APPLICATION NOTE

Microcontrollers in Home Appliance: A Soft Revolution

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INTRODUCTION

The industrial world is now an arena where many manufacturers produce low cost, high quality products. Cost cutting and outsourcing are no longer sufficient to ensure competitiveness. Creativity and time to market become a must to survive. As a result, traditional electromechanical solutions do not fit many new home appliance requirements.
Now microcontrollers (MCUs) offer a strategic advantage for the design of cheap, attractive and environmentally safe products. For example, new MCUs can operate directly from the mains and drive power loads with only few external components. They can reduce the energy consumption, motor size and the cost of the appliance.

In the first chapter, this article analyses the forces driving new appliance concepts. In a second part, it describes state of the art solutions. The third chapter presents MCUs well adapted to home appliances and tools for increasing a designer's productivity.

1 FROM ELECTROMECHANICS TO MICROCONTROLLERS

Home appliance customers are more sensitive to price than performance. Manufacturers are mainly competing by price cutting traditional solutions based on electromechanical components. They also optimize the behaviour and especially the energy consumption of their equipment [1].

Table 1: Equipment price variation 1990/1982 in USA

Air conditioning	-2%
Refrigerator	+3%
Washing machine	+7%
Car	+21%
Food	+32%
Medical care	+62%

Table 2: Energy consumption variation 1990/1972 in USA

Washing machine	-30%
Air conditioning	-33%
Disher	-36%
Refrigerator	-47%
Freezer	-59%

Source: Appliance Magazine June 1993

However competition and environmental protection standards are increasing the constraints level. Customers want more comfortable appliances for less money and these objectives are difficult to achieve with traditional solutions.

But home appliance is one of the last volume markets with so few electronics. And when electronics exist, they are usually very basic. More than 2/3 of products do not contain electronics and when they do, the semiconductor content is low (usually 1 to 3 US$). So there is a strong potential of improvement with a limited cost impact when embedding more electronics inside home appliances.

An MCU is an especially good candidate because with an MCU, speed, volume and flexibility are compatible. One design leads to one product flow, fewer components and more models [2].

2 INNOVATIVE AND SUCCESSFULL APPLICATIONS

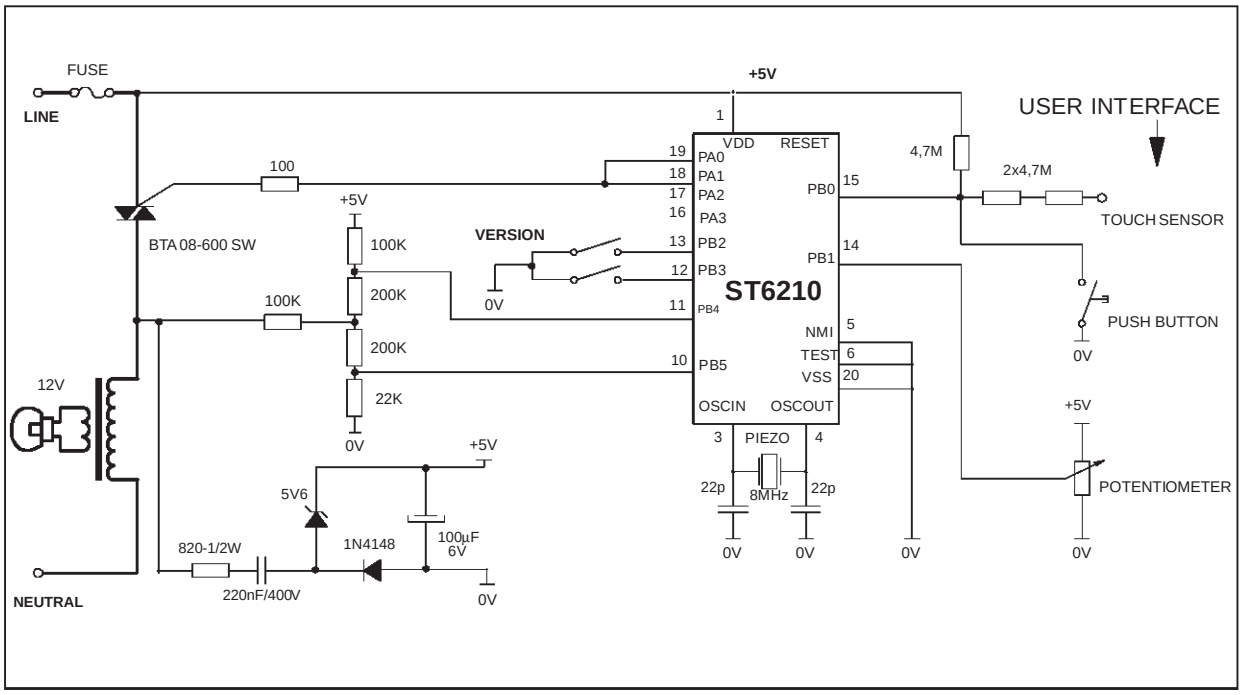
Several million MCU based appliances are presently used all over the world. The electronic content is usually not visible but it includes optimized control and protection features.

