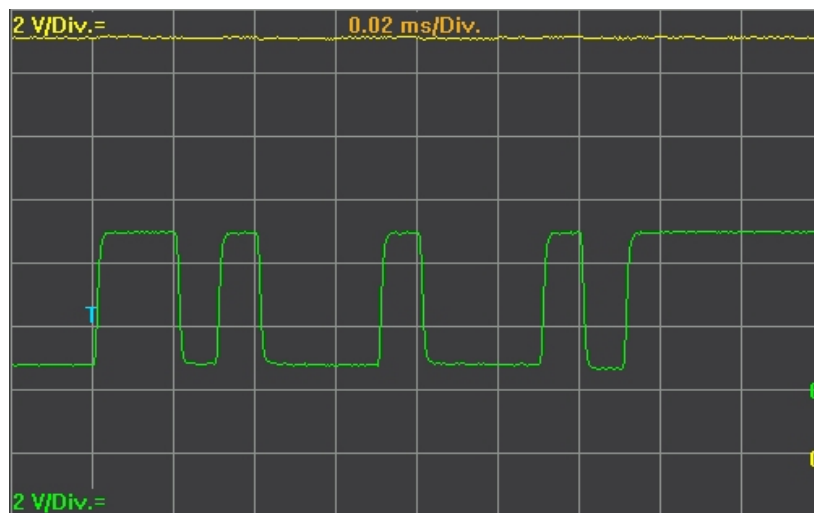


Figure 15. Waveform of CAN-High to positive short circuit fault

(3) Fault waveform 3—the waveform of CAN-High short-circuit to the positive pole is as shown in Fig.15. The voltage potential of CAN-High is approximately 12 V or the battery voltage, and the voltage potential of CAN-Low is normal. Therefore, the low-speed CAN enters the single-line working mode. As can be seen from the waveform, the fault is caused by the short-circuit of the CAN-High to the positive pole.

(4) Fault waveform 4—the waveform of the CAN-Low short circuit to ground is as shown in Fig.16. The voltage of CAN-Low is set to 0 V, and the voltage potential of CAN-High is normal. Therefore, the low-speed CAN enters the single-line working mode. As can be seen from the waveform, the fault is caused by the CAN-Low short circuit to ground.

