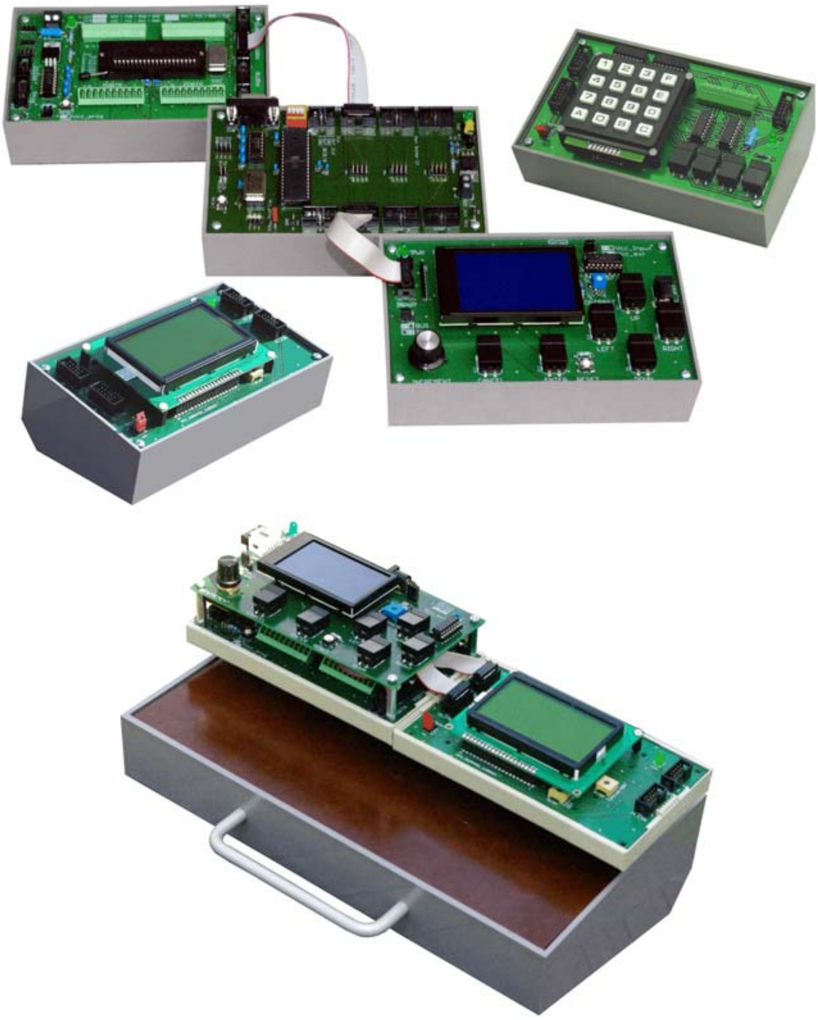
Microcontroller Modules for the Ambitious
– Design Rationale –

June 2014



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The market seems to be saturated with small, inexpensive microcontroller boards, starter kits and the like. Arduino, Digilent, EBlocks, Eloxol, Parallax, and Velleman are just a few examples of trade marks and manufacturer names. Such modules can be used without knowing much about how they work. However, to study embedded systems design, computer engineering, and the basics of programming requires much more than buying ubiquitous boards and downloading software. Ambitious students strive for acquiring hands-on experience and even craftsmanship. They want to dive as deep into the basics as possible. Hence they should build modules themselves. It is not that difficult, because state-of-the-art microcontrollers are essentially self-contained. Principally, they could be operated when held between two fingers or placed on the table while connected to power supply and peripheral devices via hookup wire (provided the wire is thin enough).

When developing own microcontroller modules, it is a matter of course to seek for opportunities to make improvements, to create something showing unique features. Here a family of microcontroller modules will be described whose unique selling points (so to speak) can be summarized as follows: The modules (Fig. 1) should be well-suited for practice, tinkering, and educational purposes. They should be reasonably sturdy. It should be possible to assemble them at the proverbial kitchen table. The modules should be well-suited to build multiprocessor systems and other complex system configurations with (Fig. 2). They should be true OEM building blocks, too; it should be possible to use them in measuring and test equipment, industrial control units, and other appliances (Fig. 3). To achieve these goals, we allow for a moderate increase in cost and dimensions. In other words, we will build somewhat larger and use components, which are somewhat more expensive.

