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A Project Course in Embedded Design

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Abstract

At Blekinge Institute of Technology, Sweden, a project course in embedded design is given for second year students of the Bachelor programs in Electrical/Computer Engineering. The assignment for the students is to specify and design an prototype control system for a mobile robot, currently a small car. The control system is based on a DSP (Digital Signal Processor). This course gives the students an opportunity to use and combine, in a practical way, the theoretical knowledge from earlier courses in electronics, microprocessors, automatic control, electrical measurements and programming. Working in a team-based project organization is also an important part of the course, as well as oral and written presentation techniques. The project is accomplished in teams of four students during a period of seven weeks. On the last day of the project there is a competition between the student teams in which the robot will race on a track with obstacles. The length of the competition track is 7 meters and the track has 5 to 7 randomly placed obstacles. The students have been very satisfied with this type of course. The design of the embedded system gives them a basic and useful understanding of sensors, electronics and a DSP. The course is given for 50 students, 3 times every year.

Introduction

At Blekinge Institute of Technology, Sweden, a project course is given for second year students of the Bachelor programs in Electrical/Computer Engineering. The assignment for the students in the course is to specify, design and build a prototype control system for a mobile robot, currently a small car. The control system is based on the digital signal processor evaluation module from Texas Instruments TMS320F240 EWM.

Pedagogical purpose

This course gives the students an opportunity to use and combine, in a practical way, the theoretical knowledge from earlier technical courses. Working in a team-based project organization is also an important part of the course, as well as oral and written presentation techniques. The students have earlier passed courses in mathematics (20 study points), programming (10 points), digital design and microprocessor (10 points), electronics and electrical measurements (15 points) and automatic control (5 points). One study point corresponds to one week of full study. This course will be given to the students after 1.5 years of university studies.

Course syllabus

The project is accomplished in teams of four students during a period of seven weeks. Each team design their own prototype control system for the mobile robot. On the last day of the project, there is a competition between the student teams in which the robot will race on a track with obstacles. In the first part of the course there are lectures regarding the DSP, DSP card, DSP software, sensors technology[1] and the system structure of the mobile robot. The main part of the tuition in the course will be project supervision. During the course the teams also performs three oral presentations. The examination is individual and the student should be able to describe the work of the whole project. The teams have access to a laboratory every day (and night) for the project work. Two teams share a workplace, which is equipped with PC (MS Windows98), oscilloscope, power supply and DSP emulator. Each team receives a mobile robot, rechargeable batteries, battery charger, tools, manuals and a locker for keeping the equipment. The cost of components per team is limited to $50. Each team makes purchases of their own to the electronic component distributor. During the first two weeks, the students begin by writing a specification requirements, which describes what to do in the project. They also draw up a project plan where all resources are allotted. This plan describes the project organization, distribution of work, estimation of costs, phase and time schedule and document organization. The specification requirements and the project plan are presented at an oral presentation. Then the design documents of hardware and software are produced. When the design is approved, the practical implementation can start. At the competition day each team makes a final presentation of the project and delivers the final project report. To pass the course it is needed to present a functional control system, make a final presentation and deliver the final report.

Description of competition track

The length of the competition track is 7 meters. The track has sideboards and 5 to 7 obstacles are randomly placed. The length of the obstacles is one meter. The robot is started with a start button, and is expected to navigate from the start area to the finish area with help of the camera system and the light source. With the ultrasound system, it is possible to avoid touching the obstacles or the sideboard. See figure 1.

Description of the mobile robot

The signal processor card is mounted on the power circuit board circuit board. On top of the robot the prototype board is placed. This board is developed by the students and is used for adapting the sensors to the signal processor card. The robot is also equipped with rails used for mounting other sensors and actuators. See figure 2 and 3.

