tinyMoBot: A Platform for Mobile Sensor Networks

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***Abstract*—In many application scenarios of wireless sensor networks parts or the whole network consist of mobile sensor nodes. Currently, no common platform is available. This paper describes a project that has developed a mobile sensor node, based on standard components: a Crossbow IRIS mote and LEGO MINDSTORMS NXT components, i.e., motors and sensors.**

I. Introduction

Wireless sensor networks consisting of mobile nodes are currently a growing research area [1], [2], [3]. In these scenarios often only few nodes of the network are mobile. Therefore, it is important that the mobile nodes are able to communicate with static nodes. Since a general mobile sensor network platform is not available, often self-developed mobile sensor nodes are used [4]. A standard sensor node is attached via an adapter hardware to an existing robot platform. In most cases the robot platform or the adapter hardware has an additional micro processor, which increases the complexity of software development. In this paper the mobile sensor network platform tinyMoBot is presented. A circuit board without a micro controller is used as an adapter. Enabling a Crossbow IRIS mote to directly operate with LEGO MINDSTORMS NXT motors and sensors. This decreases the complexity of the resulting mobile platform since software needs to be developed for one target platform only. Other benefits of this solution are the low hardware complexity and the relatively low cost of the adapter. The rich arsenal of available LEGO components make this an attractive platform.

II. The tinyMoBot Adapter

Figure 1 provides an overview of the main components of the tinyMoBot adapter and how they are connected. The ATMega1281 on the IRIS mote is connected via the 51-pin socket with the adapter. Since the adapter is mounted on a robot, removing the IRIS mote for reprogramming or debugging is not feasible. Therefore, the adapter provides appropriate interfaces so that there is no need to disconnect the IRIS mote. An ISP header is available for programming the IRIS mote while it is connected. The adapter also provides an USB connector to enable serial communication with the IRIS mote, which is convenient for debugging purposes.

To be flexible in its use, the adapter provides almost the same connectivity capabilities as the LEGO MINDSTORMS NXT brick. The adapter consists of six sockets for connecting up to three motors and three sensors. It also supports every type of LEGO sensors available. Currently, there are three types of sensors: active sensors, passive sensors, and digital sensors. Active and passive sensors are sensors that provide an analog voltage, representing their measurements. Digital sensors a controlled via the I^2C protocol. Additional circuit is needed in order to support the different sensor types. As seen in Fig. 1 the different components of the robot and the IRIS mote require different supply voltages. Since it is not feasible to carry multiple sets of batteries, voltage regulators are used to create the different voltages from the standard LEGO voltage of 9 V.

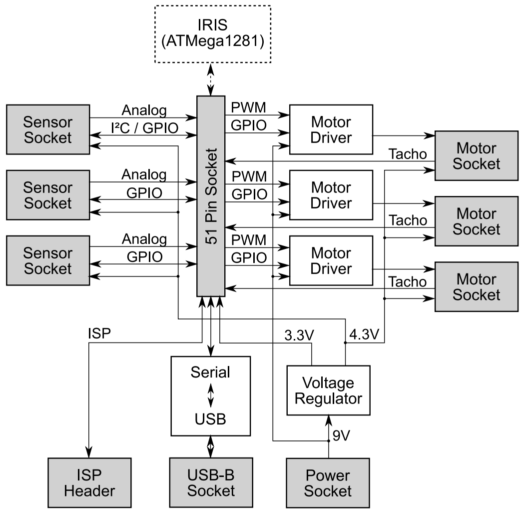

Fig. 1. Components of the tinyMoBot Adapter

III. Realization of the Adapter

In this section the realization of the tinyMoBot adapter is briefly described. The board was developed during a project work at Hamburg University of Technology [4]. EAGLE from Cadsoft was used for developing the circuit diagram. TinyOS components are available to handle the different hardware components. Figure 2 shows the layout of the finished adapter.

