# The use of MPU integrated comparator for rapid response to power fluctuations on micro servos.

The power fluctuations is due to load changes on servos, which include a DC motor.

Keywords: RC servo control, high-side current sensing, NXP LPC824, ARM Cortex-M0+, MPU integrated analog circuits, comparator, NCV47710, transient duration.

For my project based on the MCU, LPC824 with ARM Cortex-M core, I have built a small prototype with driver electronics for micro serves. The selected servo-type have no feed-back signals and is controlled solely via a Pulse Width signal. The Pulse Width signal is generated through NXP's strong State Configurable Timer (SCT) which is included in the LPC824. Specific for this setup the SCT unit also has other functions to fulfill.

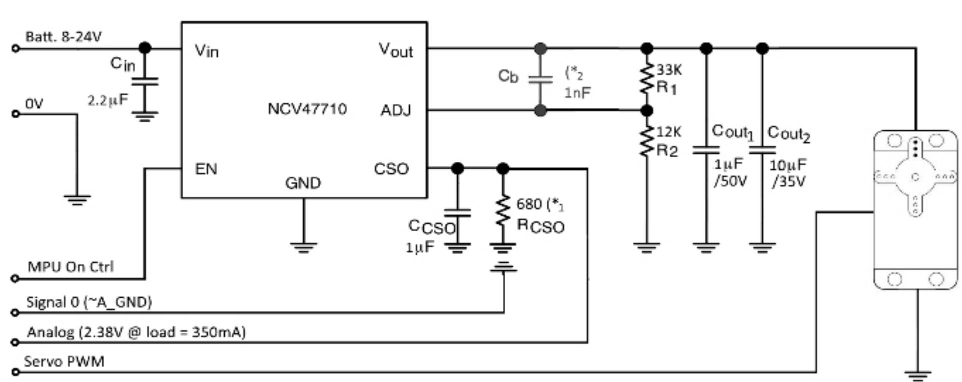
The objective of this little study is to be able to stop a servo movements when meeting not foreseen obstacles or at "end-stop" arrival. It is also of great interest for my project to cover additional functionalities of the LPC824 MCU. I have chosen to use an MPU integrated comparator, to interrupt(Signal) our RTOS Kernel when currents are crossing threshold settings. The LPC824 MCU also include ADC converter which actually offers high and low threshold interrupt(Event) generator, however, the ADC have other tasks in this setup.

The requirements are very small physical dimensions, low production cost and a total power consumption that can be controlled by the MPU. The technique of measuring the current running in an electric motor to determine the conditions present, is well known and is usually used on larger DC motors.

As part of the driver electronics for micro serve I wanted high-side current sensing with an output-area less than 3 volt and OFF/sleep function, also active in the area lower than 3 volt. The requirement on the analog and control voltages down at 3 volts is to realize a simple connection to the LPC824 MCU.

The main component selected to drive the micro servo is the NCV47710[1], it's meant to be use as a 5 to 20 volts Adjustable LDO with Adjustable Current Limit and Enable(ON/OFF) function. The device satisfies many of my demands including low cost and physical size (PCB footprint and mount method). However, the device is a little poor in power performance and efficiency. While disabled(OFF) the device typically draw 85 nA, according to data sheet, which is satisfying.

Figure no. 1
NCV47710 in test configuration.




(*1 RCSO is low according to data sheet, but is the max. when NCV47710-CSO is connected directly to MCU and to the load. (*2 Cb avoid it by using a good low ESR ceramic capacitor as Cout1.

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1- The chosen driver/voltage reg.: http://www.onsemi.com/pub_link/Collateral/NCV47710-D.PDF

The NCV47710 is intended to regulate down to a minimum of 5 volt, which is a bit high for small micro servos. The compromise has landed on 4.7 volt, which have been tested with multiple devices. The RCSO resistance in our tests setup is a little big, when we wishes a direct connection to MCU comparator input-pin and we are basically not interested in the current limit function on the chip. The RCSO resistance value is also a result of compromise, there is little current limitation and there is usable voltage signal level for the comparator.

*Concern: When I here write "direct connection to input-pin" it is in series with a 100 Ohm resistor, after an ESD protection diode on the board of the LPC824. The current flow out of CSO on the NCV47710 is 1/100th of the main-power load, that goes out of Vout to the servo motor. As inrush current on induction loads (DC motors) is known to be high, I of course risk too high voltage spikes over RCSO. The analog pins on LPC824 micro-controller is very sensitive to voltages above AVDD and VDD, it is harmful.*

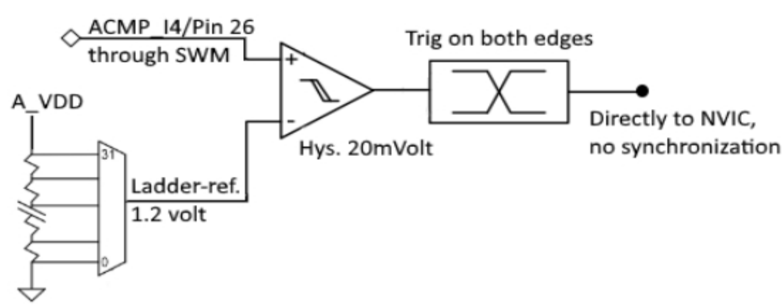
Figure no. 2, shows the final comparator configuration with both positive and negative edge interrupt trigger.