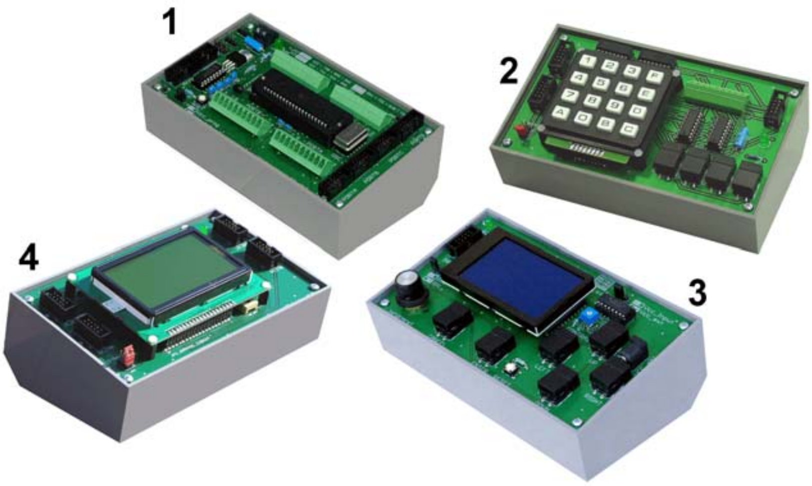

Fig. 1 Microcontroller modules. 1 - general-purpose microcontroller module 12a. 2 - keypad/input module 10b; 3 - human interface module 02/10. 4 - LCD module 10a. Modules with displays, keys and the like can be mounted behind front panels, provided appropriate connectors are inserted.

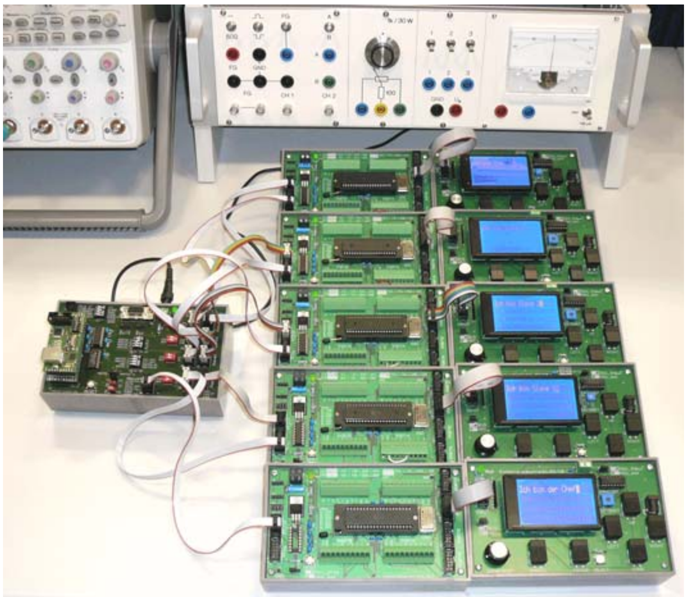

Fig. 2 An experimental multiprocessor configuration. Five microcontroller modules are connected to a passive hub. One microcontroller is the master. Each of the controllers has its own I/O console, a human interface module 02/10.

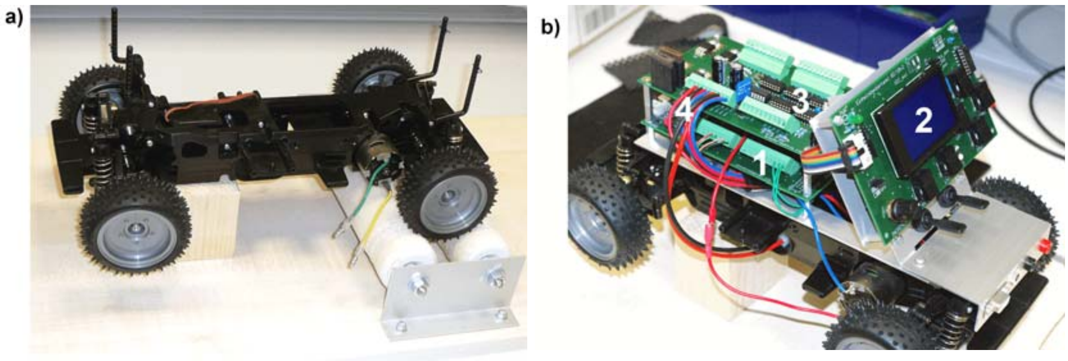

Fig. 3 An educational model vehicle. a) shows the chassis on a makeshift test bench. b) illustrates, how our modules can be used as OEM building blocks. 1 - general purpose microcontroller module 12a. 2 - human interface module 02/10. 3 - an application-specific board. 4 - power wiring.

