

Stray Pin Capacitance Effects on Signal Reading Coupled by Optocoupler on Microcontroller Boards

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Abstract—Reading high frequency signal could have possibility effecter by the internal capacitance from microcontroller pins. Study case is between Arduino and encoder coupler with optocouplers. High frequency signal is struggle to high logic due to slower rise time. Turns out slower rise time caused by internal capacitance causing 1st order response system, by adding pull-up resistor on input pin, rise time could be reduce. As final result, adding pull-up resistor does affecting the rise time, but there are still other factors beside internal capacitance.

Keywords: Arduino, Optocoupler, Encoder, Frequency.

I. INTRODUCTION

Obtaining good feedback from encoder is crucial in calculating position, speed, and acceleration. It is often to have encoder that have different working potential with the microcontroller. Putting optocouplers and pull-up resistors could accommodate to passing signal from two different potential. This coupling method cause signal problem at high frequency. Signal that passed from optocoupler is not reach the minimum voltage to set logic into high condition. It was observed that higher the input frequency at optocouplers, the output signal become more distorted. This problem is could result reading problem in microcontroller, accumulate error in long term running, or direct system failure. Adding proper pull-up resistor could reduce distortion on passed signal.

II. INVESTIGATION METHODOLOGY

The experiment was simulated by using 2 Arduino Mega, optocouplers, and oscilloscope to shown the signal. first Arduino Mega was acting as a signal generator, signal frequency could be varied by using program. Second Arduino was acting as a signal receiver, both Arduino Mega coupled by optocoupler Figure 1 Oscilloscopes probe is attached on second Arduino between receiver pin and receiver GND.

Since Arduino that produce pulse needs to make signal frequency as high as possible. The Arduino was programmed using Direct Memory Access (DMA) to avoid unnecessary processing time, using DMA could increasing the generated frequency up to 500kHz compare to 29 kHz while using standard programming command. DMA was almost 30% faster to be execute compare to standard programming language

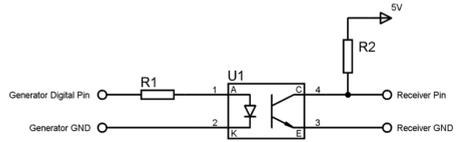


Fig. 1. Testing Circuit Assembly.

Figure 2. For experiment 1kHz signal was generated from the Arduino.



Fig. 2. DMA processing time (left) Standard processing time (right).

Output signals that shown on oscilloscope after probes are attached were not in good form, it was observe that signal was depended on pull resistor value.

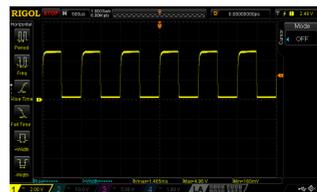


Fig. 3. 1kHz signal with 3.3 kΩ±5% pull-up resistor.

Signal shown on oscilloscope was a transient respond (Figures 3—5). This signal commonly generated by combining resistor and capacitor with give known equation (1). T does time need by the system to reach 63% of the steady state

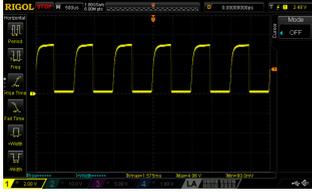


Fig. 4. 1kHz with 10 kΩ±5% pull-up resistor.

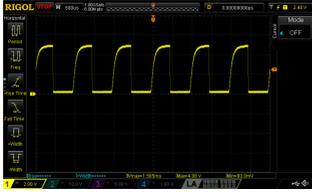


Fig. 5. 1kHz with 20 kΩ±5% pull-up resistor.

condition, this could be measured by using oscilloscope. R is pull-up resistor value, and C is value of pin capacitance. By rearrange the variables, C could be found:

$$T = R \times C \quad (1)$$

where: T = Responds Time (s), R = Responds Value (Ω), C = Capacitor Value (F).

Input signal is generated by fix frequency, 100 kHz, with period of $T = 10 \mu\text{s}$ for one complete wave. $5 \mu\text{s}$ during high state and $5 \mu\text{s}$ during low state condition. Since the controller need to detected high state in time range of high state condition. This resulting in time range of $5.0 \mu\text{s}$. The pulses should reach maximum value to set high logic.

$$V_C = V_S \times (1 - e^{-\frac{t}{\tau}}) \quad (2)$$

where: V_C = Voltage across capacitor, V_S = Supply Voltage, t = Elapsed Time, and τ = Time Constant ($R \times C$).