This chapter presents some of these appliances. Then it describes state of the art motor drive techniques. Finally it analyses the cost of these controls and the impact of an MCU on the testing.

2.1 State of the art appliances

If a light dimmer works well with discrete components, there is no reason to use an MCU. The MCU is useful if additional features such as soft start, soft stop, touch sensor interface or drive of a 50/60Hz transformer are required [3].

Figure 1: Light dimmer circuit

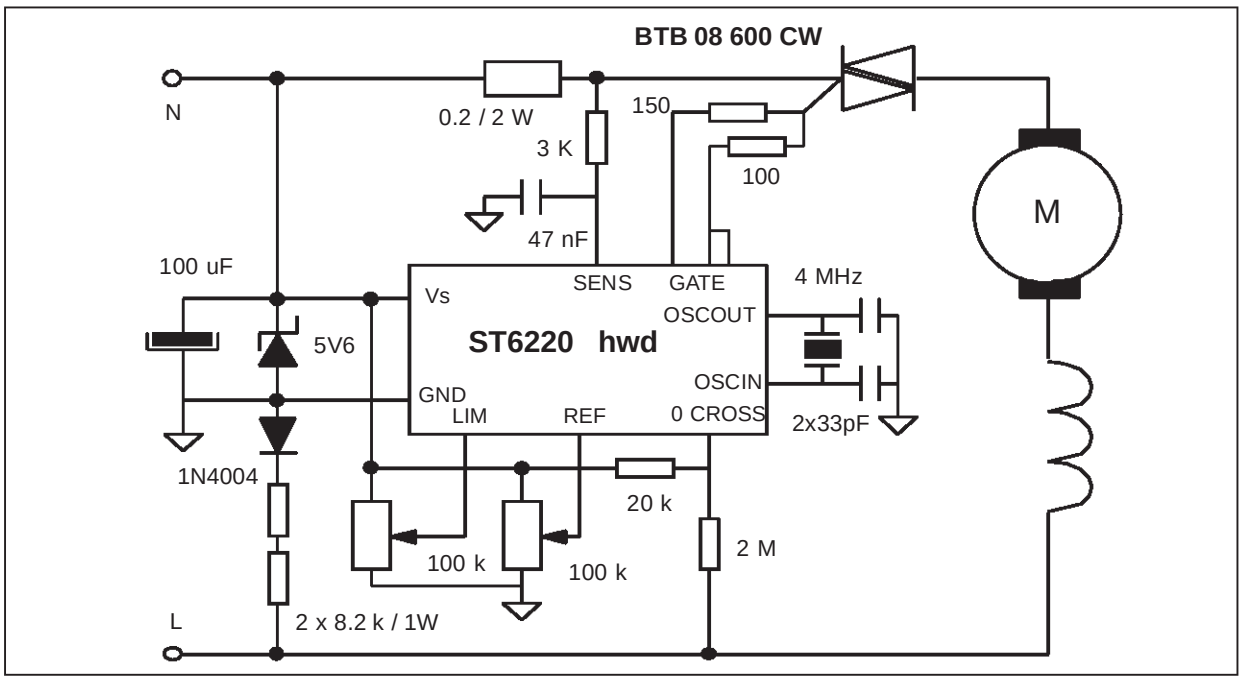


The majority of European vacuum cleaners have an electronic speed adjustment. Many include an MCU which controls the air flux temperature and the power transmitted to the motor through a triac. Standards make it mandatory that the motor is protected if the air flux is reduced. The air flux temperature is monitored and the power is continuously decreased if the motor gets overheated. This electronic protection avoids oversizing of the motor.

Inside vacuum cleaners sold today on the market, parameters are stored in the MCU memory which select different programs, I/O configurations and motor or display parameters. The same MCU is used in a few boards which are mounted in more than ten different models.

In drills and food processors, the load torque can vary greatly, leading to unacceptable speed variations when using a universal motor. As a result, the speed of the motor is often measured with a tachogenerator. This sensor is expensive and difficult to install; using an MCU, the current in the motor is measured and the speed sensor is avoided. Specific control rules are applied in the MCU software to keep the speed almost constant when the load or the input voltage vary [4].