Form Factors

The modules should be mounted in enclosures or on a chassis. For educational and training purposes, where all components should be accessible easily, a sloped console would be most appropriate. Preliminary design studies gave pc board dimensions of approximately the size of an eurocard (about 100 by 160 mm) or somewhat less. Sifting through catalogues resulted in the selection of a Teko enclosure, which can accommodate a PC board of approx. 92 by 156 mm (approx. 3 5/8" by 6 5/32")[1]. Such boards fit also nicely into enclosures for DIN rail mounting (Fig. 4). For larger boards, it was a natural choice to use enclosures of the same TEKO series.

1: Hammond Mfg. Co. has a series of enclosures with similar dimensions.

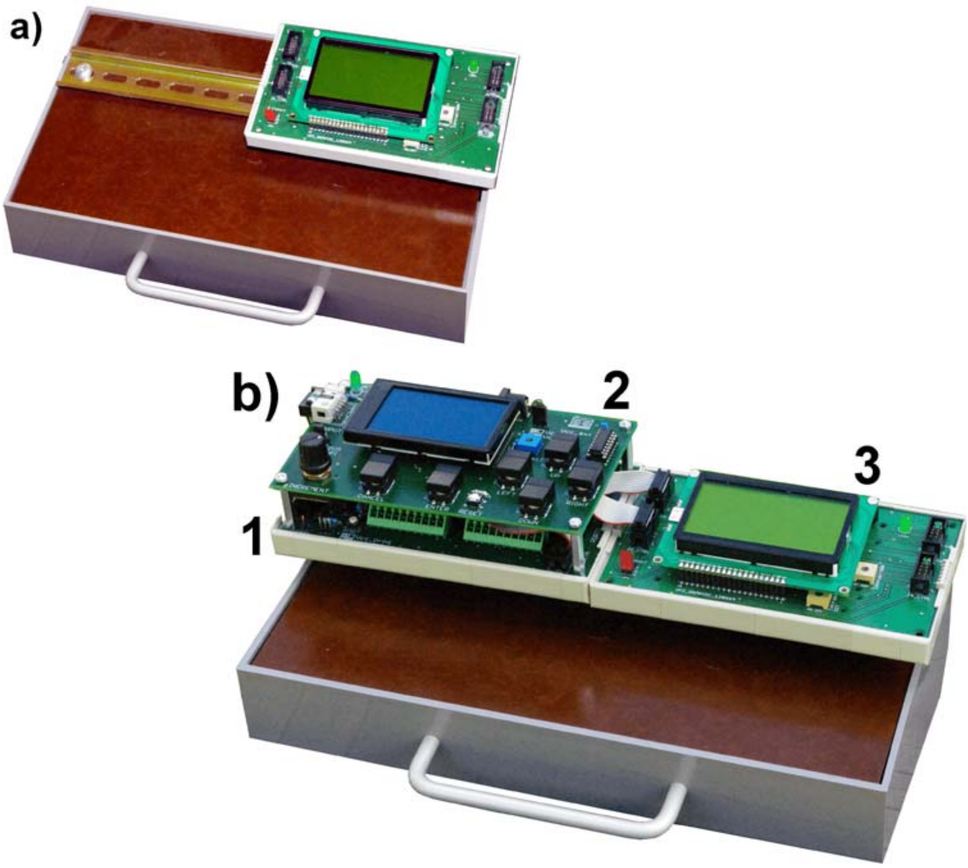

Fig. 4 Modules mounted on a DIN rail. a) shows the mounting principle. b) is an educational system consisting of a microcontroller module (1), a human interface module (2) stacked above, and an LCD module (3), carrying a graphical LCD display.

Connectors

The preferred connectors are pin headers for signal lines and terminal strips for power lines. We use pin headers with two rows and 100 mil pin pitch. Various types can be inserted. Depending on the connectors, other modules can be attached via cables or stacked one upon another. The contact assignment for I/O ports and programmer connectors was patterned after the industry standards set by Atmel AVR starter kits and programmers. Terminal strips have a pin pitch of 150 or 200 mil, respectively.