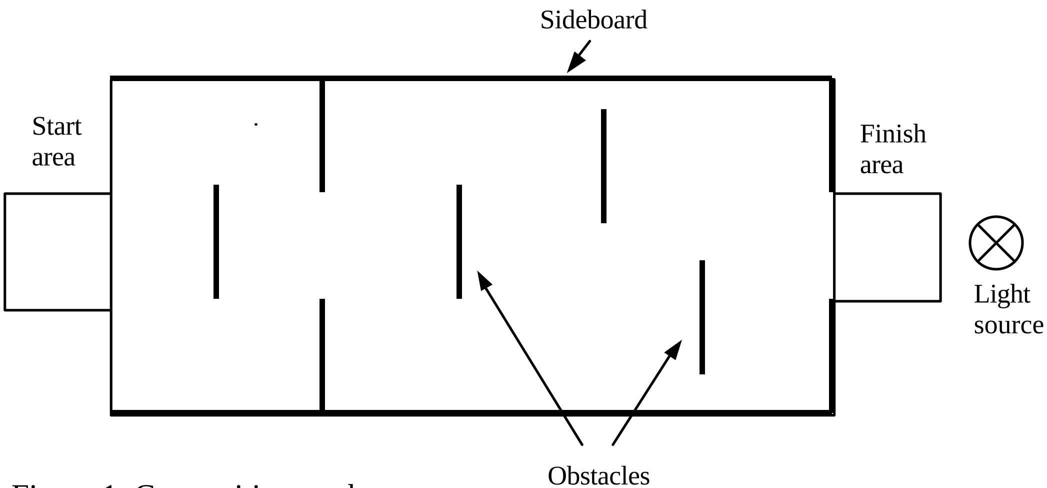

Figure 1: Competition track

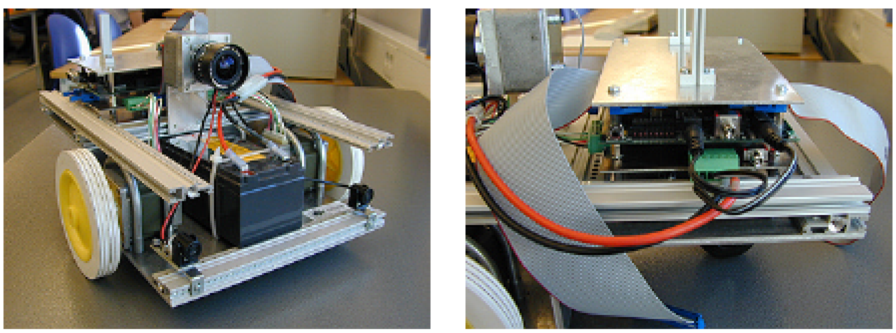

Figure 2,3: The mobile robot

The robot have two wheels at the front and one at the back. The wheels at the front are motorized by two step motors. The wheel at the back is only for support and follows the motion of the robot. Each step of the step motors rotates the wheel 1.8 degrees. The step motor and power-supply board contains electronics for controlling the step motors and power supply for the signal processor. The electronics for the step motor is built up by two dual H-bridges and a PAL-circuit that generates phase switch signals for the motors. The power supply for the signal processor has a switch regulator for the digital supply and a linear regulator for the analog supply. The step motors driving the wheels can be independently rotated clockwise and counter clockwise. The direction and the speed of the wheels can also be independently controlled through inputs. Because of the weight of the robot it cannot go from zero to max speed at once, but needs a certain distance to build up the speed. The highest pulse rate that the robot can start from is 60 Hz and max speed is reached at 200 Hz. The lower the pulse rate is the higher is the power consumption in the motors. When the motors are running very slow or standing still the power consumption becomes so high that the board will shut itself down in order to avoid overheating. Therefore, the motors must be disabled with the enable inputs when the robot is standing still.

A one-dimensional camera is mounted on top of the robot. With help of the camera system, the robot navigates towards a light source at the end of the track. The camera sensor contains a horizontal linear optical array with 128 light sensitive pixels. With completion of appropriate electronics, the camera will give an analog video signal that can be A/D-converted by the DSP.

The robot has an ultrasound sensor system to find obstacles on the track. The ultra sound sensor is mounted at the front of the robot close to the ground and can be used for distance measurement. It is built up by two units, one transmitter and one receiver. The transmitter sends a burst of pulses, typically 5-20 pulses at 40 kHz, and the reflected sound pulses are received, amplified and detected by the DSP. The receiver is equipped with a preamplifier.
The robot is equipped with a 12 Volt lead battery accumulator with a capacity of 3Ah. This capacity is sufficient for running the robot for about two hours.

