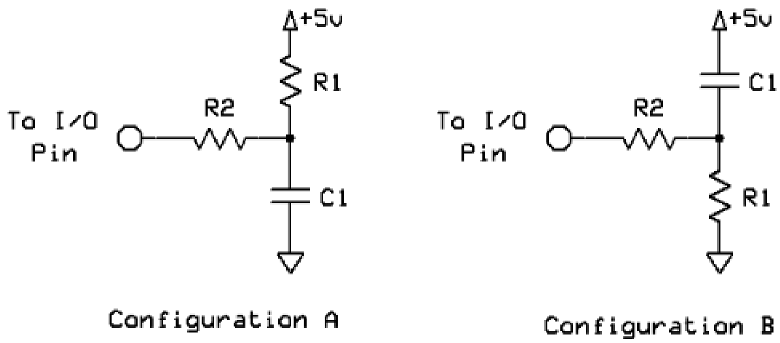
ZBasic

Application Note

AN-202 Using RCTime() to Measure Charging Time

Introduction

The `RCTime()` function measures how long it takes for a pin to change logic states – from zero to one or vice versa. One of the common applications for this capability is to measure the time that it takes for a capacitor to charge. There are two possible configurations of the external circuitry that may be used as shown below. Although they function similarly, using the Configuration B circuit below is preferable for reasons to be discussed.



Configuration A

To use Configuration A, you prepare the circuit by outputting a logic zero to the I/O pin. This allows the capacitor to discharge through R2. Ideally, this resistor value would be zero ohms because it simplifies the math involved. However, a non-zero resistance is required in order to limit the current flow in the I/O pin to a safe level. A typical value would be 330Ω. This limits the current to about 15mA.

In order to ensure that the capacitor is fully discharged, you must hold the zero output level for approximately 4 times the R-C time constant (the product of the resistance, in Ohms, and the capacitance, in Farads). For example, if the capacitor is 0.1µF and R2 is 330Ω, the time constant is 33µS (1e-7 * 330) so holding the pin at logic zero for 140µS or more will ensure that the capacitor is reasonably fully discharged.

Note, however, that when the pin is outputting logic zero, resistors R1 and R2 form a voltage divider so the voltage at the resistor-capacitor junction will not go to zero. Instead, the voltage will not drop below 5V * R2 / (R1 + R2). If R1 is 10K Ω and R2 is 330Ω the minimum voltage level will be about 0.16V (actually slightly higher because the logic zero output is not exactly zero volts).

After holding the pin at logic zero for a suitable amount of time, you can then call `RCTime()`. Since the pin has been held at logic zero, the second parameter to `RCTime()` should be zero.

```
Const pin as Byte = 20

Call PutPin(pin, 0)
Call Delay(1.4e-4)
i = RCTime(pin, 0)
```

The `RCTime()` routine will re-configure the pin to be an input (tri-state mode).At this time (referred to as t=0) the capacitor will begin charging along an exponential curve toward 5 volts, starting from the minimal initial voltage, as

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shown in the graph of Figure 1. The `RCTime()` routine will monitor the pin and as soon as it changes from a logic zero to logic one the elapsed time will be computed and returned.

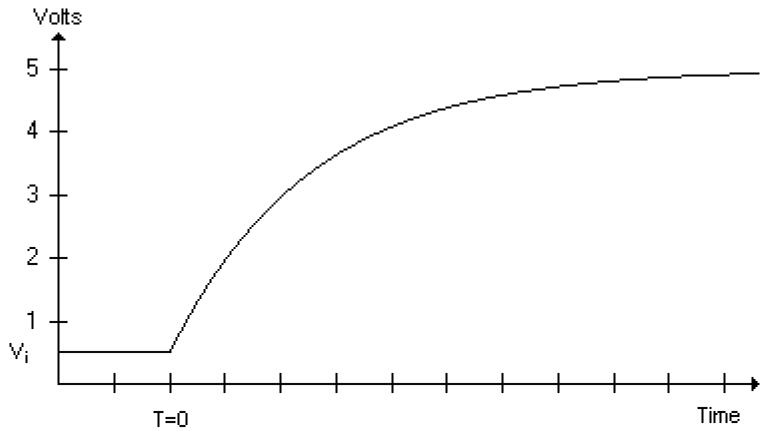

Figure 1: Typical R-C Charge Curve for Configuration A

The equation for this curve, beginning at time t=0 is $V_t = V_f + (V_i - V_f) * e^{-t/R*C}$, where V_t is the voltage at time t, V_i is the initial voltage from which the capacitor begins charging, V_f is the final voltage toward which the capacitor is charging and t is the time in seconds. The R in this equation is the value of R1 since the capacitor charges through that resistor. The value of R2 does not affect the process other than the effect that it has on the initial voltage.

