Microcomputers in TV Sets

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Silicon integrated circuits first started to be employed in TV sets in the early seventies. They were initially used to perform analogue functions such as colour signal decoding and sound processing. With the advent of ultrasonic and then infra-red remote control, also teletext, digital chips started to appear in TV receivers. They were at first specifically designed to perform one function or group of functions in a TV set, but before long microprocessor based systems began to appear. The reason for this was mainly economic. Whole systems could be arranged on one chip at low cost and with high yield, giving enormous flexibility – the same basic chip could be made to perform many different tasks simply by changing the software inside. This in turn led to new possibilities in TV design, for example digital tuning, enhanced teletext with page storage and intelligent selection, computer controlled setting up, and signal processing in digital form (e.g. the ITT Digivision system).

Terminology

First a note on terms. The basic difference between a microprocessor chip and a microcomputer chip relates to the internal memory facilities. A microprocessor chip has built-in ROM only, being designed to work with other chips to provide a microcomputer system. A microcomputer chip contains both ROM and RAM and on its own provides a simple microcomputer. The single chip microcomputer is often referred to as a microcontroller, since it's basically intended as a computerised control system for such applications as car engine and VCR control. Its instruction set is designed to handle small quantities of data very fast, often in the form of single binary bits rather than bytes. It looks like a custom designed chip from the outside since it requires minimal support hardware.

Microcomputer Types

A large variety of microcomputer/microcontroller chips are available from various manufacturers. They employ the same basic operating principles, the differences lying in memory size, instruction set, operating speed, numbers of inputs and outputs and word length (whether four, eight or 16 bit). Additional peripherals can be added on chip, such as analogue-to-digital converters and serial communication interfaces. Some chips are customised for specific end users. These are generally referred to as ASICs (application specific integrated circuits). Almost all microcontroller chips are mask programmed – the software required is put into the program memory during manufacture and cannot be changed later. Some microcontroller chips with an internal EPROM are available however. These are suitable for low-volume jobs and home use (see later).

Most TV microcontroller chips are descended from the 8048 family. The 8048 is in fact fast becoming the industry standard, with many "second sources". Mullard use it in their MAB8400 series and ITT in their CCU2000 family. Other microcontroller chips that have been used in TV sets include the Texas Instruments TMS1000 and the Motorola 6805. There are also of course a number of Japanese devices, whose origin is not easy to trace. In this article we'll concentrate on the 8048.

Internal Arrangements

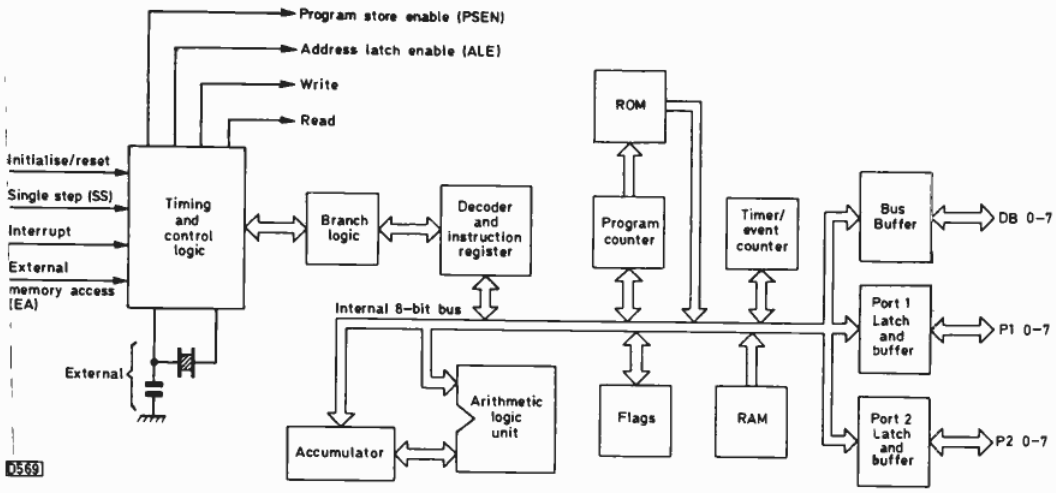
A microcontroller chip contains a central processor unit (CPU), program and data memories, input/output lines that are known as ports, and on-chip peripherals. It's not necessary to know in detail how the CPU works in order to understand or use a microcontroller chip. We'll adopt a "black box" approach therefore, concentrating on what the chip does with its data rather than how it goes about doing this. Fig. 1 shows the internal arrangements of an 8048 microcontroller in block diagram form.