Wiring

The modules are connected together via ribbon cables. Some modules provide for insertion of terminal strips, so that peripheral circuitry, power stages and the like can be attached simply via hookup wire. Arbitrary connector types can be inserted, provided the pin pitch is 150 mil (3,81 mm). We prefer detachable connectors from Phoenix Contact (Fig. 05; compare also Fig. 3b). They are somewhat more expensive, but leave the field or application wiring intact when the module is to be removed or swapped.

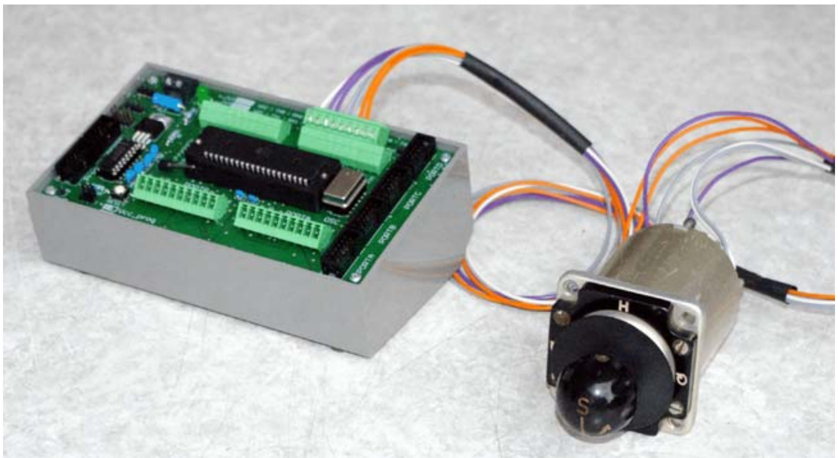

Fig. 5 Microcontroller module wiht a historical joystick.

Power supply
Most of the modules have a nominal supply voltage of 5 V. Lower voltages (like 3,3 v or 1,8 V) are delivered from low dropout regulators (LDOs) on the modules. The supply voltage is fed to the modules via terminal strips or the ribbon cables of the I/O connections. Some enclosures are equipped with appropriate jacks. A configuration of two or more modules has a common ground and a common 5-V-supply. A typical microcontroller configuration is powered via a 5 V mains adapter connected to the microcontroller module. The peripheral modules are powered via the interface cables. To facilitate bring-up and troubleshooting, the modules are equipped with power indication LEDs. Some modules can be operated with externally supplied 3,3 V. However, the problems of different signal levels have to be considered carefully, when other modules are to be connected.

Microcontroller families
The first modules are based on Atmel AVR microcontrollers. They are ubiquitous, inexpensive and can be comprehended far more easily than other microcontroller families. Hardware design is not that difficult. The time a novice requires to become familiar with the basics and have first programs up and running, can be measured in hours instead of weeks, even if assembler is chosen as the programming language. There are simpler architectures. However, they impose stronger restrictions. Although one has to learn fewer instructions, more subtleties and quirks are to be taken into consideration. Other families of microcontrollers are significantly more powerful. But they are also much more complicated.

Interfaces
The most versatile interfaces are the microcontroller's I/O ports. A typical interface between microcontroller and peripheral modules is organized as a bidirectional data bus of 4 or 8 bits, accompanied by 4 or 8 control and strobe signals.

The primary communications interface is the serial interface. 5 V signalization is used for connecting modules over short distances (0,5... 1 m). RS-232 signalization is available for connecting to personal computers and other equipment. We use only the TX and RX lines. Synchronization issues are to be resolved at higher protocol layers. This venerable interface has particular advantages. It allows for independent transmissions in both directions (full duplex mode). It transmits bytes, not packets. Hence one is completely free in defining own protocols with minimum overhead and low latencies. Application programming is easy. This is true for the microcontroller as well as for the personal computer. Most operating systems have built-in APIs supporting serial communication. A wide range of converters and adapters is readily available (RS-485, Fibre, USB, Ethernet and so on). TWI (I2C) and SPI remain available for application-specific system expansion (Ethernet, USB host, serial memory, displays and the like).

Multiprocessor systems

Microcontroller modules are connected by serial interfaces. The connection can be by wiring, via a passive hub or an active switch (compare Fig. 2). When only two modules are to be connected together, a simple crossover wiring will do. 5 V signalization uses open-collector drivers, so bus configurations with one or two wires can be built. However, the more effective solution is the star topology with an active hub (switch) in the center (similar to USB, but considerably simpler).