The remaining variable in this process is the voltage level at which the input pin is considered to be a logic one. The datasheet for the CPU indicates that the maximum voltage that is guaranteed to be recognized as logic zero is 0.2 times Vcc. That would be 1.0V in this case. The data sheet also indicates that the minimum voltage that is guaranteed to be recognized as logic one is 0.6 times Vcc or 3.0 volts in this case. The zone between 1.0V and 3.0V is the “undefined” region where a particular CPU may recognize the input as either a logic zero or logic one. You can test your device to determine what the actual threshold is; one that we measured was 1.9 volts. (Because the inputs of the CPU all have Schmitt Trigger circuitry, the switching threshold when going from zero to one is higher than it is when going from one to zero.) With these values known, you can compute the time that it should take to charge up to the threshold voltage at which the logic change will be seen.

Configuration B

For Configuration B, the process is similar but the equation and the procedure are slightly different. You prepare the circuit by outputting a logic one to the I/O pin. This allows the capacitor to discharge through R2. Here again, a non-zero R2 value is needed to limit the current flow in the I/O pin to a safe level. A typical value would be 330Ω. In this case, we still have a voltage divider but the ratio is reversed. The highest voltage attainable at the resistor-capacitor junction is 5V * R1 / (R1 + R2), about 4.84V if R1 is 10KΩ and R2 is 330Ω.

After holding the pin at logic one for a suitable amount of time (> 4 * R * C), you can then call `RCTime()`. Since the pin has been held at logic one, the second parameter to `RCTime()` should be one.

```
Const pin as Byte = 20

Call PutPin(pin, 1)
Call Delay(1.4e-4)
i = RCTime(pin, 1)
```

The `RCTime()` routine will re-configure the pin to be an input (tri-state mode) and the capacitor will begin charging toward zero volts along an exponential curve as shown in the graph of Figure 2. The `RCTime()` routine will monitor the pin and as soon as it changes from a logic one to logic zero the elapsed time will be computed and returned.

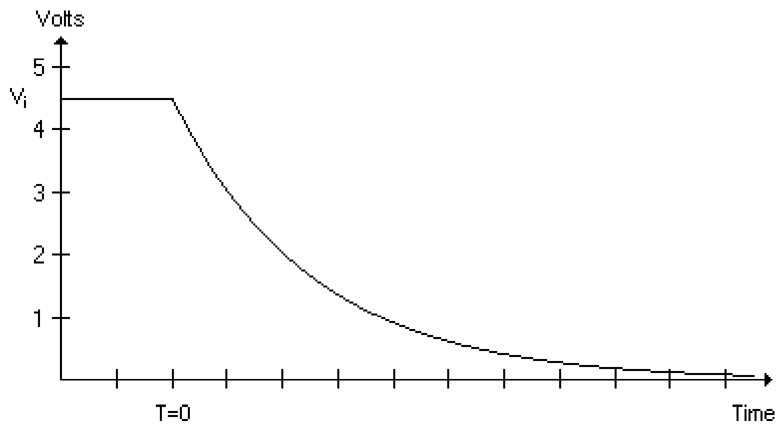

Figure 2: Typical R-C Charge Curve for Configuration B

The equation for this curve, beginning at time t=0 is $V_t = V_i * e^{-t/R*C}$, where V_t is the voltage at time t, V_i is the initial voltage from which the capacitor begins charging and t is the time in seconds. This is really the same equation as for Configuration A; it's just that V_f is zero. As before, the R in this equation is the value of R1 since the capacitor charges through that resistor. The value of R2 does not affect the process other than the effect that it has on the initial voltage.

As in the previous configuration, the remaining variable is the threshold voltage at which the CPU recognizes the input as logic zero. We measured switching threshold (for logic 1 to logic 0) on one device as 1.4V compared to 1.8 volts in the opposite direction. This reveals why Configuration B is favored over Configuration A. The capacitor charges from near 5 volts down to 1.4 volts in Configuration B compared to charging from near zero to 1.8 volts in Configuration A. This larger voltage swing allows the voltage level to move to a flatter portion of the curve before reaching the switching threshold resulting in better accuracy.

Author

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