The 8048 is an eight-bit device, i.e. it manipulates data in bytes (eight bits) at a time. It has a repertoire of some ninety-six instructions, in many ways similar to those of the well-known 8080 and F8 microprocessors – this is not surprising in view of the fact that it was Intel (spawned from Fairchild) who designed the 8048 shortly after the 8080. The instruction set is designed for ease of use and to be memory efficient. It can handle both binary and BCD (0 to 9) arithmetic and in addition single bits for control operations. The ROM has a capacity of 1K (1024 bytes). As mentioned above the program is put into the 8048 during manufacture and cannot be changed. An EPROM version called the 8748 is available however: this allows memory erasure with ultra-violet light and programming with a desk-top programmer. The data memory (RAM) has a capacity of 64 bytes. The 24 input and output lines are organised as three eight-bit ports. Two, P1 and P2, can handle a mixture of inputs and outputs. The other, DB, can handle either all inputs or all outputs or be used as a data bus for communication with other chips. The outputs can be latched and will drive one standard TTL load (1·4mA). All the inputs are TTL compatible, i.e. they can be driven by TTL logic chips.

The 8048 has three other inputs which are called T0, T1 and /INT. These can be used as single-bit ports, for example to monitor switch inputs. But they do have other uses. T0 can be used as a clock output at one-third of the 8048's crystal oscillator frequency while T1 can work in conjunction with the internal eight-bit timer/counter as an event counter input – every time a falling edge occurs at T1 the counter increments by one. /INT can be used as an interrupt input to make the program jump to execute a different routine (for example to refresh a display). The uses of the three inputs are specified in the software at the beginning of the program (see later).

The eight-bit timer/counter can be loaded, read, started and stopped by software. Unlike most microprocessor peripherals it counts upwards. When it "overflows", moving from count 225 to 0, it can interrupt the main program. This feature is used to prompt the processor to do something at a specific time (called a "watchdog").

There are also a number of pins for general processor operation: XTAL1 and XTAL2 for the crystal oscillator; PROG to enable the EPROM version (8748) to be programmed or to drive an output expansion peripheral (8243); /RESET to initialise the processor; /SS to allow



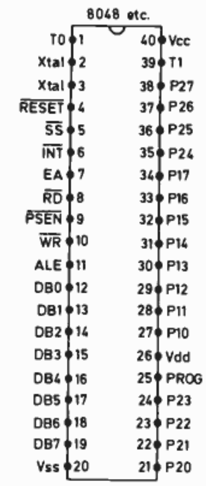


Fig. 1 (left): Basic block diagram for a 48 series microcomputer/microcontroller chip.

Fig. 2 (right): Pin connections for the 8048, 8049, 8748, 8035 and 8039.

single-stepping of the programs for debugging. The Vcc and Vdd pins are connected to a 5V rail while Vss is the chassis pin. There's access to peripheral chips via the data bus, with /RD the read pulse output and /WR the write/strobe output. /PSEN allows external or additional program storage. ALE stands for address latch enable, which gives the 8048 a proper address bus in conjunction with an eight-bit latch (74LS373) or a 1/15 crystal frequency clock. Some versions of the 8048 have a standby mode for low-power consumption: this is initiated by a software command and terminated by a hardware reset.

Fig. 2 shows the 8048's pinning.