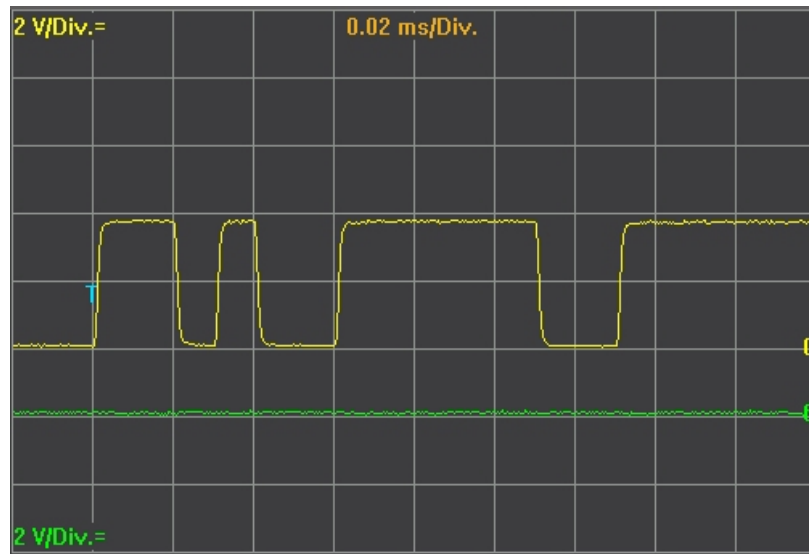


Figure 16. Waveform of CAN-Low short circuit to ground

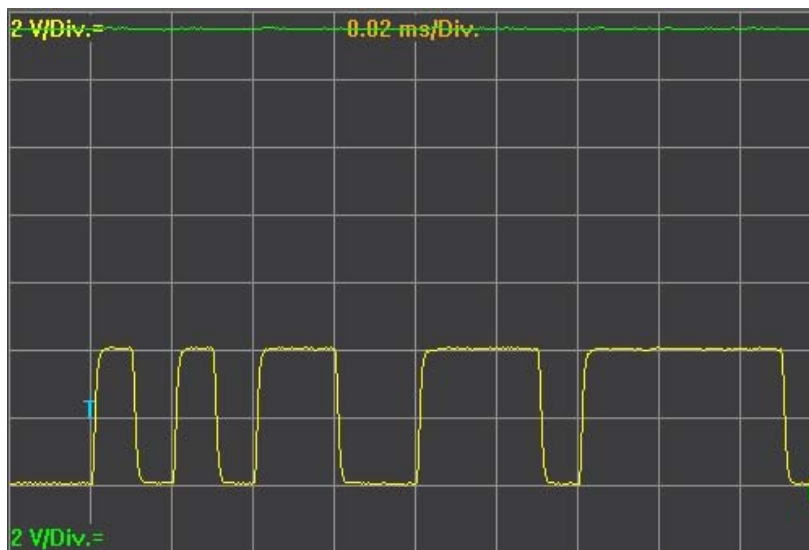


Figure 17. Waveform of CAN-Low to positive short circuit fault

(5) Fault waveform 5—the waveform of the CAN-Low short circuit to the positive pole is as shown in Fig.17. The voltage potential of the CAN-Low line is approximately 12 V or the battery voltage, and the voltage potential of the CAN-High line is normal. Therefore, the low-speed CAN enters the single-line working mode. As can be seen from the waveform, the fault is caused by the short-circuit of the CAN-Low to the positive pole.

(6) Fault waveform 6—the waveform of CAN-High for shorting the positive pole through the connection resistor is as shown in Fig.18. At this time, the recessive voltage potential of CAN-High is pulled toward the positive direction. As can be seen from the waveform of the digital oscilloscope, the recessive voltage potential of CAN-High is about 1.8 V, and the normal value should be about 0 V. Therefore, the 1.8 V voltage is analysed due to the connection resistance. The smaller the resistance, the larger the recessive voltage potential. This voltage value is equal to the battery voltage without a connection resistor.

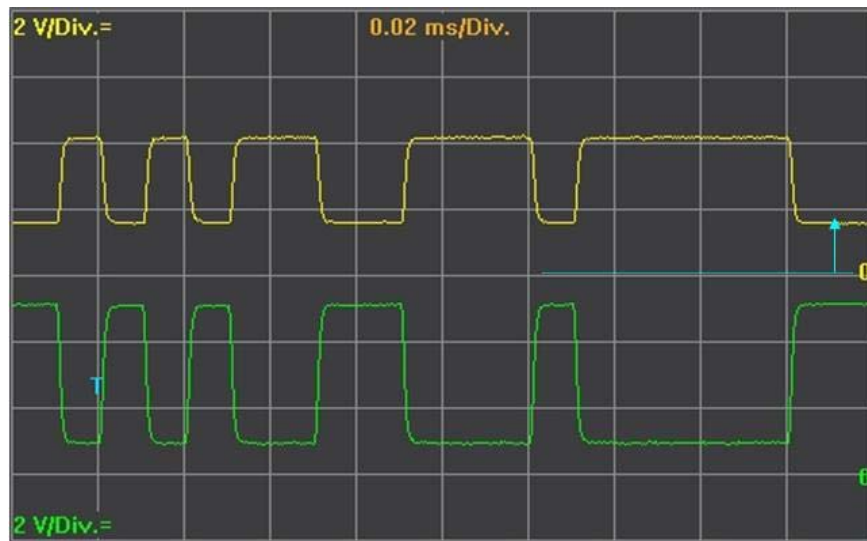


Figure 18. Waveform of CAN-High on the positive pole short circuit through the connection resistance