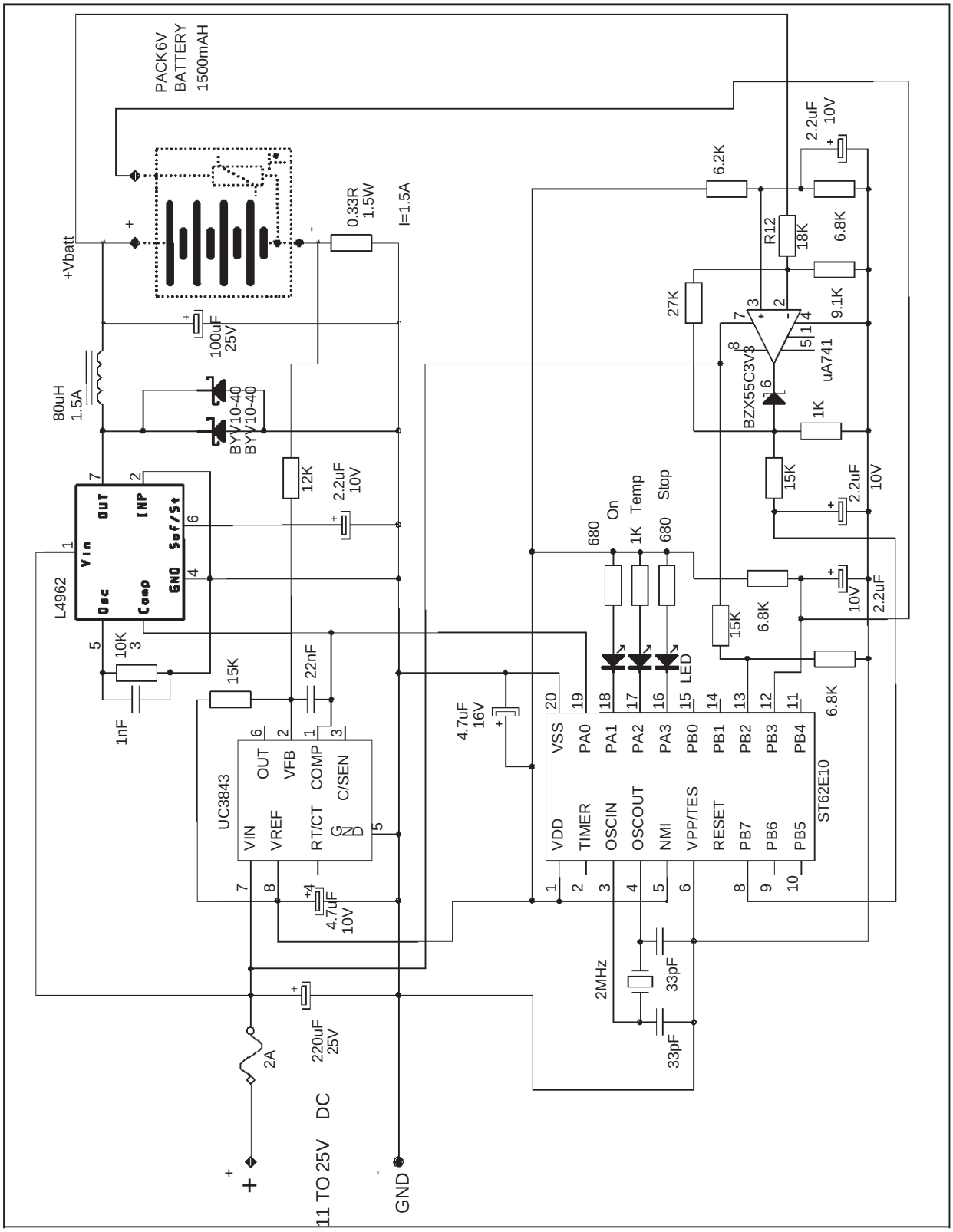
Figure 2: Speed sensorless drill control



MCUs are also used extensively in washing machines. An MCU program controls first the acceleration and the washing speed of the drum. It includes also safety features and washing patterns to reduce the washing time and the power consumption. Using an MCU, modified features can be introduced quickly and without new components. Going away from the analog IC, the parameter tuning is greatly simplified and design improvements such as new washing patterns are protected. The MCU is usually used in association with electromechanical timers which drive power pumps or resistances and interface to the user.