The 8048 Family

There are three main members of the 8048 family – the 8048, 8049 and 8050. In each case the program and data memory capacity is doubled (1K, 2K and 4K of ROM and 64, 128 and 256 bytes of RAM). ROM-less versions of the first two devices are available – the 8035 and 8039. With these an external EPROM is connected via the data bus port (DB) and port 2 (P2) to provide the program memory. The advantages of this arrangement, in terms of ease of programming, are unfortunately outweighed by the loss of input and output lines. The EPROM versions of the 8048 and 8049 are the 8748 and 8749. They provide

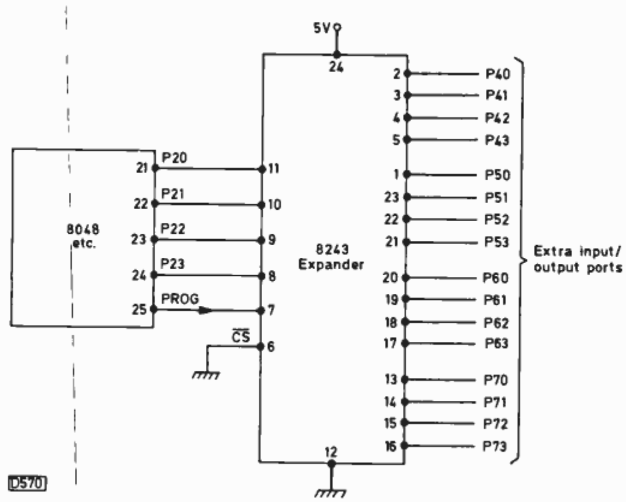


Fig. 3: Adding an input/output expander chip.

easy programming and ultra-violet erasure whilst maintaining the full complement of inputs and outputs. These two chips were originally intended as software prototyping aids for the ROM versions, enabling prototypes with programmed software to be tested before commitment to manufacture, thus preventing costly mistakes. When first introduced they were quite expensive (£120). They are now mass-produced at around £7 each (NEC version), making their use in many new products very attractive. Another variant is the "one time programmable" version with an EPROM for laboratory programming but no erasure facility. The advantages of this approach are that the simpler packaging makes the chips cheaper while the mask charge for factory programming is avoided. Future developments will include an EEPROM in place of the EPROM. An EEPROM is an electrically erasable programmable ROM, its use allowing non-volatile data to be changed without the need for ultra-violet radiation.

Manufacture and Packs

The 8048 series is manufactured in NMOS or HMOS versions, the latter being faster and consuming less power. CMOS versions are also available for lower power applications – the C is placed in the middle of the type number, e.g. 80C48. To date there are no CMOS versions of the 8748 and 8749. The 8048 family generally live in 40-pin DIL plastic packs, but the 8748 and 8749 have ceramic packs with quartz windows for the ultra-violet erasing light.

I/O Expansion

For serial interfacing the input/output capacity of the 8048 can be increased by attaching peripherals like the 8255 and 8251, but there's a custom chip made for the purpose – the 8243 I/O expander (see Fig. 3). This is a 24-pin chip which connects to the four lower bits of port P2 and the PROG line. It adds another 16 bits of I/O in the form of four four-bit ports, addressed as P4 to P7. P2 0-3 are lost however. Each port can be used as a latched output or an input – it's not possible to assign individual bits. The 8243 can drive fairly large loads, like LEDs, at up to 80mA. The main 8048 can support more than one 8243 – to address a particular chip the chip select line (/CS) is taken low. I've not seen this particular chip used in TV circuits yet, but in view of its usefulness this could well happen.

Mullard MAB Series

Mullard make all the members of the 8048 family (MAB8048H etc.) except the EPROM devices. A modified 8048 is used in their MAB8400 series of microcontroller chips which are to be found in sets produced by Thorn, GEC, Panasonic and others. The MAB family offers several memory options: up to 6K bytes of mask program and 128 bytes of data. A "bond-out" chip with connections for an EPROM can be supplied for software development but its availability is limited. With the MAB8400 the number of pins is reduced to 28 by cutting out the parallel peripheral interface circuitry. It can drive a multiplexed LED display direct from port P1. It also has a zero-crossing detector for slow-moving a.c. signals applied to pin T1. The main addition is a serial interface for communication with other chips and microcontrollers – the inter-i.c. bus, or I^2C for short.

Serial Buses

The I^2C bus is a more recent development in a generation of serial buses used in TV circuits to connect remote control receivers to tuner units and teletext boards, the most widespread being IBUS. The use of a serial bus reduces the amount of wiring required and hence the cost of implementing a control system. IBUS has a 6·25kHz clock line called DLIM and a seven-bit serial data line called /DATA. Thirty-two instructions can be sent, with two bits for TV/teletext or viewdata. The DLIM clock operates at twice the speed of the data, which is valid on the second rising edge.