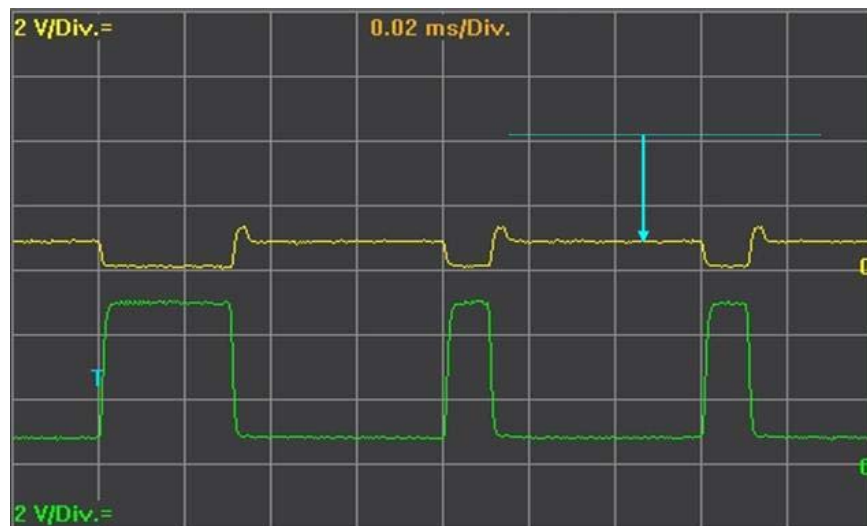


Figure 19. Waveform of CAN-High short-circuit fault to ground by connecting resistor

(7) Fault waveform 7—the waveform of CAN-High shorted to ground by the connection resistor is as shown in Fig.19. At this time, the dominant electrical displacement of CAN-High is in the grounding direction. As can be seen from the waveform of the digital oscilloscope, the dominant voltage of CAN-High is about 1 V, and the normal voltage is about 4 V. The voltage of 1 V is analyzed by the reduction voltage principle due to the influence of the connection resistance. The smaller the resistance, the smaller the dominant voltage. This voltage is 0 V in the case of a short circuit without a connection resistor.

(8) Fault waveform 8—the waveform of CAN-Low short-circuiting the positive pole through the connection resistor is as shown in Fig.20. At this time, the recessive voltage potential of CAN-Low is pulled toward the positive direction. As can be seen from the waveform of the digital oscilloscope, the recessive voltage potential of CAN-Low is approximately 13 V, and the normal voltage should be approximately 5 V. This 13 V voltage is due to the connection resistance. The smaller the resistance, the larger the recessive voltage potential. In the absence of a connection resistor, this voltage value is the battery voltage.

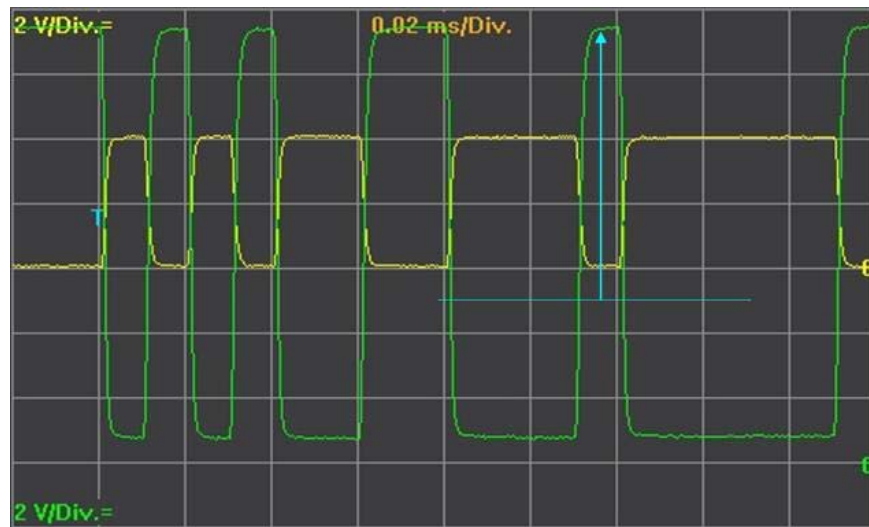


Figure 20. Waveform of CAN-Low to the positive pole short circuit through the connection resistance