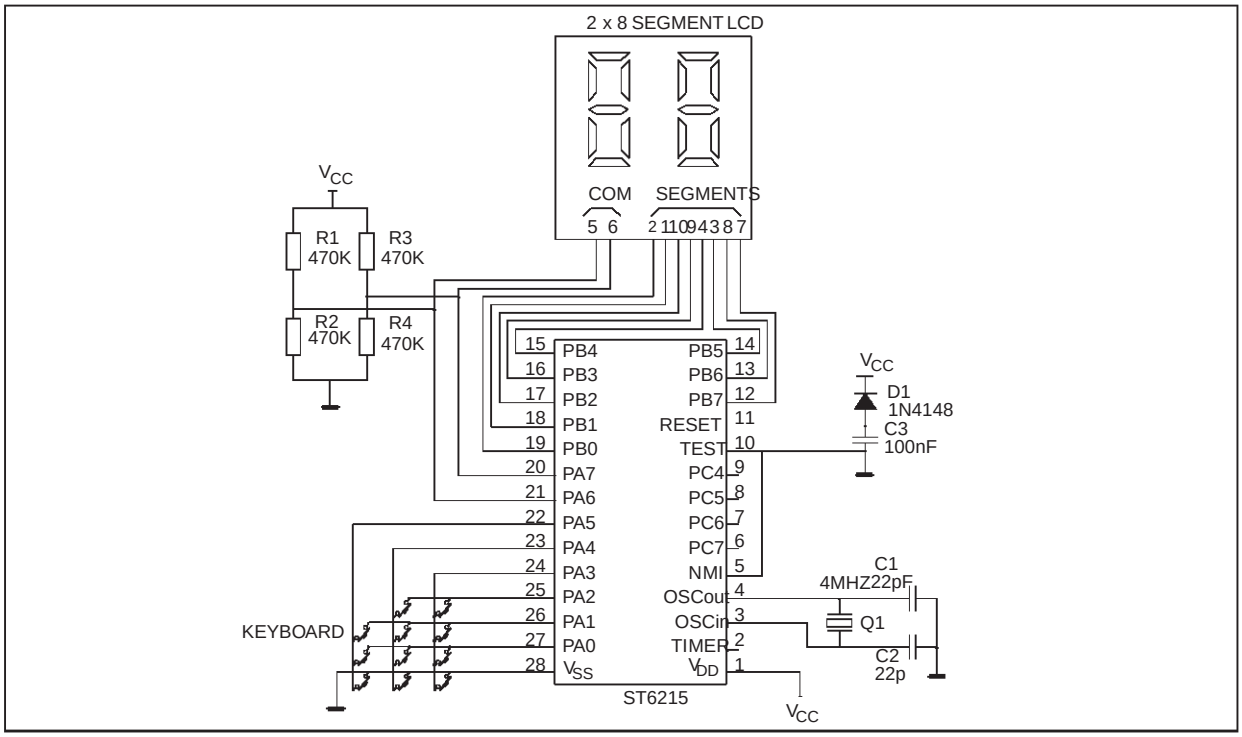
A cordless tool requires fast and safe battery chargers. And the faster the charge is, the more accurate the control has to be, especially with new types of batteries such as NiMH. So several parameters are controlled which may vary for different battery types. The charger presented in figure 4 charges NiCd and NiMH batteries in less than one hour. It monitors the variation of the battery voltage (inflexion point and -deltaV), its temperature and the charge time. The method is independent to the battery capacity and charge time. All this is done with a general purpose MCU and as a specific software [5]. Evolutions such as display, charger gauge, simple/double charger, Alkaline or Lithium-Ion charger can be implemented from this basis.

Figure 3: Fast battery charger (15W - CD/DC)



User friendly interfaces can be implemented without MCU oversizing. MCUs such as ST62 include A/D converters and I/O pin functionality reconfigurable by software. These MCUs drive directly an LCD [6], LEDs, a triac, an audiotransducer or a keyboard [7] with a minimum of pin count and components. They enable the design easily and quickly of features attractive for the customers.

Figure 4: Direct LCD drive



In summary, experience suggests many solutions for the design of cheap home appliances, attractive for users and environmentally safer. These appliances are using MCUs which enable optimization of the control and the inclusion of user friendly interfaces for a low cost.