I^2C bus timings are shown in Fig. 4. I^2C was developed from IBUS as a multimaster bus for use with microcontroller chips and intelligent peripherals. Like IBUS it uses two connections, serial clock (SCL) and serial data (SDA), but in this case the signals can originate from several different points along the bus – both lines are bidirectional. The clock operates only when data is being sent or received: its speed is variable so that it can work fast or slow. The data is distributed in bytes, with an address (of the device being written to or read from) followed by any amount of data. After each byte the receiving device sends back an acknowledgement bit to show that all is well. An arbitration system ensures that two sources don't use the bus at the same time. The maximum data rate is 100kbits/second.

Mullard have available a number of peripheral chips for I^2C use in TV sets, for example the PCF8570/1 256-byte CMOS RAM, the PCF8572 128-byte EEPROM, the PCF8573 clock/calendar for providing real-time information, and the SAB3035 CITAC (computer interface for tuning and analogue control) chip. The RAM and EEPROM are particularly useful for storing factory alignment and user data.

ITT Version

ITT use an 8048 as the basis of the CCU2000 family of microcontrollers. There are two versions, the CCU2000 and CCU2030, with a program size up to 6·5K bytes and a data memory of 120 bytes. Fig. 5 shows a block diagram. The microcontroller is housed in a 40-pin plastic pack which also includes a remote control decoder and a serial

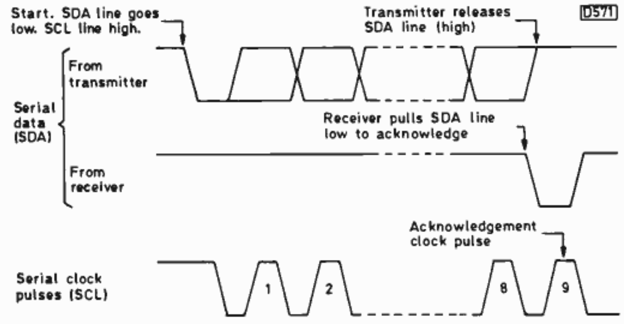


Fig 4: Pulse timing with an I^2C bus.

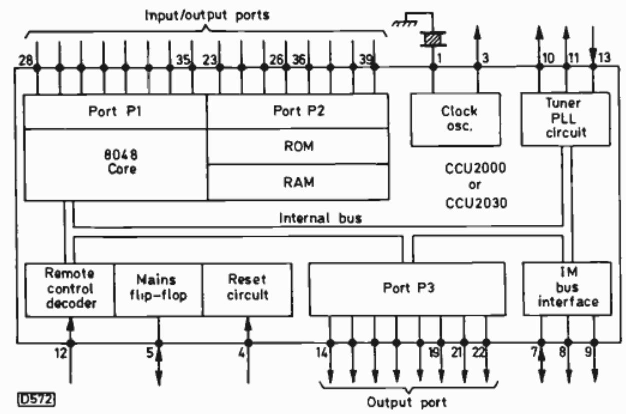


Fig. 5: Block diagram for an ITT CCU2000/2030 microcomputer chip – an 8048 with extra items added.

communications interface to what ITT refer to as the IM bus (Intermetall bus). Both these functions could be done using software but this would take up a great deal of code and execution time. Other items incorporated in the package are a tuner phase-lock loop, a mains flip-flop for standby operation, and a high-power port (P3) for driving an LED display direct.

The IM bus has three lines, ident (I), clock (C) and data (D). I and C are unidirectional between the microcontroller and peripheral devices while D is bidirectional. Data transmission originates from one place only along the bus. At the beginning of a transmission, I goes low to indicate a start condition. An eight-bit address is then sent along the D line serially, with eight clock pulses being issued – D is valid on the rising edge of C (see Fig. 6). I then goes low for the duration of an eight- or 16-bit data word travelling along D. Completion of the bus transaction is signalled by a short pulse on line I. The maximum clock speed is 170kHz.

Various peripheral devices have been developed by ITT for operation with the IM bus, for example the MDA2061 128-byte EEPROM, the MEA2050 eight-way digital-to-analogue converter and the MEA2901 tuner interface.

