Zero current, when not in use...

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1. Introduction

Have you not rejected battery operated projects with the BASIC-Tiger®, simply because it uses too much current? The situation gets far more annoying when the BASIC-Tiger® is only supposed to operate from time to time in the planned application – its current consumption is still comparatively high, even during breaks. Think, for example, of a control with two little motors which pans and turns a video camera sensitively. Once you have focussed your object all motors stand still. The BASIC-Tiger®, however, still requires about 50 mA, which, in the long run, is not acceptable for batteries. There are similar problems with e.g. alarm systems, measurement systems or access controls. The computer should be activated by pressing any button on the operation panel, then work its way through its program, possibly write data into the Flash and then switch itself off entirely so that the battery is no longer in use. Only on the next button pressed or impulse of an alarm system power is required again. Would that be interesting for you? If so, have a look at the following – the solutions presented in this application note could also be helpful for other projects!

The system solution presented here is only one example how a BASIC-Tiger® circuit uses valuable rechargeable battery power only in an active state. It builds up on the experiences gained with motor controls from the previous application note. Again we will control two small motors with a Polulu motor controller. The system should work with a battery consisting of 3 cells with 1.2 V each, i.e. it operates nominally with 3.6 V. A motor will be started up sensitively at the push of a button and then gradually accelerated until the maximum speed is reached. If the button is released the motor stops. If the button is pressed again the motor will slowly begin to rotate again – the same with a second button in reverse. Such a drive can, for example, be used for the above mentioned camera positioning or for the focussing of a telescope. The initially slow and then faster movement allows an elegant fine adjustment, as well as the swift run over wide areas. Considering the experiences from the last report you may think this is not a problem…

2. The concept

As always we will now list all the things that our circuit should accomplish.

- The BASIC-Tiger® requires a stabilised voltage Vcc (+5V), which is not guaranteed during direct battery operation. We will therefore use an efficient step-up-converter, which will generate a constant operation voltage of 5 V from the smaller and less stabilised battery voltage. The motor itself should however use the lower battery voltage and therefore not be a load for the regulator. We choose a battery with 3 NiCD or NiMH cells, i.e. a nominal voltage of 3.6 V.

- The BASIC-Tiger® and the whole power supply should be switched off completely during breaks. However there must be enough time beforehand to, for example, write data into the Flash. In doing so positioning drives can be realised, which will "remember" their current position for as long as you like. If now a button is pressed again, the data is read from the Flash, the Flash is erased and the read values are further processed. Once the button is released the BASIC-Tiger® moves the updated data back into the Flash and then returns to its "sleep mode".

- There are two motors which should be controlled by the Pololu motor controller. The motor voltage should be gained directly from the battery, the logic supply voltage from the disconnectable and regulated 5 V. As the required functionality is rather little, an ECONO-Tiger® shall be sufficient.

3. Details

Figure 1 shows the complete circuit, explanations will follow at the end.