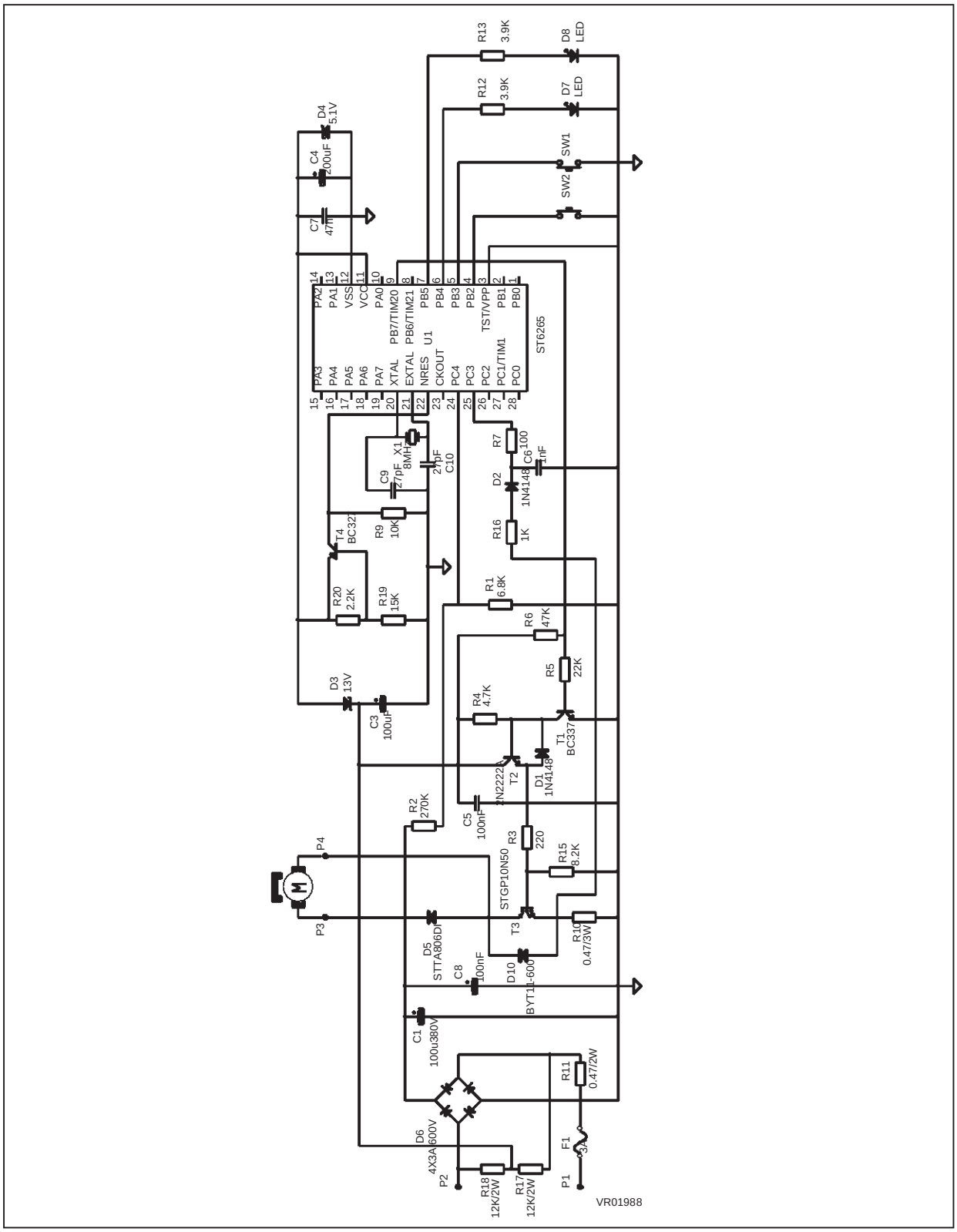
2.2 Improved motor drive

The motor and its drive have a high impact on most home appliances features, including cost, size, noise and efficiency. Electronic control is usually necessary when variable speed or energy savings are required.

Progressive improvements on material and control techniques lead to the development of ”electronic motors”, smaller, less noisy and more efficient. These products find applications in freon-free refrigerators, pumps, air conditioning, fans,... but no dramatic breakthroughs are anticipated.

The universal motor will be still used if the brushes are accepted. Brushless motors such as the permanent magnet motor for low speed and the reluctance motor for high speed have also a bright future. For whatever motor, low cost MCUs exist today to optimize the control.

Figure 5: DC Permanent magnet motor control



2.3 Cost evaluation

In most appliances, a motor or a programmable timer is usually more expensive than an electronic board. However even if a MCU is a bit more expensive than a traditional control, the performance/cost ratio is strongly in favor of the MCU approach. The overcost of optional features such as an LCD or a tachogenerator feedback is also limited because it does not lead to an MCU oversizing.