Memory Map

To understand software operation it's necessary to take a look at the memory map for the 8048/9 (see Fig. 7). The data memory is arranged as three blocks plus the RAM. There are two register banks, R0 to R7 and R0′ to R7′. These are directly addressable by instruction, but it's first necessary to select the required register bank (RB) – RB0 for R0 to R7, RB1 for R0′ to R7′. A further block comprises an eight-level "stack" which stores return addresses generated by subroutine calls and interrupts. The rest of the memory is uncommitted – free for use as a general-purpose RAM.

The program consists of a list of instructions, stored sequentially as one or two bytes in program memory, starting at 0. Instructions from memory are executed in sequence unless there's a branch instruction (jump, call or return), or one of three hardware conditions: a low on the /RST line produces a reset, restarting the program at 0; a low on the /INT line causes an interrupt, with the program sent to location three and the previous address stored in the stack; and finally a timer overflow interrupt tells the program to go to location seven – the address, where the program had got to before the interrupt, is stored in the stack as before.

Other Registers

The 8048 contains a number of other registers to help it do its work. The most important of these are the accumulator (A), the carry flag (C), and flags F0 and F1. These flags are just single bits that can be set or reset by software operations. Almost all processor instructions however act on data held in the eight-bit accumulator – to move it in or out of the microcontroller, perform mathematical functions or just store the data for later.

8-bit Operation

Being an eight-bit machine the 8048's instructions and data are stored as bytes, or eight binary digits. A convenient way of expressing bytes is to use the hexadecimal or hex notation. This splits the byte into two four-bit chunks (known as nibbles) and converts them to the decimal numbers 0 to 9 plus A, B, C, D, E and F for the remaining possibilities (16). Thus 01010001 in binary is 51 in hex, which is somewhat easier to handle. As another example, 11000100B is 0C4H. Note that a zero is placed in front of the C to indicate that it's a number. The suffixes B and H signify binary and hexadecimal notation respectively.

Program Instructions

As mentioned above, for memory efficiency the instructions consist of only one or two bytes. They are represented by letter or mnemonic to make it easier to construct and write a program. It's a bit like Basic programming, although each line does far less (it's called assembly language). There's not sufficient space here to go through the entire 8048 instruction set, but I'll highlight the important areas and give a few examples.

(1) Control instructions: These allow the program to control interrupts, select register banks and control the internal clock output. Here are some examples:

EN I	enable interrupt.
DIS I	disable interrupt.
ENT0	clock output on T0 at one third crystal frequency.
SEL RB0	select register bank 0 (i.e. R0 to R7).
SEL RB1	select register bank 1 (i.e. R0′ to R7′).

(2) Data move instructions: These control the movement of data within the microcontroller. Registers R0 to R7 can be addressed directly but other data memory locations must be addressed indirectly using the contents of R0 or R1 as the address. Examples:

MOV A,R6	move the contents of R6 (or R6′ if register bank 1 is selected) to the accumulator.
MOV A,@R1	move the contents of the data store addressed by R1 to the accumulator.
MOV R5,#6	put the number six into R5.

(3) Timer/counter instructions: These start, stop, read and write to and from the eight-bit timer. Examples:

MOV T,A	move the contents of the accumulator (A) to the timer (T).
STRT T	start the timer (internal clock).
STRT CNT	start the timer – event count through the T1 input pin.
STOP TCNT	stop the timer.

(4) Accumulator instructions: These perform mathematical and logical functions. Examples:

INC A	increment (add 1) to the accumulator.

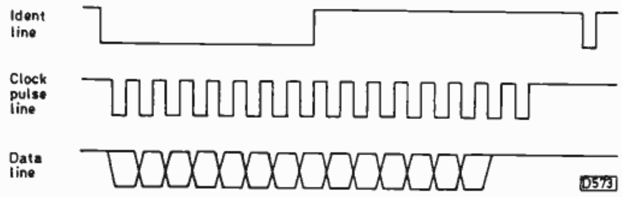


Fig. 6: Pulse timing with an IM bus.