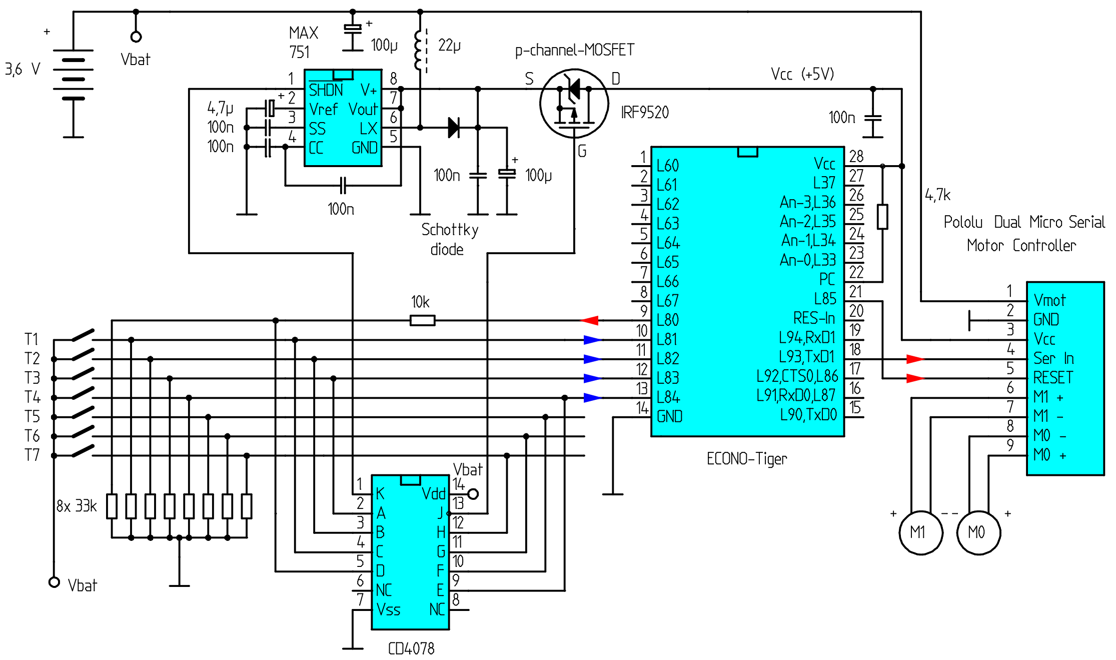

Fig. 1 the motor control circuit with Stand-By-behaviour

The heart of the BASIC-Tiger's® voltage supply from a battery is the step-up-regulator MAX751 with its standard components, which we already know from previous experiments.

Data sheet MAX751: http://pdfserv.maxim-ic.com/arpdf/MAX751.pdf

Pin 1 of this IC is called "shut down" or abbreviated SHDN. The regulator can be switched off with this and now uses only a few µA itself. There is, however, a handicap – just as shown in the circuit (figure1), the battery voltage reaches the connected pins 7/8 via the very low impedance coil S1 and the Schottky diode D1. During normal operation of the MAX751 the regulated 5 V – voltage is taken there. Despite it being switched off via SHDN, the hard battery voltage of 3.6 V (minus voltage drop) would still be applied via coil and diode at this point and therefore also at the Vcc pin of the BASIC-Tiger. This means that although it does no longer function, it still consumes current. Hence the "shut down" is actually misleading. Therefore a p-channel-MOSFET IRF9520 is inserted into the output line that is also locked when the MAX751 is switched off, so that there is definitely no current flow anymore.

Data sheet IRF9520: http://www.irf.com/product-info/datasheets/data/irf9520.pdf

The next question for the posed task was: How can pressing one single key activate the entire power supply, set off a program activity and then systematically shut down the system when the key is released? The solution is a simple CMOS-gate, the CD4078.

Data sheet CD4078: http://www-s.ti.com/sc/ds/cd4078b.pdf

This IC contains an 8-fold OR/NOR-gate and is usable between 3 V and 18 V thanks to its technology – and all this with very low static quiescent current. Herewith it functions with nominal 3.6 V and even when the battery is almost empty with 3 V (3 connected rechargeable batteries of this design must not be run down to 0 V, but to a minimum of 3 V!) The CD4078 gets its operating voltage directly from the battery and all inputs are connected to ground through an 8-fold resistor network of 22 - 33 kΩ. At a maximum 7 of the 8 available inputs of the CD4078 there are keys, which can connect its inputs with 3.6 V. If all contacts are open, a Low-level (ca. 0 V) is created in quiescent condition (via the resistors to ground) also at the OR-output, which locks the MAX751 via its SHDN-input. If a key is pressed (or several of them!) the relevant input goes High and the OR-output switches to High as well (+3.6 V), which securely starts up the MAX751. The NOR-output, which is equally available at the CD4078, does exactly the opposite and goes Low in this case, thus opening the p-channel MOSFET IRF9520, i.e. it becomes extremely low impedance between source and drain. Seen in practice it passes on the stabilised 5 V virtually pure. The keys not only operate the CD4078, but are also connected to the inputs of the BASIC-Tiger. Concurrent to bringing up the Vcc its program starts, which immediately after initialisation asks for the state of these key-inputs and then initiates appropriate activities. So we now have a power supply, which additionally switches on the operating voltage when any key is pressed.

