Integrated analog circuits

- Basic structures:
  Stabilized-voltage supply, stabilized-current supply, differential amplifier components, switching elements, potential shift, output stages.
- Application-oriented classes:
  Operational amplifiers (OP), voltage regulators, comparators, timers, converters, interface circuits.
- Special analog ICs:
  Voltage references, wideband amplifiers, analog multipliers, function generators, phase-lock circuits, analog filters, analog switches.

Integrated digital circuits

The spectrum ranges from LSI (simple logic chips) through to ULSI (memories, microcomponents).

Several conditions must be met before logic chips can be combined within a single system: The power supply, logic level, the circuit speed, and the signal transit time must all be identical. This requirement is met within the respective circuit families. The most important are:

- Various bipolar types (e.g. TTL: Transistor-Transistor-Logic)
- MOS logic, in particular CMOS logic

MOS and CMOS chips make up more than 99% of the production of integrated digital circuits. Bipolar logic circuits are only used in exceptional cases. Here, too, CMOS devices are taking their place more and more.

Semiconductor memories

Data storage includes the following operations: recording (writing, entering), storage (data storage in the narrow sense), retrieval, and readout. The memory operates by exploiting physical properties that facilitate unambiguous production and recognition of two opposed states (binary information). In semiconductor memories, the states produced are "conductive/non-conductive" or "charged/discharged"; the latter state relies on special properties in the silicon/silicon oxide or silicon nitride/metal junction. In future magnetic memory chips (FDRAM) will also be used. They have small ferromagnetic areas integrated on the chip. The direction of the magnetic field is used to store information.

Semiconductor memories are divided into the two main categories of "volatile" and "non-volatile". Virtually all of them are manufactured according to CMOS technology.

- Volatile memories (short-term memories) can be read and over written any number of times, and are therefore referred to as RAMs (Random Access Memories); the information content is lost when the power supply is switched off.
- Non-volatile memory chips (long-term memories) retain their data even when the power supply is switched off; they are also referred to as ROMs (Read-Only Memory).

The chart on the facing page shows the relationships and classification of the most common types of memory chip.

Microprocessors and microcomputers

The microprocessor represents the integration of a computer's central processing unit on a single chip. Microprocessor design seeks to avoid individualization in the face of large-scale integration, and the units can be programmed to meet the varied requirements associated with specific operating conditions. There are two different main groups of processor. A PC (Personal Computer) uses CISC processors (CISC: Complete Instruction Set Computing). These processors are very versatile and user-programmable. A WS (work station) normally uses RISC processors (RISC: Re-duced Instruction Set Computing). These processors are very much faster for the specific tasks frequently associated with WS use, but are significantly slower for all other tasks. A microprocessor cannot operate by itself: it always acts as part of a microcomputer.

A microcomputer consists of:

- Microprocessor serving as CPU (central processing unit). The microprocessor contains the controller and the arithmetic-logic unit. The arithmetic and logic unit performs the operations indicated by its name, while the controller ensures implementation of the commands stored in the program memory.
- Input and output units (I/O), which control data communication with the peripherals.

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Overview of semiconductor memory chips

- Program memory which provides permanent storage for the operating program (user program), thus ROM, PROM, or EPROM.
- Data memory for the data being run at any given time. This data changes continuously; thus, the storage medium for this application is the RAM. Part of the RAM (cache) is integrated on the microcomputer since CPU speed would otherwise be drastically reduced due to the high data rates, and there would be no use in deploying a high-speed processor if the required data were always sent over external buses. SRAMs are always used in these cases owing to the low access times required.
- Clock generator and power-supply system.
- The bus system links the individual elements in a microcomputer.
- A clock generator makes sure that all the operations in the microcomputer take place within a specified timeframe.
- Logic circuits are chips that carry out special tasks, such as program interrupts, inserting intermediate programs, etc.
- The periphery includes input/output devices and external memories, e.g. the main memory (DRAM) or the hard disk.

The main components of a microcomputer are normally combined as separate components on printed-circuit boards. "Single-chip" computers are becoming used more and more for simpler tasks, e.g. internet access in wireless communications, which is a growing trend, or functions integrated on a single silicon chip (SoC: System on a Chip). The performance of these high-integration systems is limited by the relatively small amount of RAM which can be accommodated at reasonable expense on the chip.

