Automotive Technology
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Experiment 1

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1 Reflections at open wire ends

This experiment aims to make you familiar with the electrical processes that take place in the case of high frequencies on ordinary bus cables. The analysis focuses on the runtime of signals and the signals' reflections when lacking the adaption by a terminating resistor.
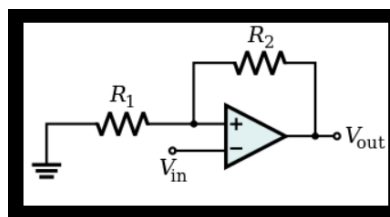
Be careful: Following this experiment, we are working, as usual in the case of bus systems, with very high frequencies. If ever you desire set up such an experiment on your own, be careful to keep the wire lengths as short as possible. Wire jungles on the breadboard are supposed to distort the experiment's result drastically!

Introduction

Answer the following questions. The videos available online might help you.

- Sketch the transfer function of the Schmitt trigger!

  For inverting Schmitt trigger, the transfer function equation is $V_+ = R_1 / (R_1+R_2) \times V_s$.

- Why is the Schmitt trigger useful for signal processing?

  Because of the hysteresis curve (between 0.98 volts to 18 volts) with fluctuating input, stable level at output.

- What are the switching thresholds of the 74LS14 used here? Find a datasheet on the web.

Absolute Maximum Ratings (Note)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Supply Voltage	7V
Input Voltage	7V
Operating Free Air Temperature Range	
54LS	−55°C to +125°C
DM74LS	0°C to +70°C
Storage Temperature Range	−65°C to +150°C

Note: The "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed. The device should not be operated at these limits. The parametric values defined in the "Electrical Characteristics" table are not guaranteed at the absolute maximum ratings. The "Recommended Operating Conditions" table will define the conditions for actual device operation.

Recommended Operating Conditions

Symbol	Parameter	54LS14 Min	54LS14 Nom	54LS14 Max	DM74LS14 Min	DM74LS14 Nom	DM74LS14 Max	Units
V_{CC}	Supply Voltage	4.5	5	5.5	4.75	5	5.25	V
V_{T+}	Positive-Going Input Threshold Voltage (Note 1)	1.5	1.6	2.0	1.4	1.6	1.9	V
V_{T-}	Negative-Going Input Threshold Voltage (Note 1)	0.6	0.8	1.1	0.5	0.8	1	V
HYS	Input Hysteresis (Note 1)	0.4	0.8		0.4	0.8		V
I_{OH}	High Level Output Current			−0.4			−0.4	mA
I_{OL}	Low Level Output Current			4			8	mA
T_A	Free Air Operating Temperature	−55		125	0		70	°C

Electrical Characteristics over recommended operating free air temperature range (unless otherwise noted)

Symbol	Parameter	Conditions		Min	Typ (Note 2)	Max	Units
V_I	Input Clamp Voltage	V_{CC} = Min, I_I = −18 mA				−1.5	V
V_{OH}	High Level Output Voltage	V_{CC} = Min, I_{OH} = Max V_{IL} = Max	54LS	2.5	3.4		V
			DM74	2.7	3.4		
V_{OL}	Low Level Output Voltage	V_{CC} = Min, I_{OL} = Max V_{IH} = Min	54LS		0.25	0.4	V
			DM74		0.35	0.5	
		V_{CC} = Min, I_{OL} = 4 mA	DM74		0.25	0.4	
I_{T+}	Input Current at Positive-Going Threshold	V_{CC} = 5V, V_I = V_{T+}	DM74		−0.14		mA
I_{T-}	Input Current at Negative-Going Threshold	V_{CC} = 5V, V_I = V_{T-}	DM74		−0.18		mA
I_I	Input Current @ Max Input Voltage	V_{CC} = Max, V_I = 7V	DM74			0.1	mA
		V_{CC} = Max, V_I = 10.0V	54LS				
I_{IH}	High Level Input Current	V_{CC} = Max, V_I = 2.7V				20	µA
I_{IL}	Low Level Input Current	V_{CC} = Max, V_I = 0.4V				−0.4	mA
I_{OS}	Short Circuit Output Current	V_{CC} = Max (Note 3)	54LS	−20		−100	mA
			DM74	−20		−100	
I_{CCH}	Supply Current with Outputs High	V_{CC} = Max			8.6	16	mA
I_{CCL}	Supply Current with Outputs Low	V_{CC} = Max			12	21	mA

Note 1: V_{CC} = 5V.