Here is another trick! The author had initially used an AND/NAND-module CD4068 instead of the OR/NOR-module CD4078. This works as well, obviously with appropriate reverse input and output signals. However, the rest levels at the inputs of the switched off BASIC-Tiger would then be at 3.6 V. As a result of the input protective circuit of these inputs, which have, amongst other, a diode to the Vcc of the BASIC-Tiger, this internal Vcc is pulled up to ca. 2 V through the eight 33 kΩ-resistors and thus causes a current flow of slightly more than 1 mA within the BASIC-Tiger. This was unacceptable and therefore rejected. The OR/NOR-module puts Low-levels to the BASIC-Tiger inputs in quiescent condition and therefore this parasitic current consumption is also eliminated. Please remember for further experiments – only use Low-levels in a switched off and battery operated BASIC-Tiger® and for an unavoidable High-level take care that it is applied with high impedance! In the worst case a BASIC-Tiger® could really be supplied with operating voltage through a low impedance High-level at an input and begin to run!

But what happens if the key is released? Is the operating voltage abruptly switched off again? We now come to the next clever detail. Perhaps you have been wondering why an 8-fold gate only uses a maximum of 7 keys. The answer is simple: We are using one gate input to lock the module. The BASIC-Tiger® is programmed in such a way, that a logic pin (here L80) almost immediately after the start of the program puts out a static High-signal. This signal is then put on the still free 8th input of the CD4078 and thus a permanently pressed key is simulated. As long as this control pin of the BASIC-Tiger® remains High, the operating voltage is maintained. The BASIC-Tiger® can now operate as long as it wants. Only when all is accomplished – e.g. data is saved in Flash – the program sets the control pin to Low, the OR/NOR falls into the other state and switches off the BASIC-Tigers® operating voltage. In this condition the control pin does not deliver a Low-level anymore, but is at high impedance, which does not matter to the CD4078 – the relevant input is now again supplied with GND (Low) via the resistor network. The 10 kΩ resistor in the locking section is used to limit the current to the gate input. Considering that the BASIC-Tiger® outputs at least 4.5 V in active state, but the gate operates with a minimum of 3 V, it is possible that without protective resistor inadmissible current flows into the gate input.

The rest is routine. You already know the Pololu Dual Micro Serial Controller, which is used for the motor drive: http://www.pololu.com/products/pololu/0401/

Opposed to the “normal” Pololu Dual Serial Controller, which we used in the previous note, there are hardly any differences regarding electrics and programming. We have chosen it because it can operate at motor voltages of down to 1.8 V, while the Pololu Dual Serial Controller can only operate up to nominal 4.5 V. With this skill the “Micro” fits better to our battery voltage of 3.6 V.

The chronological sequences of events in our circuit are shown in figures 2 and 3.

Following the pressing of a key (Level at gate input goes to High) the regulator begins to operate. As the 100µF capacitor before the MOSFET was already at ca. 3 V, the Vcc reaches this value almost immediately after opening the MOSFET. It now becomes more difficult; the switch regulator must charge this capacitor and supply the entire circuit. For this reason the full stabilisation to 5 V takes somewhat longer. This is not a problem for BASIC- or TINY-Tigers®, because they have an internal Power-On-Reset circuit. For the ECONO-Tiger®, which does not have this for cost and space reasons, this may lead to starting problems.

Although the author did not experience any problems with the Power-On-Reset behaviour during his own experiments, it is more secure to use such a circuit.