A microcontroller includes at least the CPU function, read-only memory (ROM, EPROM, or EEPROM), input/output capability (I/O), and random-access memory (RAM) on a single chip. In some cases, analog functions are only integrated on the chip. In contrast to a microcomputer, the controller reacts with a specified program that provides particular output values depending on the input information. It is used to control self-governing systems, e.g. engine management.

The transputer is a special type of microprocessor which is especially useful for building parallel computer networks. In addition to the standard microprocessor components, the chip is also equipped with communications and processing hardware.

It has at least four serial bidirectional transmission channels (links), allowing extremely high-speed (>1 Gbit/s per link) communications with many other transputers. As communications are completely asynchronous, distributed networks do not require a common clock circuit. Each link has its own DMA controller; once initialized by the CPU, it can carry out data transmission on its own. Thus, processing and communication are essentially parallel operations. Of particular significance are the extremely short process switchover and interrupt-response times of $\ll 1$ µs. The transputer does not need a real-time operating system for this; instead, it has the necessary processing commands directly in its command set.

The transputer operates as a communication node within the parallel network, meaning that it serves as both computer and communications interface. The transputer can therefore be employed to avoid one of the gravest liabilities of many parallel systems, which is the inherent need to share a common bus. Maximum-performance computers are therefore built using transputers.

Application-specific ICs

Application-specific IC (ASIC: Application Specific Integrated Circuits or also ASSP: Application Specific Standard Product) are only designed for a single application, as opposed to standard ICs. ASICs are produced for, and sold only to, one customer. ASSPs are application-specific ICs which are sold to several customers for the same application. Both are the result of a successful cooperation between users who share special system experience, and producers who possess suitable technologies. The essential advan-

Data processing and communication networks in motor vehicles

Requirements

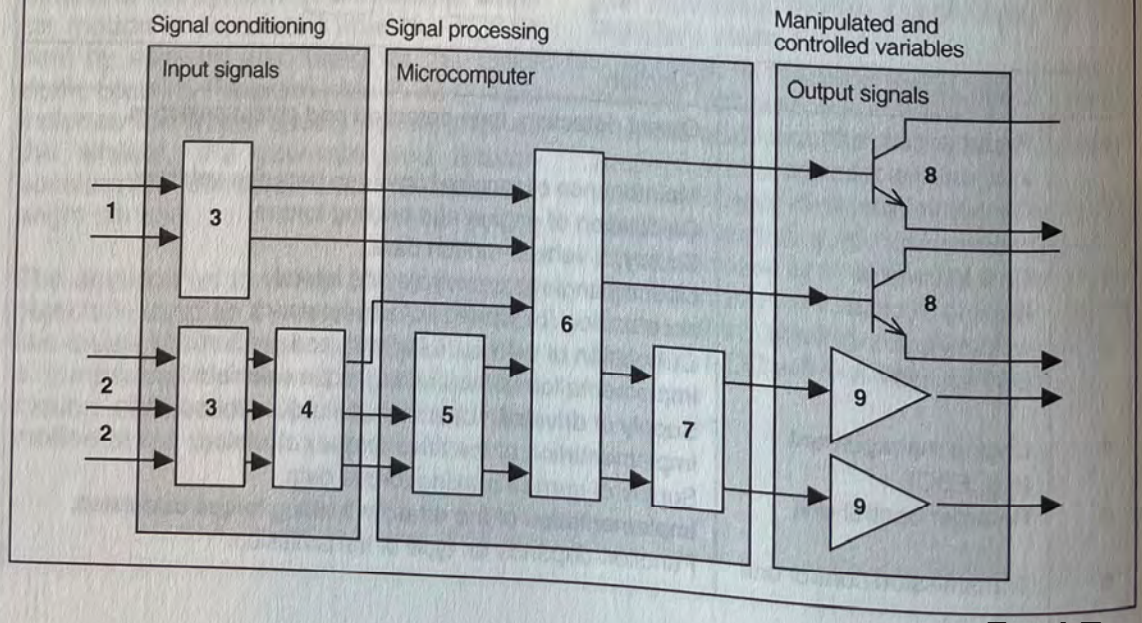
Highly sophisticated state-of-the-art open-loop and closed-loop control concepts are essential for meeting the demands for function, safety, environmental compatibility and convenience associated with the wide range of automotive subsystems installed in modern-day vehicles. Sensors monitor reference and controlled variables, which an electronic control unit (ECU) then converts to the signals required to adjust the final-control elements/actuators. The input signals can be analog (e.g. voltage characteristic at pressure sensor), digital (e.g. switch position) or pulse-shaped (i.e. information content as a function of time, e.g. engine-speed signal). These input signals are processed after appropriate conditioning (filtering, amplification, pulse-shape modification) and converted (analog/digital), preferably by digital signal-processing methods.