Equation (2). could be rearrange to find R into equation (3)., with $V_C = 5$ Volt as final voltage value to set high logic, $5 \mu\text{s}$ as time to reach final value, T substituted with RC, and C will come from equation (1).

$$\ln(0.4) = -t(RC)^{-1} \quad (3)$$

$$R = t(0.9C)^{-1} \quad (4)$$

where: t = Elapsed Time, C = Pin Capacitance (F), and R = Resistor Value (Ω).

III. INVESTIGATION RESULT

Output signal was shown on oscilloscope, time needed to reach 63% from steady state or first-time constant was measured using oscilloscope function. To calculate value of C, 3

TABLE I
TIME CONSTANT MEASUREMENT AND PIN CAPACITANCE CALCULATION

Rated pullup resistor (kΩ)	Measured pullup resistor (kΩ)	Time reach to 63% (μs)	Current Flow (mA)	Pin Capacitance value (nF)
10 ±5%	9.88	48	0.51	4.86
15 ±5%	14.75	68	0.34	4.61
20 ±5%	19.85	84	0.25	4.23
Average				4.57

experiments with different resistor values for each experiment was conducted, each resistor value was generating different time needed to first time constant (Table 1). Final value of pin capacitance is average from 3 different experiments.

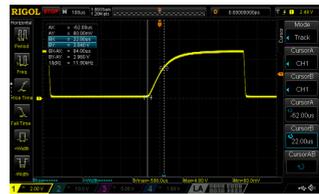


Fig. 6. Signal form with 20kΩ±5%.



Fig. 7. Signal form with 15kΩ±5%.

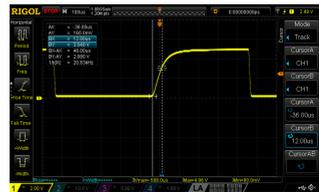


Fig. 8. Signal form with 10kΩ±5%.

Shown on Figure 9, time to reach first time constant (63%) is slower with increasing of pullup resistor value. Following Ohms law, higher Pull-up resistance also reduce current flowing thru. All current flow could be consider charging the pin

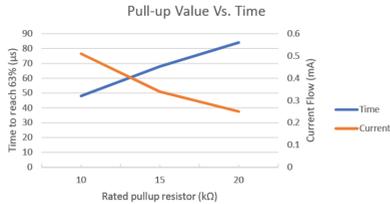


Fig. 9. Pull-up Value Vs. Time Vs. Current.

capacitance. Thus, lower resistance will cause bigger current flow, and faster to charge pin capacitors.

Using the formula to calculate the pull-up calculation.

$$R = \frac{t}{0.9C}$$

$$R = 1215,66\Omega$$

$$R \approx 1K\Omega$$

where: $t = 5 \mu s$, $C = 4.57 \text{ nF}$, $R = \text{Resistor value } (\Omega)$. By using $1k\Omega$ as pull-up resistor, there was no output signal on the other side of optocoupler (Figure 10). Signal were shown after replacing pull-up resistor into 470Ω (Figure 11).



Fig. 10. Output Signal with 1kΩ pull-up resistor.

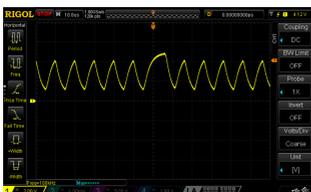


Fig. 11. Output Signal with 470Ω pull-up resistor.

IV. CONCLUSIONS

In order coupling between encoder or other signal generator with Arduino via isolation devices such as optocoupler. Rise time form the signal me be considered, this signal must in certain voltage to giving input into the Arduino. Whole

experiment shown that by adding pull-up resistors, system could be having faster rise time. It seems there are other factors beside the internal capacitance that effect the rise time, due to final testing result is not as expectation. 100kHz signal must be matched with lower pull-up resistor than calculated value, instead of using around $1k\Omega$ same with calculation.

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