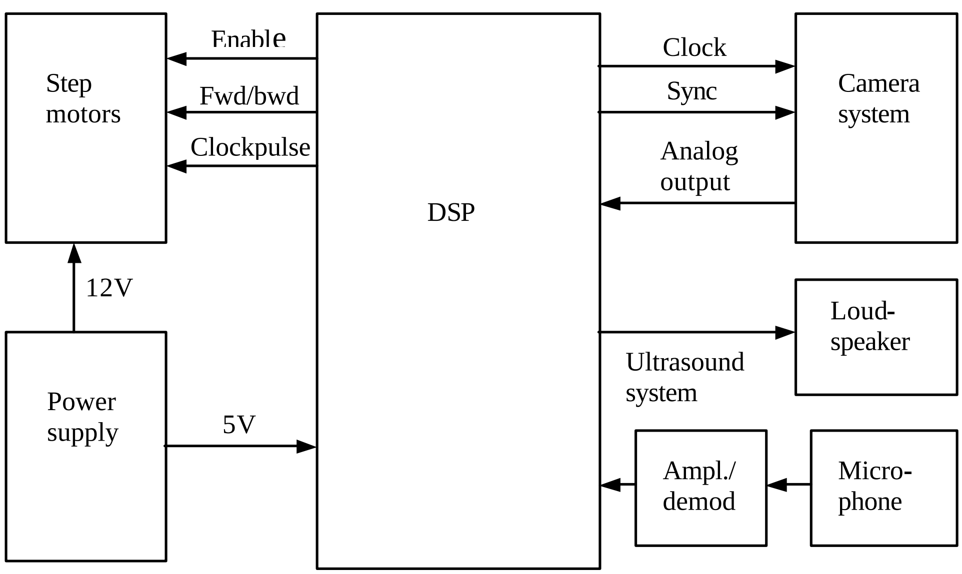

Figure 4: System overview

Description of the DSP

The TMS320C24x evaluation module ('C24x EVM) is a DSP development package to evaluate the 'C24x family of DSP controllers. The evaluation board is connected to the parallel port of the PC through the XDS510PPE emulator. The emulator and evaluation board, together with the 'C24x EVM C source debugger, allow for real-time verification of 'C24x code. The board is built around the TMS320F240 ('F240) DSP controller, which is optimised for digital motor control and power conversion applications. The ’F240 is a fixed-point DSP controller. This device operates at 20 MIPS with an instruction cycle time of 50 ns. It is optimized for digital motor control and power conversion applications. Some features of the ’F240 device are: Event manager with three 16-bit, 6-mode, general-purpose timers, 12 pulse-width modulation (PWM) channels. Four capture units. Dual 10-bit, 8-channel ADCs, Synchronous and asynchronous communications peripherals, A programmable PLL clock module, 544 words of dual access RAM, 16K words of on-chip Flash memory.

The signal processor board has two 34 pin flat cables from the I/O and ANALOG connection to the prototype board. The ADDRESS/DATA and the CONTROL buss is not used. The analog and digital power supplies are separated.

The software for the control systems is written in C. The students use the Texas’C2x/C2xx/C5x C compiler and the TMS320C2xx C Source Debugger.

Conclusions

The students have been very satisfied with this type of course. The construction of the embedded system gives them a basic and useful understanding of sensors, electronics and a digital signal processor. Working in a team-based project organization is also much appreciated.

The course is given for 50 students, 3 times every year.

Bibliography

1. Gustavsson I., “A Remote Laboratory for Electrical Experiments“, submitted to 2002 ASEE Annual Conference.

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The author was born in Sweden 1963. He received a M.S.E.E at University of Linköping 1991. He is currently working as an Assistant Lecturer at the Department of Telecommunications and Signal Processing, www.bth.se/its/, Blekinge Institute of Technology. He has been teaching several courses in microcomputers, automation and automatic control.