Figure no. 2

Final configuration of LPC824 comparator.

```
#define ACMP_POS_INPUT    ACMP_POSIN_ACMP_I4 /* On positive comparator input */
#define ACMP_NEG_INPUT    ACMP_POSIN_VLO     /* On the negative, LADDER out */
#define ACMP_HYSTERESIS   ACMP_HYS_20MV      /* 20mVolt Comparator hysteresis */
#define ACMP_LADDER_REF   3.3                /* Here equal to VDD (in Volt) */
#define ACMP_POS_TRIG     1.2                /* Positive trigger level in Volt */
#define ACMP_LADDER_STEP  (uint32_t)((float)ACMP_POS_TRIG / ((float)ACMP_LADDER_REF /31))

#if defined (MICK_OS)
// The time of the event in CLOCKS_PER_SEC (small platform 1mSec)
volatile clock_t comparatorEventTime;
#endif
```

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The definitions ACMP_LADDER_REF and ACMP_POS_TRIG from figure no. 2 is not a result of measurements and is not needed to be entirely accurate. The inaccuracy alone on the math for ACMP_LADDER_STEP is more than 2% due to the ladder's dividing resolution, down at 1/31.

In figure no. 2 it's also shown that there is time-stamps involved, it is the Interrupt Service Routine's (IRS) obligation to initializes that the clock is recorded and to tell the system (RTOS) about the event. The time can be used to clarify what type of event that cause the current change.

The largest and fastest growing current peaks, come when we start a stagnant DC motor (inside the servo), that's what we call inrush current. In the case of inrush current, we can from the timestamps estimate that the motor has just began it's movement and when we microseconds later received an Event(interrupt) more for declining power consumption we can assume, yes, it was just inrush current.

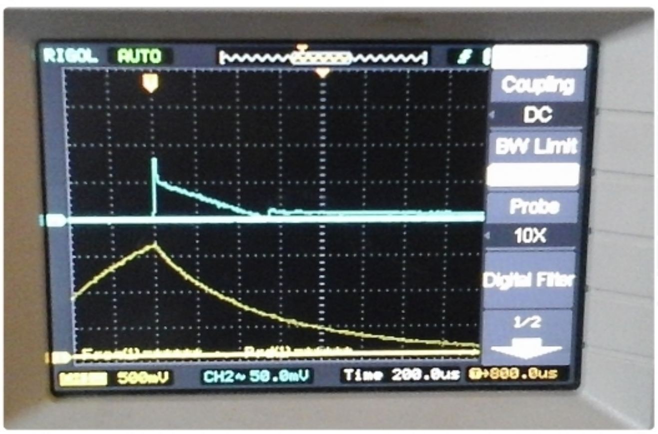
The running real-time kernel is named Minimum Inter-process Communication Kernel (MICK), also by me, Kent del Pino. The MICK which aims at ARM Cortex-M0+ cores, is not yet published.

To confirm the selected components (shown in Figure 1) suitability for use as a micro servo driver, measurements on electrical transients peak level and duration was done. Of particular interest was the signal fluctuations when servo movement meets an end-stop. An end-stop is here is a physically intentionally placed limits. The idea here is to completely avoid the use of mechanical switches, also for end-stop detection. The meeting with obstacles under servo movement were stimulated by loading the servo by hand.

Current pulse measurements was made as voltage swing over the RCSO resistance (shown in Figure 1), this is the voltage swing, that is feed'ed to the MCU comparator and internally resulted in interrupts.

Figure no. 3
Verification of levels and duration.

Large and fast growing current peaks, when stationary servo starts (inrush current), however the resulting voltage peaks are limited due to proper combination of Cout.




Blue line; AC measurement on the regulator 4.7 volt output (inrush).

Yellow line; DC measurement over RCSO resistance with large signal fluctuation, more than 1.5 volts.

Duration in the range of 1 mSec, satisfying.

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Figure no. 3, presents a "neat" transient progress as a result of the beginning of motion on the servo. During the prototype test I observed find signal levels with useful signal duration. As stated "neat", some measurements were less lovely to look at, and earlier I raised a concern about the very large signals we direct feeds to the comparator input.

The conclusion is that we in a systems view have good resolution on both the signal variation due to different load situations and time. The inclusion of system-time helps us to clarify the nature of the Event so that we through our ARM Cortex-M0+ based unit can react, effectively. The solution gives us complete control over the energy consumption, we can turn off the servo-system with the Enable-pin. The solution also ensure compliance with requirements for small PCB footprint and low cost.

As for my concern about too high voltage spikes on the LPC824's analog comparator pin, the answer is, in this particular case, to lower the value of the RCSO resistance, we have lot of signal. In our case the RCSO resistance is not used as intended, according to data sheet.
Another little experiment I want to make, is adding a power transistor as a booster to the NCV47710 voltage regulator. The power indicator is then intended to be the current that goes in the transistor base and the load-current will be approximately the transistor's hFE times greater, it's for monitoring of small irrigation pumps.