Because of limitations of the ATMega1281 and to simplify the design of the adapter its supports only digital sensors on the first sensor socket. Active and passive sensors are supported on all three ports. Analog sensors provide an analog output voltage between 0 V and 5 V. By using a voltage divider this

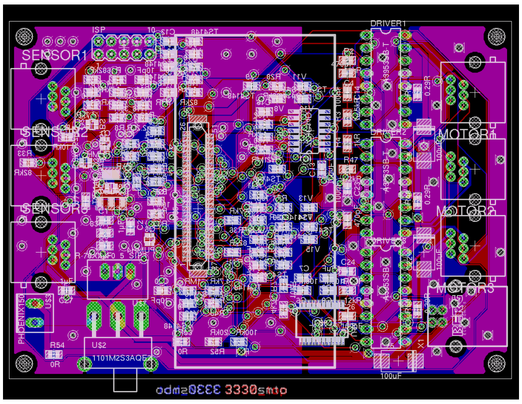

Fig. 2. Final Layout of the Adapter

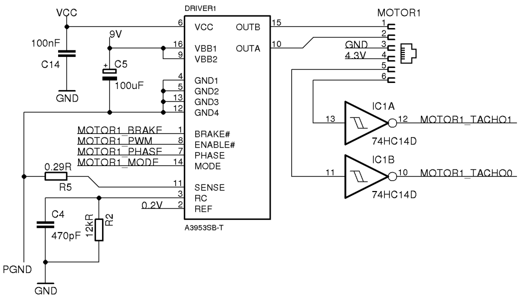

Fig. 3. Schematic of a Motor Port

output voltage is limited to a maximum of 3.3 V, in order to use the sensors directly with the ADC of the IRIS mote.

LEGO MINDSTORMS NXT motors are DC motors and the speed is controlled utilizing PWM. The adapter consists of motor driver ICs to enable the ATMega1281 to control the motors directly. The LEGO MINDSTORMS NXT motors also provide a tacho signal that delivers an accurate measurement of the current speed. These signals are connected to interrupt lines of the ATMega1281.

Figure 3 shows the schematic of the first motor port, which is same for all three ports. DRIVER1 is the motor driver IC used to drive the motors. The driver IC also limits the maximum current of the motors for preventing damages. The IC does this by temporarily switching off the current. The length of this period is determined by the time constant of the RC circuit consisting of C4 and R2. The IC measures the actual current, by using the voltage drop over R5. The lines MOTOR1_BRAKE, MOTOR1_PWM, etc. are directly connected to the ATMega1281 and are used to control the motor. As the tacho signals of the motor use 5 V, they cannot directly be connected to the ATMega1281, which uses 3.3 V. Inverting Schmitt triggers IC1A and IC1B are utilized therefore.

A switching voltage regulator is used to provide 5 V from the supply voltage of 9 V, then a linear LDO voltage regulator is used to provide 3.3 V. The 4.3 V are created by using the 5 V and the voltage drop of a diode. The adapter works in a voltage range between 6 V and 9 V. As the motors are driven directly by the supply voltage, the speed of the motors will be slowed down when the voltage drops.

TABLE I
ENERGY CONSUMPTION WITH A SUPPLY VOLTAGE OF 7.5 V

Action	**Measurement**
no movement, sleep mode (calculated)	25 mA
no movement, radio enabled	30 mA
straight driving	270 mA
turn driving	300 mA
maximum speed	$0.28\ \frac{m}{s}$

IV. EVALUATION

Table I shows the energy consumption of the completely assembled robot. Under the assumption of batteries with 2000 mAh the robot should be able to drive for about 6.6 h. During that time the robot would travel a distance of 6.72 km.

The adapter draws a relatively high current of 25 mA even in sleep mode. This relative high consumption is due to the following effects. A fixed consumption of 7 mA for each motor (in this case 14 mA) that is plugged must be assessed. The reason for this may be some internal details of the LEGO motors. The motor driver ICs are another source for this high consumption. Each of the ICs have a leakage current of 1 mA. Unfortunately, the voltage regulator that provides the 5 V has a very low efficiency at low current output, so that is takes a few mA even if no current is needed at the output. Additionally, the voltage dividers used on the board have a current consumption of around 1 mA. In a next version of the board these leakages must be considered in more detail.

The adapter board was successfully used in a student project to develop a remote control for the tinyMoBot. The software of the remote control is executed on a separate IRIS mote equipped with an acceleration sensor. Based on gesture recognition the remote control creates movement commands. These are transmitted wirelessly to the tinyMoBot.

V. CONCLUSION

The tinyMoBot is currently used in programming courses at Hamburg University of Technology. In the near future a new hardware revision should resolve the existing problems, especially the high current consumption in sleep mode.

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