Figure 21. Waveform of CAN-Low short-circuit fault to ground by connecting resistor

(9) Fault waveform 9—the waveform of CAN-Low short-circuited to ground by the connection resistor is as shown in Fig.21. At this time, the recessive voltage potential of CAN-Low is pulled in the 0 V direction. As can be seen from the waveform of the digital oscilloscope, the recessive voltage potential of CAN-Low is about 3 V, and the normal voltage should be about 5 V. It is analysed that the 3 V voltage is caused by the connection resistance. The smaller the resistance, the smaller the recessive voltage potential. In the absence of a connection resistor, this voltage is 0 V.

(10) Fault waveform 10—the waveform between CAN-High and CAN-Low that is short-circuited by the connection resistor is as shown in Fig.22. In the case of a short circuit, the recessive voltage potentials of CAN-High and CAN-Low are close to each other. The recessive voltage of CAN-High is approximately 1 V, while the normal value is 0 V; the voltage of CAN-Low is approximately 4 V, while the normal value is 5 V. The dominant voltage potential of CAN-High and CAN-Low is normal.

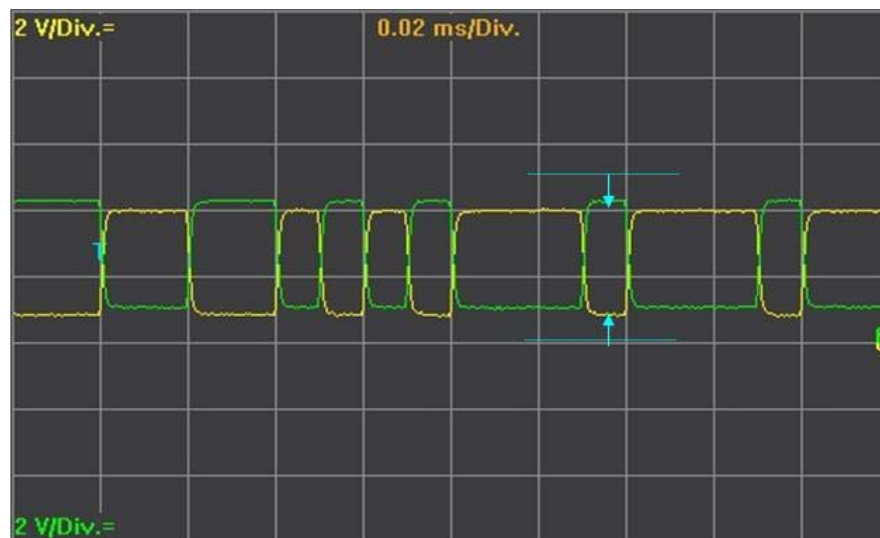


Figure 22. Waveform between CAN-High and CAN-Low through a short-circuit through the connection resistor

5. Conclusion

In this paper, the fault waveform is studied by the process of vehicle network information communication detection. Based on the basic principle and working characteristics of the CAN Bus, it analyzed typical faults of 17 different vehicle-mounted network communication faults. The corresponding analysis ideas and diagnostic methods are put forward, which can be used for reference and promotion of automotive network communication diagnosis research.

Acknowledgments

Guang'an Vocational and Technical College Research Projects in 2019: GAZYKY-2019A01. Chen Yiqing (1987-), male, Sichuan Gangland, master's degree candidate, mainly engaged in teaching and research work in vehicle system dynamics, vehicle electronic control technology, and etc. email: 527731272@qq.com.

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