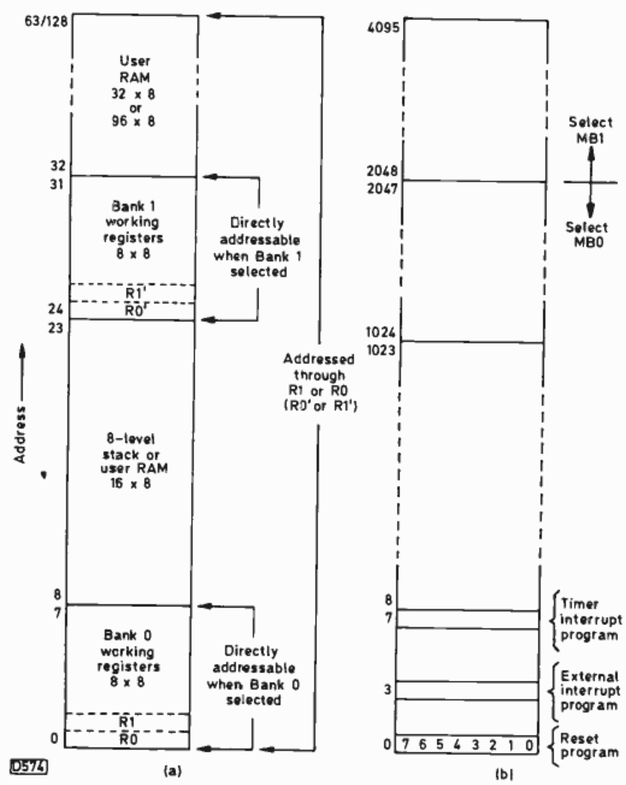


Fig. 7: Memory maps for a 48 series chip, (a) data memory, (b) program memory.