With modern semiconductor technology, powerful microcomputers can be integrated on relatively few chips together with their accompanying program and data memories, and special peripheral circuits designed specifically for real-time applications.

Modern vehicles are equipped with 20 to 60 electronic control units, e.g. for engine management, Antilock Braking System (ABS), and transmission-shift control. Improved performance and additional functions are obtained by synchronizing the processes controlled by the individual ECUs and by mutual real-time adaptation of the respective parameters. An example of this type of function is traction control (TCS), which reduces the drive torque if the driving wheels spin.

Originally, data exchange between the ECUs (in the example cited above, ABS/TCS and engine management) took place via separate wires. However, this type of point-to-point connection is only suitable for a limited number of signals. The introduction of automotive-compatible communication networks for serial transmission of information and data between ECUs has expanded the data transfer capabilities and represents the logical development of autonomous "microcomputers" in motor vehicles.

Signal processing in the ECU
1 Digital input signals, 2 Analog input signals, 3 Protective circuit, 4 Amplifier, filter, 5 A/D converter, 6 Digital signal processing, 7 D/A converter, 8 Circuit breaker, 9 Power amplifier.



Electronic control unit (ECU)

ECUs developed for use in motor vehicles all have a similar design. Their structure can be subdivided in the conditioning of input signals, the logic processing of these signals in the microcomputer, and the output of logic and power levels as regulation or control signals (see figure).

Digital input signals
Detect a switch position or digital sensor signals (e.g. rotational-speed pulses from a Hall-effect sensor).

Analog input signals
Signals from analog sensors (lambda sensor, pressure sensor).

Pulse-shaped input signals
Signals from inductive wheel-speed sensors. After signal conditioning, they are then processed as digital signals.

Initial conditioning of input signals
Protective circuits (passive: R and RC circuits; active: special surge-proof semiconductor components) are used to limit the voltage of the input signals to acceptable levels (operating voltage of the microcomputer). Filters remove most of the superimposed noise from the useful signals, which are then amplified to the microcomputer's input voltage.

Signal processing
ECUs generally process signals in digital form. Rapid, periodic, real-time signals are processed in hardware modules specifically designed for the particular function. Results, e.g. a counter reading or the time of an event, are sent in registers to the CPU for further processing. This procedure substantially reduces the CPU's interrupt-response time (µs range).

The amount of time available for calculations is determined by the controlled system (e.g. milliseconds in the case of engine management) The software contains the actual control algorithms. Depending on the data, almost any logical operation can be implemented, and any data records can be stored and processed in the form of parameters, characteristic curves, or multidimensional program maps. For more complex requirements in the field of image processing, the use digital-signal processors (DSP) is becoming more widespread.

Manipulated and controlled variables
Manipulated and controlled variables in the output module provide the required signals or power levels for peripheral actuators (e.g. electric motors for seat adjustment, power windows or power-assisted steering). Circuit breakers and amplifiers raise the microcomputer's output-signal levels (0...5 V, a few mA) to the power levels required for the actuators concerned (e.g. up to 100 A for short periods for engine cooling).

Architecture

The structural building blocks are assembled in hardware platforms or modular kits by using identical components (chipsets). These modules are also increasingly used for multiple applications (e.g. engine management for gasoline and diesel engines).

The same procedure is also suitable for function modules for control algorithms, which then become modular, reusable components within the overall system. Essentially, there are two elements that are important for implementing this type of methodology transfer:

- A concept for configuring and structuring functionality within the vehicle (CARTRONIC).
- Communication networks over which ECUs can interexchange information.

The building plan for assembling functions, network hardware and software is referred to as the architecture. System architecture describes the entirety of the structural and dynamic characteristics of distributed systems.

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