Note 2: All typicals are at V_{CC} = 5V, T_A = 25°C.

Note 3: Not more than one output should be shorted at a time, and the duration should not exceed one second.

1.1 Control unit

1.1.1 Setup

For this experiment, we set up a simple input stage for a control unit. Watch the video "Experiment 1.1.1" that explains the hardware when setup is completed. The input stage consists of two inverting Schmitt triggers placed in series.
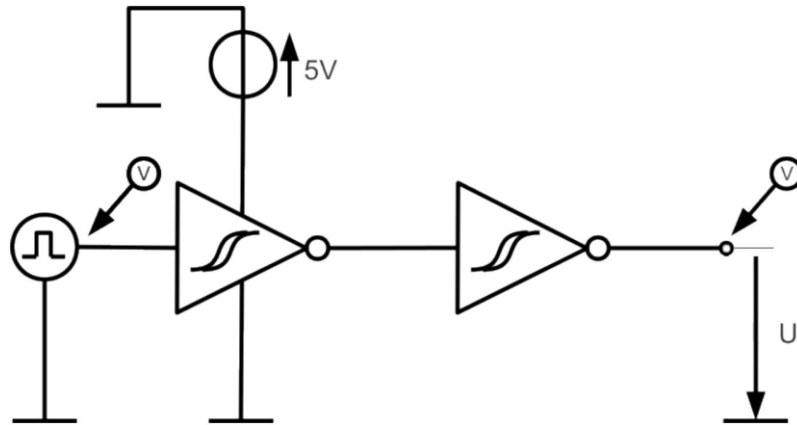

Figure 1.1: input stage for small control unit

- Why do we place in series two inverted Schmitt triggers?

  Because it produces an inverted output signals.

1.1.2 Data source

As usual for CAN and LIN networks, the logical values for "0" and "1" will be represented by different voltage levels. Therefore, an AC voltage in pulse form is set with the following values (see the video "Experiment 1.1.2"):

- $f = 1\text{MHz}$
- $V_{pp} = 4\text{V}$
- $V_0 = 2\text{V}$ (Offset voltage)
- Duty cycle $\eta = 20\%$

Now, watch the oscilloscope's display (video), showing many periods of the signal on the screen.

- What (periodical) bit sequence does the voltage correspond to?

  1001 0

- How many bits does a "data word" contain?

  5 bits.

- What is the level of the bit rate? (Note: The bit rate does *not* correspond to the generator's frequency!)

  5 MHz.

1.1.3   Runtime in the control unit

Now the output of the control unit will be connected to another channel of the oscilloscope (please find corresponding information in the video).

- Specify the runtime of the signal Δt in the "control unit". Therefore, take note of the corresponding display in the video, showing the measurement by the use of the cursors.
- How many percent of the bit time is the signal edge's delay at the output of the "control unit"?
  22%

1.2   Control unit
1.2.1   Runtime in the control unit

Now we want to measure the speed of the bus signals' propagation in our system. Therefore, we need a signal edge that should be as sharp as possible.
The setting of the signal generator will be a pulse voltage with maximal amplitude, the signal should alternate between 0V and V_{max} with a frequency of 1MHz. In addition, a duty cycle that should be as short as possible will be set (you will find the settings in the video).

- What are the settings for amplitude, offset and duty cycle?

  Amplitude = 10 V
  Offset = 0
  Duty cycle = 4%

- What are the values of the signal that will be displayed on the oscilloscope's screen?

  5V

Now the bus cable will be connected to the output of the signal generator. The other end of the bus wire will be connected to the probes of the oscilloscope (find the setup in the video).

For the next measurement, take note of the values in the video. Read the runtime Δt between the peaks of the input signal and the reflected signal and write it down.

$\Delta t =$ 20.00 ns

Now the bus cable will be extended by a wire of 2 meters. Thereby, the reflected signal will be slightly delayed. See the measurement of the difference in runtime Δt_1 between the original cable and the cable with extension (using the cursors of the oscilloscope's screen in the video).

$\Delta t_1 =$ 40.00 sec

Using the values of the last measurement, calculate the velocity c of the signal:

c = 25m/s

Using the signal's velocity and the values of the first measurement, determine the length l of the bus cable:
l = 133.4 m

1.2.2 Reflections and terminating resistor

Now the 2-meter-long wire will be removed from the bus's end and the open end will be short-circuited.

- How does the reflected signal behave, when the bus's end is short-circuited? Describe the behavior using the video!