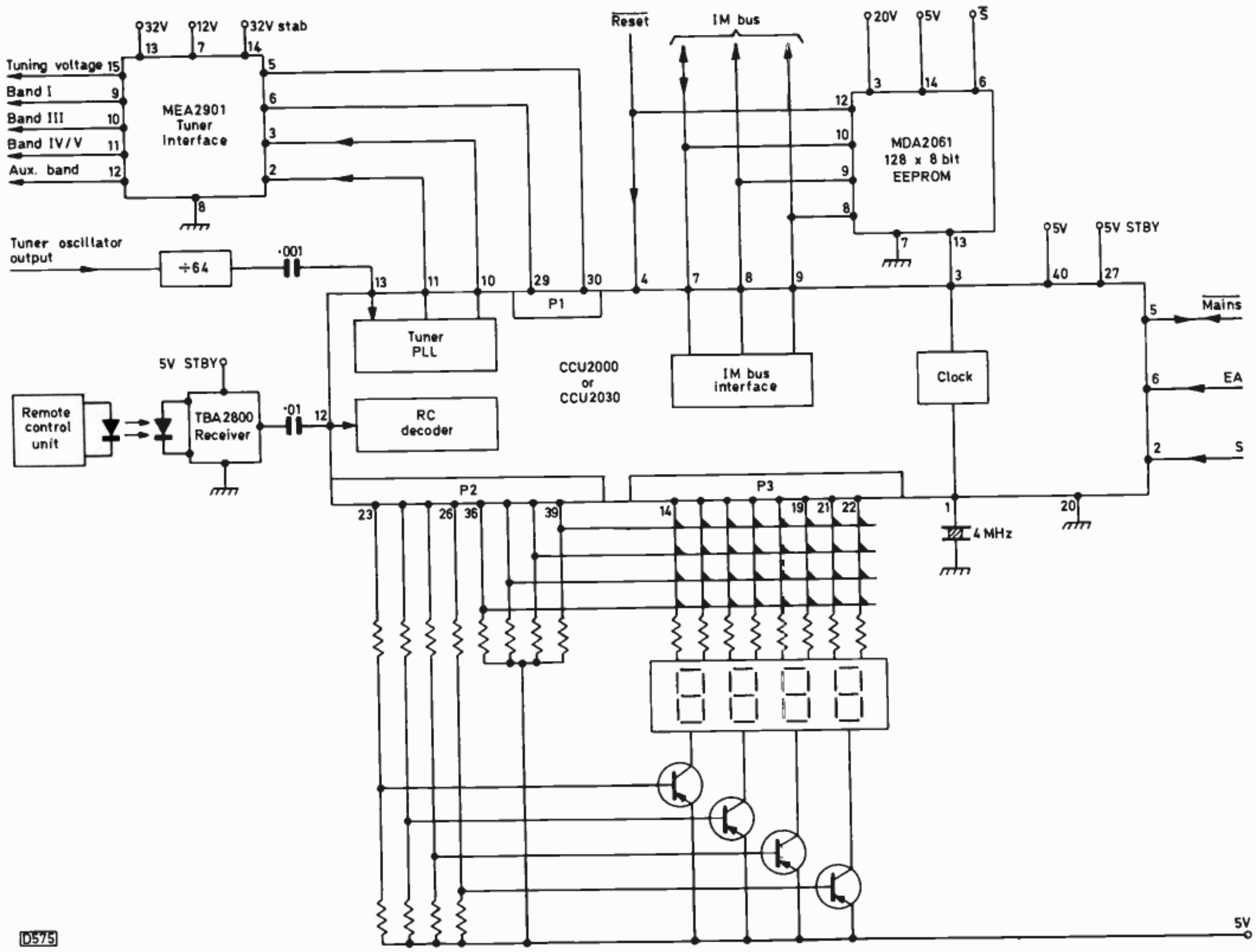


Fig. 8: Method of using a CCU2000/2030 central control unit in a TV set.

ADD A,R3	add the contents of R3 to the accumulator.
ANL A,#01H	logic AND the contents of the accumulator with 01H.

(5) Branch and subroutine instructions: These allow jumps to any part of the memory, either conditional or otherwise, and calls to subroutines. Examples:

JMP 100H	go to location 100H.
JC 20H	jump if the carry flag is set to address 20H.
JT0 30H	jump if input T0 is at one.
DJNZ R6,50H	decrement register R6, and jump to 50H if not zero.
CALL 100H	go to address 100H, but put a return address in the stack.

(6) Input/output instructions: Enable data from ports P1, P2 and BUS to be read into the accumulator. These ports can also be used as latched outputs. Port BUS can be driven in a non-latched mode if required. The bits at P1 and P2 are made into inputs by writing a one to them in the first few lines of the program. Examples:

OUTL P1,A	P1 has as output the contents of the accumulator.
ANL P2,#0FEH	zero bit 0 at port 2, leave the other bits as they are.
ORL BUS,#01H	set bit 0 on the BUS, leave the other bits as before.
IN A,P1	read the data at port P1 into the accumulator.

(7) Miscellaneous: There are various other instructions to do such things as setting flags. There's no HALT instruction – the program is expected to continue to loop.

Not all instructions are allowable. For example it's not possible to move data directly between registers without going through the accumulator. What is and isn't allowed doesn't seem to follow a logical pattern. So prospective programmers must acquaint themselves with the instruction set more closely. Further details are available in the data books published by Intel (Microcontroller Handbook) or National Semiconductors (48-series Data Book).

Writing Programs

It's possible to write very effective programs that are quite short for the 8048. These can be hand-assembled, i.e. the bytes corresponding to the mnemonics are looked up in a table and entered into the program memory. This is a tedious process for long programs, so a computer can be used to enter the program in mnemonics and assemble it. 8048 assemblers are available with the IBM PC (and its clones) and the BBC microcomputer. The program is put into the 8048 mask in the factory, or into the 8748 EPROM version using a desk-top programmer (optionally attached to a computer).

Applications

So what can the 8048 actually do with its elaborate software and hardware? It can simulate blocks of logic by reading inputs and providing outputs according to Boolean logic. But what it's best at is reading keyboards, feeding displays and transmitting serial data. This is well illustrated by the control system shown in Fig. 8. Here a CCU2000/CCU2030 microcontroller drives a four-digit multiplexed LED display and scans a keyboard via port P3. Port P2 selects the display with its lower half and reads the keyboard output with its upper four bits. An EEPROM is attached via the IM bus. A remote control input is handled as well as TV tuning.

In a future article we'll explore hardware design using 8048s in more detail and include a simple 8748/9 programmer design for home or laboratory use. Software development will be illustrated by going through the program I used for the IBUS controller in the low-cost teletext decoder project (December 1986 and January 1987 issues of *Television*). From the above, those more concerned with VCRs should be able to appreciate how microcomputer/microcontroller chips are used in syscon/mechacon arrangements.