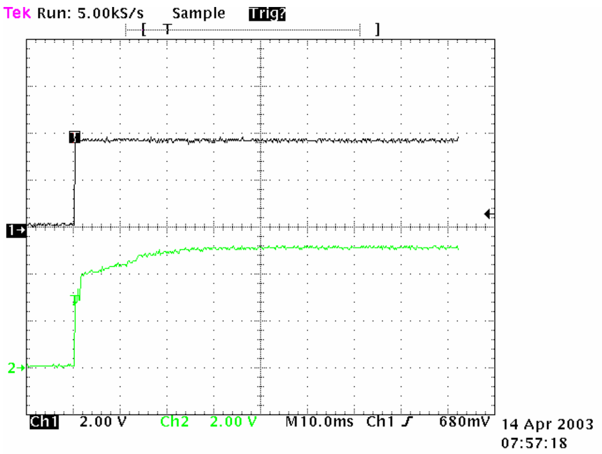

Fig. 2 Switching on (black: level on a key, green: Vcc)

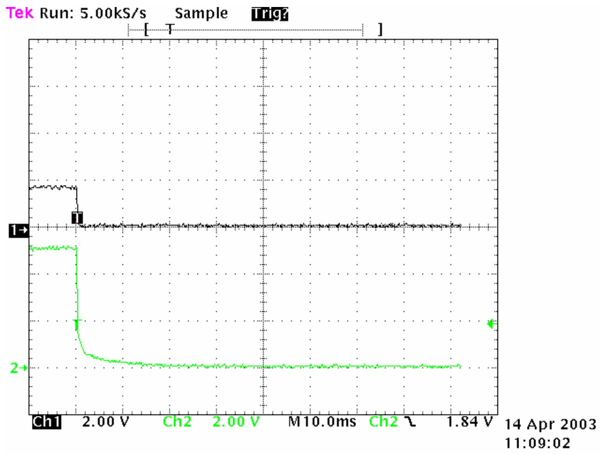

Fig. 3 Switching off (black: again level on the now released key, green: Vcc)

Why is the level at an open key in figure 3 with the resistors against GND not 0 V? Because the pins of the ECONO-Tiger® that are set as inputs have internal Pull-up-resistors of 50 to 100 kΩ, which then generate just under 2 V as voltage divider in combination with these 33 kΩ resistors. Please therefore be aware that your resistor network will always work together with these internal Pull-up-resistors in such a way, that there is still a secure Low-level. If you decrease the values of the resistor network, this has no consequence for the quiescent current consumption of your circuit.

4. Program example

The functions of the program POWER01.TIG are easily explained. The four keys almost immediately switch on the power supply and control two motors in such a way that they start running slowly and accelerate up to their maximum number of revolutions. This acceleration is dynamically, meaning that it is slower in the lower rpm range as it is in the upper (intervals become shorter between higher rpm values). If the key is released the motor stops and the power supply of the entire system is switched off. A subroutine, which currently only initiates a reset of the motor controller, could be used in other projects for e.g. saving data into Flash.

5. Outlook

As mentioned at the beginning of the application note, the possibilities of the presented flexible and sparing voltage supply from a battery are not restricted to the control of motors. Everywhere, where the BASIC-Tiger® must react to short-term outer incidents, this circuit is useful. Interesting examples would be alarm systems in cars or in places where there is no electric network, perhaps in a summer house. Additional components such as mobile phones or similar can be supplied as well without problem (see our application note "BASIC-Tiger® sends SMS"). Taken the other way around such a telephone also could supply the BASIC-Tiger® with voltage, if the latter should only operate occasionally. Think of solar operated measuring stations, which are seldom active, whose buffer-accumulators must take over the power supply at night. Instead of the keys used in the example all other contact variations can naturally be used (door contacts, timers etc.). In the same way normal TTL- or CMOS-levels can be used as trigger-signal for activation of the switchable power supply, after appropriate adaptation even signals of a serial RS232 connection. You are also free to choose the switching components. You do not have to use 8 or rather 7 inputs via the CD4078 to the BASIC-Tiger®. If fewer keys or inputs are needed or the pins from the BASIC-Tiger® are needed elsewhere, another CMOS circuit can take over the same task. It is merely important that this IC comes from the same family and works on 3 V operating voltage, which the battery supplies.