Table 3: Typical cost a small appliance motor drive (drill)

Block	Components	MCU board
Active	IC Triac	1.7$
Passive	Supply Snubber Capacitors Resistances Resonator	0.8$
Mechanics	Heatsink PCB	1.0$
Total board		3.5$
Universal motor		10.0$
Grand total		13.5$

Table 4: Typical cost of option examples

Block	Components	Cost
LCD display	Display Zebra strip	1.2$
Tachogenerator	Sensor Wiring Diodes Transistor Passive Components	1.1$

2.4 Test for quality

The same MCU can also improve the quality of the finished appliance. During the final test, the MCU can be used in a special ”test mode”. Then the behaviour of the different sensors and actuators is analysed and stored in the MCU. This data is later transmitted to a PC via a serial port and a PC identifies immediately any possible defects.

A washing machine manufacturer proclaimes to have decreased his test times by 20% to 30% when including such autotest features in the program.

Once connected to the board, the PC can also load parameters in the RAM or in the EEPROM of the MCU to compensate for some variations in sensors or to indicate the reset conditions of the MCU for the target application.

In summary, this second part shows that MCUs are used with success in Europe for home appliances. They enable the design of flexible equiment, cheap to manufacture and test. They open the door to improved motor control which reduce the noise, energy consumption and the size of the appliance. In addition, the manufacturing efficiency reduces the system cost.

3 AN MCU SIMPLE AND SECURE

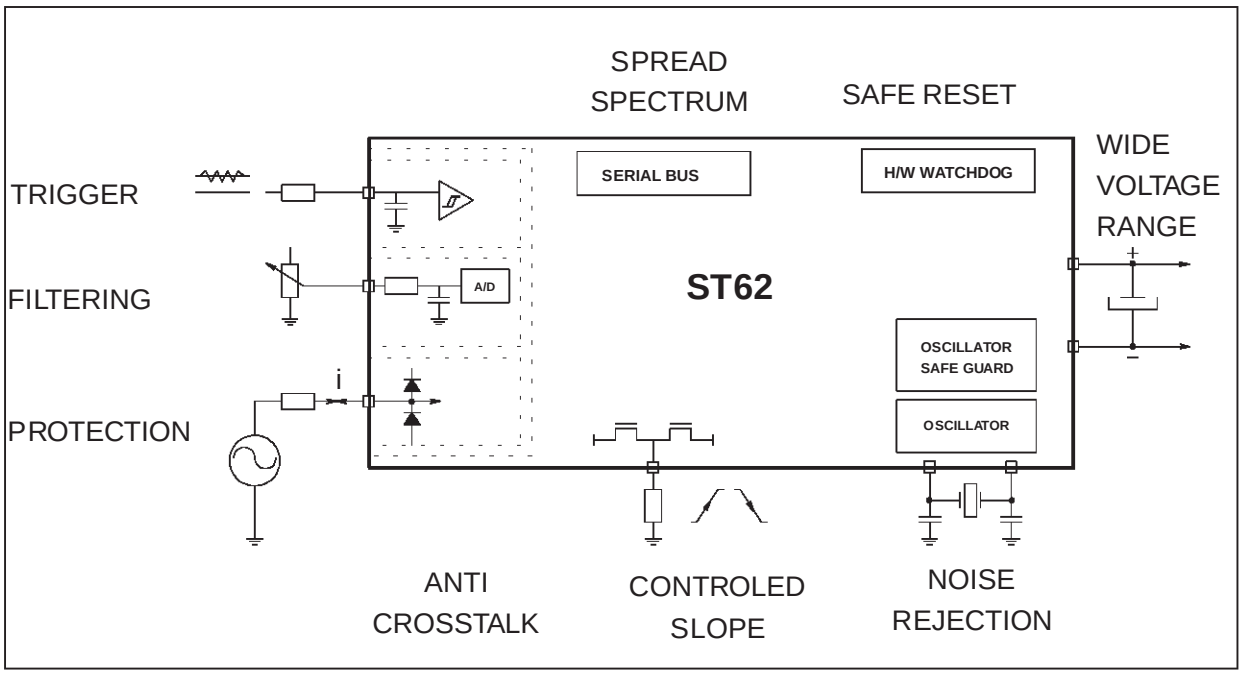
This chapter describes MCUs well adapted to home appliances: the ST62 family. These MCUs are safe when operating directly on the mains in a power environment and they include the features required for appliances.

3.1 Hardware features:

Home appliances include strong noise sources such as power motors, micromotors, relays, valves and the power supply. An MCU works in sequential logic, so there is a potential risk that it becomes unpredictable at reset and during other disturbances.