High-speed measurement instruments are able to detect this transit time from source to line-end and back to the source again and may be used for the purpose of determining a cable's length.
This technique may also be used for determining the presence and location of a break in one or both of the cable's conductors since current will "reflect" off the wire break just as it will off the end of an open-circuited cable.

In order to avoid reflections on the cable, there must be an adaption using a terminating resistor. This terminating resistor must have the same value as the wave impedance of the cable.
Therefore, the end of the cable will be short-circuited by the potentiometer (5kΩ) integrated in the component (see the video). The potentiometer will be adjusted until the reflected wave is completely damped. Specify the potentiometer's resistance measured by the ohmmeter in the video.

R = 150.33 KOhm

- What do you conclude by observing this behavior, when it comes to work with high frequency signals on the CAN bus?

1.3 Control units on the bus

1.3.1 Highspeed CAN

A positive pulse voltage with $T = 8\mu s$ and a pulse width of $1\mu s$ will be set on the signal generator. The values for "HiLevel" (4V) and "LoLevel" (0V) will be controlled (see the video).

- What is the data rate (bit/s) corresponding to this setting?
  1Mbit/s.

- What is the resulting bit sequence?
  1100 0010 0101 1010 100

Now, the input of our "control unit" (input of the op-amp) will be connected to the function generator and the bus wire (draft in figure 1, for the real setup watch the video).
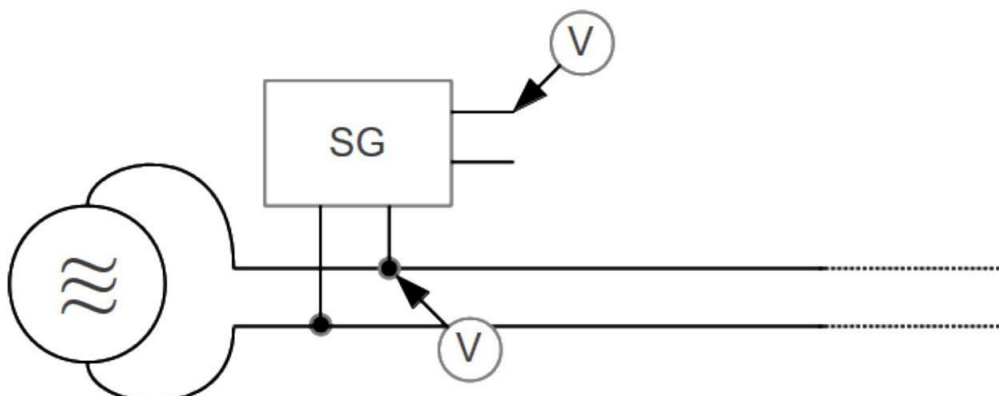

Figure 2: Connection of control unit and bus wire

The voltage level at the input side of the control unit (input of the op-amp) and at the output side of the control unit (output of the op-amp) will be measured using the oscilloscope (see in the video). Calculate the duty cycle on the bus.

- How does the duty cycle on the bus change when terminating the bus with a 120 Ω resistor?
  The yellow graph from the oscilloscope will appear without any reflection and the processing unit will process a correct bit-time.

- What would be the consequence for the receiver, if we dealt with real data on the bus?
  It could lead to an accident as it leads to a breakdown in vehicle communication.

- What is the conclusion you draw for the work with the highspeed CAN?
  The highspeed CAN bus is really important to be presented in one of CAN bus.

1.3.2   Lowspeed CAN

Now the settings on the function generator will be changed so that the same bit sequence as in the previous task is sent with 100 kBit/s. The measurement of the previous task (see figure 2) will be repeated using these values.

- What are the settings for time and pulse width that need to be made?

T = 80µs

Δt = 10µs

- How does the duty cycle on the bus change now when the bus is terminated with a 120 Ω resistor (see the video)?
  The yellow graph from the oscilloscope will appear with a small reflection of the highspeed CAN graph.

- How can you explain the difference to the measurement with the highspeed CAN?
  High Speed CAN offers baud rates from 40 Kbit/s to 1 Mbit/sec, depending on cable length. This is the most popular standard for the physical layer, since it allows for simple cable connection between devices. This is the physical standard used in the DeviceNet and CANopen specifications. High speed CAN networks are terminated with 120 ohm resistors on each end of the network.

- What is the conclusion you can draw for the work with the lowspeed CAN?
  The lowspeed CAN doesn't produce a strong or huge Bit error because the terminationg resistance doesn't have big impact on the signals.