Review: SSMU1 Signal-strength Meter

Roger Bunney

A signal-strength meter should be essential equipment for the aerial engineer. With it he can check that a satisfactory set of channel readings is obtained on completion of an installation. All too often cowboys rapidly erect a "rigger-quality" aerial and dismiss the poor results as being due to local conditions. Such operators do the trade a great deal of harm.

Unfortunately many signal-strength meters are rather expensive though Manor Supplies and Fringe Electronics offer modestly priced meters. HRS Electronics Ltd. have recently introduced a meter, Model SSMU1, at a "budget price". This firm sells only direct to the trade, but the meter is available retail from firms such as Aerial Techniques which advertises regularly in *Television*. I've recently been trying one out.

The meter is of attractive appearance, being housed in an RS Components cream case measuring 6⅛in. wide, 2½in. high and 6¼in. deep (excluding the knobs). It weighs 1lb 10oz, the black leatherette case with shoulder strap adding a further 7oz – the strap has no adjustment. The meter is a firm fit inside its cover and is retained by a large "popper" stud. The meter movement is small, about 1 7/16in. wide by 13/16in., and is calibrated 0-4mV (upper scale) and ±12dB relative to 1mV (lower scale). A battery check is incorporated.

Two large, centrally positioned knobs are used for channel tuning. The left-hand knob is a rotary one with six click positions (positions 7-10 are unused). Position one is the battery check while positions 2-6 are for channel groups in sections of ten channels per click position. The adjacent knob is a rotary potentiometer, calibrated 1-10, to tune in the individual channels. As an example, if channel 43 is required the click control is set to 4 and the rotary potentiometer to 3. An unusual arrangement, but tuning is simple with practice.

The standard Belling-Lee surface mounted aerial input socket is on the right-hand side. There are three slide-switch controls across the bottom of the anodised front panel. From left to right these are "off-on-light" (switches the meter on and adds an optional light behind the movement), "audio off-on" (there's a low-level audio output from a small surface-mounted transducer under the top of the case), and "gain". The latter is a three-position switch giving ÷10, ×1 or ×10, i.e. a meter f.s.d. of 0·4mV, 4mV or 40mV (±20dB relative to the centre setting).

The case has to be dismantled (two screws) for battery replacement (eight AA/HP7 pen cells), though a rear socket for a charger input is provided for use with ni-cad batteries. Inside there's a high-quality PCB on which are mounted a Mullard U321 u.h.f. tuner, two signal i.c.s, a voltage-stabiliser i.c. and four transistors. The surface transducer is stuck to the underside of the plastic case and plugs via a sub-miniature socket to the main PCB.

Evaluation

So much for description. How does it perform? I found the two channel tuning knob arrangement a little inconvenient at first (having previously used meters with continuous tuning) but one soon gets used to it. No operating instructions are provided, though it's all fairly straightforward. I felt that some paperwork should however be included. Aerial Techniques inserts a photocopy of the HRS catalogue description, giving the basic technical features.

The readings always seemed to be on the high side when measured with a 75Ω source – up 4dB in comparison with the readings obtained with a known, calibrated meter. This applied throughout the range. There's probably a simple adjustment inside but this would require return of the meter to the manufacturer. The technical leaflet specifies an accuracy of ±4dB, so maybe my findings were within tolerance. When used indoors (leatherette case removed) the output from the internal transducer is hardly sufficient: when packed up for use outdoors the level is too low for sensible operation. It would have been much better to include provision for headphone monitoring. The audio level varies with the setting of the slider gain switch.

The coverage is ch. E21-E69 and the ranges are 20μV-400μV, 200μV-4mV and 2mV-40mV. Current consumption is typically 50-55mA, the quoted cell life being 36 hours (AA cells) or 500mAh at 9 hours per charge with ni-cad batteries.

To sum up, this is a useful field strength meter at an attractive price. The scale accuracy error noted should be rectified by better quality control. Audio monitoring is poor and all but useless outdoors. In use it's a comfortable, light-weight unit. The leatherette case seems to be strong and gives excellent weather protection to the meter facia. Service engineers and u.h.f. TV-DXers could well find it of great help in their activities. The retail price is approximately £150 including VAT.