ST62 operation is safe even in hostile environments. These MCUs include protection on the I/O pins, a hardware watchdog circuit to restart the MCU if the program flow is lost and other cells shown figure 6. These characteristics simplify the circuitry and make the difference between a product which works in the lab or at customers [11]. They avoid also the usage of expensive shields, PCBs and capacitors networks.

Figure 6: Noise immunity by design on ST62



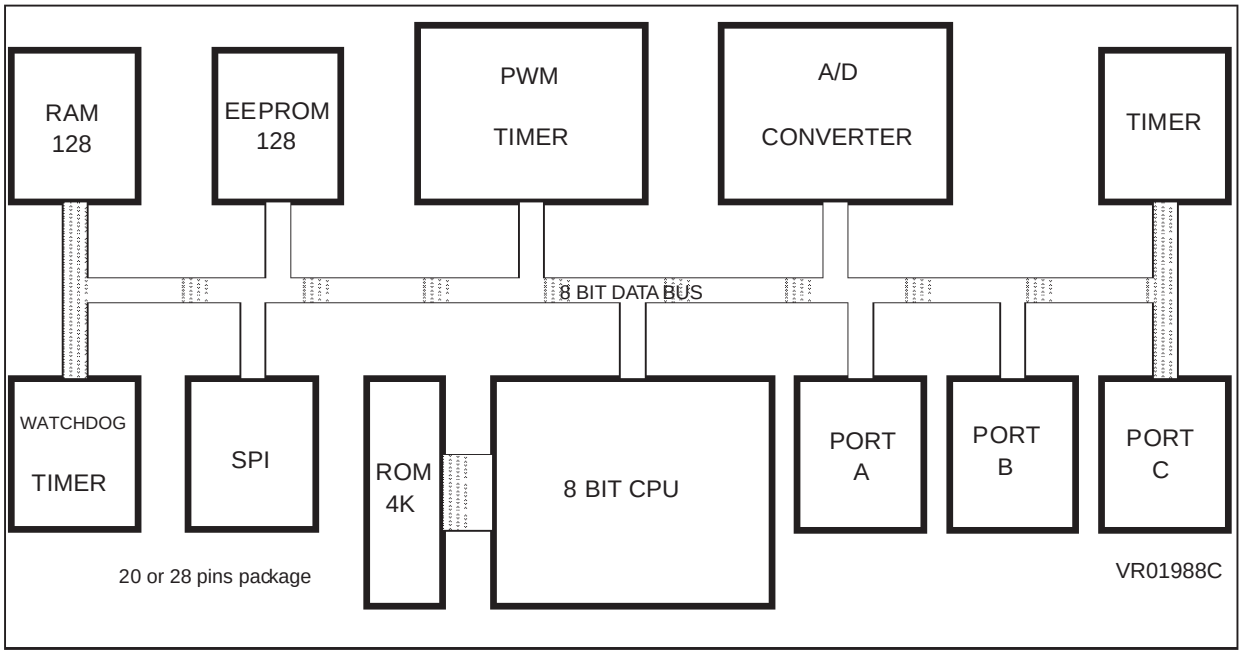
The ST62 can be seen as an analog programmable controller which interfaces sensors, stores data, controls feedback loops and drives power loads. Inside an ST62, the Analog-to-Digital Converter (ADC) and the timers measure sensor information. The same timer provides accurate and stable time bases adjustable for long and short durations without additional components.

The 8-bit core treats the data which is stored inside the memory RAM or EEPROM. The multifunction I/O pins drive directly a triac, an LED, an LCD or a serial port. This port flexibility

is a major factor for adaptation of a single product to different models only by software selection.

The ST62 are designed in CMOS technology. So they have a low consumption and they can be supplied from the mains through a low cost RC style circuit.

Figure 7: Block schematic of ST6265



The One-Time-Programmable versions contain an EPROM memory instead of the ROM. Programmed by the user, they enable the immediate test of any modifications and avoid the cost and delays induced by a ROM mask. The typical overcost versus ROM parts is between 1.5 to 2 for similar quantities. These OTPs are a key element to accelerating the time to market of new designs.

Some ST62 include also an EEPROM memory to store parameters in the production flow or during the product life time, even in case of power fail.

With MCUs such as ST62, an home appliance designer can implement sophisticated controls for a low cost. He can develop innovative solutions, quickly adaptable to the market evolution.

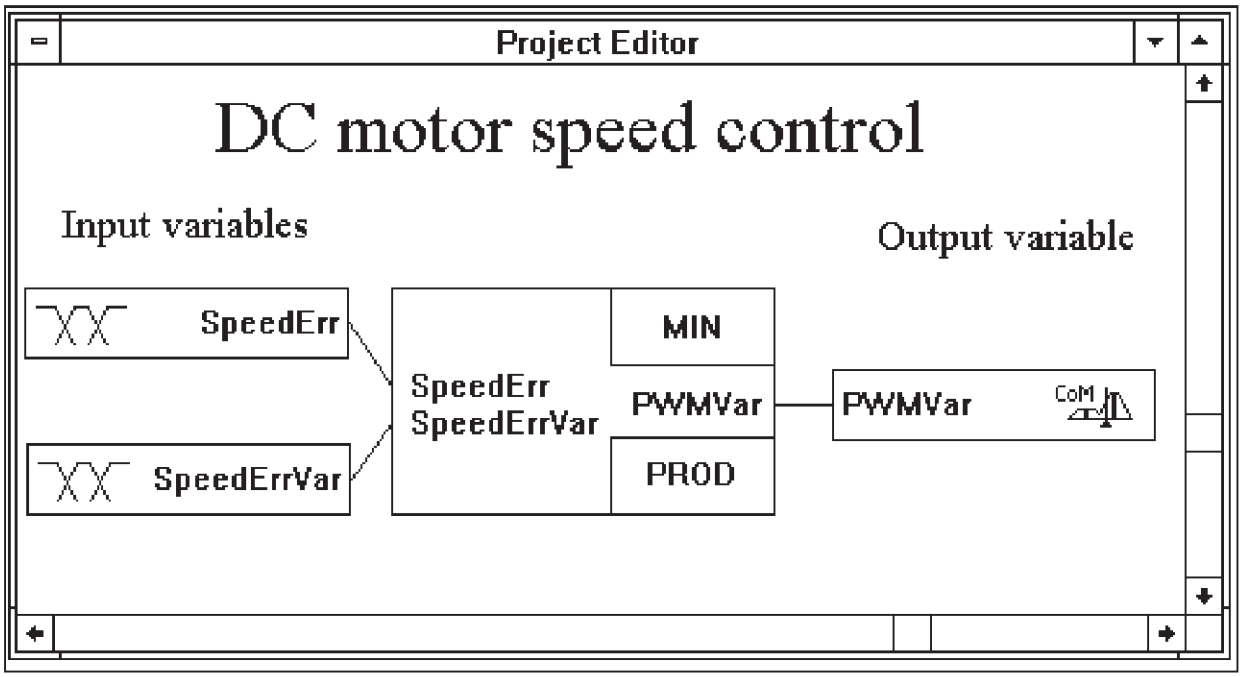
3.2 Software features

The move from electromechanics to MCUs is delicate and a new design is never straightforward. Easy-to-use development tools are mandatory to accelerate training and design. ST62 tools are designed for this purpose. They include application notes, program libraries and low cost demonstration or programming circuits such as a Power Kit and several Starter Kits.

High level languages can also accelerate the design. Fuzzy logic is used today extensively in Asia and Europe. For instance, it optimizes the charge of a battery, it minimizes the water and the energy consumption in a washing machine, it filters the IR sensor in a passive presence detector and it regulates the temperature in an air conditioner and in different compartments of a refrigerator.

The fuzzy logic approach is especially powerful in home appliances to help a designer with an analog background to develop an MCU based control. Using tools such as fuzzyTECH ST6 Explorer Edition, a designer can develop, test and optimize a regulation loop quickly. For instance, the fuzzy logic motor control described in the bibliography [12] has been done in few weeks.

Figure 8: Graphical interface of fuzzyTECH ST6 Explorer Edition



In summary, this third part shows that simple MCUs well adapted to power environments such as home appliances are now available. When development tools optimized for these applications are chosen, a designer takes full advantages of these MCUs: he learns fast the product and tests quickly his solutions.

SUMMARY

In the present global market, companies can not rely solely on price and brand recognition to remain competitive. They have to be innovative and quick to market.

Practical experience demonstrates that microcontrollers (MCUs) are now mature for home appliances. A company which masters both traditional techniques and MCUs has a major advantage to answer to new market trends.

MCUs such as ST62 match well home appliance requirements. They are secure in the power environment and include cells which minimize the board cost. With OTPs, they give the flexibility to develop rapidly low cost appliances adapted to market evolutions.

These products are driven more by imagination than material.

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[12] An Approach to Motor Control with Fuzzy Logic / AN419

Notes: