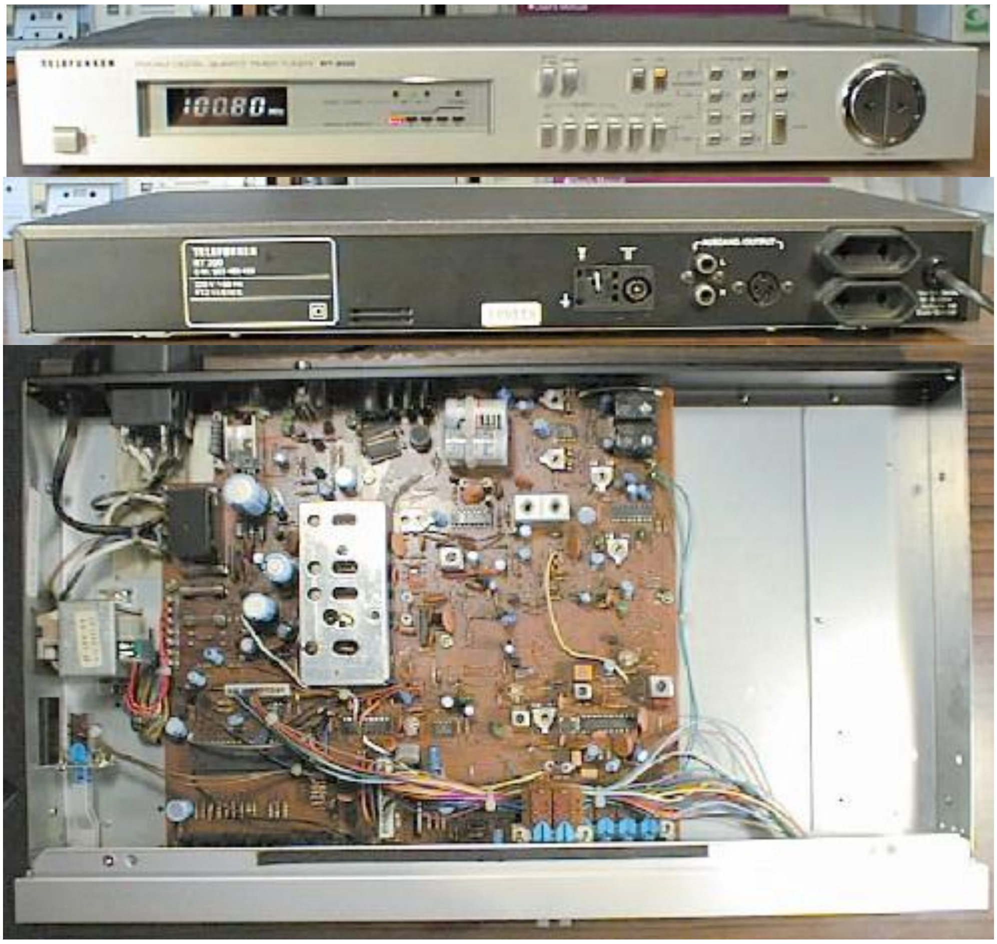
2011.X.27

Telefunken RT200



Device Type

Digital Synthesizer Tuner

Start of Sale

1981

Original Price

DEM 799,-

General Description

The medium-sized tuner of the Silver Series includes a feature even not present in the larger RT300: a digital timer/clock, allowing to turn the tuner plus two other devices on and off at preselected times. A single point of time and a daily-repeating time may be programmed. The tuner is never really off: the power switch is in reality only a key that instructs the microprocessor to turn the relay for the outlets and the tuner section off; the display then switches to a 24-hour time display. Since there are only five digits available, the time display doesn't include the seconds.

In contrast to the RT300 and MT1, the other digital tuners in the Silver Line, the RT200 does not allow entering a frequeny via the numeric keys. Note that '16 program memory places' means 8*FM and 8*AM; you can't have more places in one range and less in the other!

Features

UKW/MW, 16 program memory places, manual and automatic station search, PLL tuning system, LED signal strength indicator, exact tuning indicator, digital timer clock, mono switch, AFC (switchable)

Connectors

AF Output (DIN and Cinch), Antenna (75 Ohms asymmetric 240 Ohms symmetric AM/FM), 2 switched outlets for timer operation

Technical Data

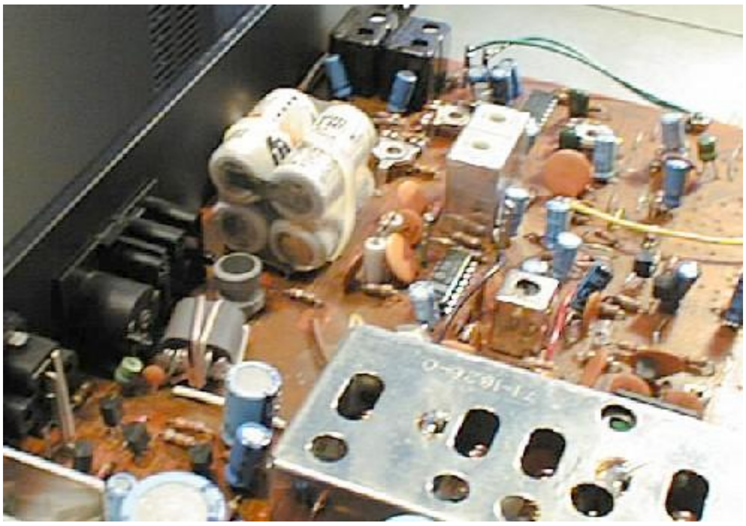
(taken from the user's manual and the service manual; I took the values from the service manual in case of contradictions)

FM Receiver	
Wave Band:	87.5 - 108 MHz
Circuits:	11, 4 adjustable
Sensitivity:	0.8 µV / 2.6 µV Mono/Stereo at 26 dB at 75 Ohms 1.6 µV / 5.2 µV Mono/Stereo at 26 dB at 300 Ohms
Limit Range:	<1.0 µV for -3 dB at 75 Ohms
Intermediate Frequency:	10.7 MHz
IF Bandwidth:	160 kHz
Selection:	65 dB (2 signal method)
Mirror Selection:	>=70 dB
Capture Ratio:	<1 dB
Phase Suppression:	>55 dB
Carrier Signal Suppr.:	>70 dB
Frequency Response:	10 Hz - 16.0 kHz
Distortion Factor:	<0.5 % stereo <0.3 % mono at 1 kHz and 40 kHz deviation
Cross Talk Dampening:	>38 dB at 1 kHz >30 dB at 12.5 kHz
Voltage Ratio:	>62 dB stereo (eff) >65 dB mono
S/N Ratio:	>64 dB stereo >67 dB mono
Range of Strength Display:	1 µV - 2 mV
Accuracy of Standards:	0 digit for station frequency in 50 kHz steps
AM Receiver	
Wave Band:	MW 522 - 1611 kHz

Sensitivity:	9 µV at 600 kHz (at 1 kHz 30% Modulation)
Circuits:	6, 2 adjustable
Intermediate Frequency:	450 kHz
IF Bandwidth:	4.8 kHz
Voltage Ratio:	36 dB at U = 1 mV,
Accuracy of Standards:	+/- 1 digit
Range of Strength Display:	8 µV - 5 mV
Frequency step:	9 kHz
General	
Components:	13 Integrated Circuits 42 Transistors 43 Diodes, 20 LEDs
Mains Connection:	220 V
Fuses:	1 x T 2.5 A (primary) 1 x T 630 mA 1 x T 100 mA
Dimensions:	435 x 56 x 250 mm
Weight:	~ 4.5 kg

Common Failures

Leaked Accumulator



The RT200 contains a 4.8V NiCd accumulator pack. This is needed to keep the processor and the clock running while the device is disconnected from the mains supply (as I noted above, the microprocessor and its supply is still on when you turn the tuner off). During normal operation, the accumulator will be recharged. However, there is no protection against driving the accumulator into deep discharge when the tuner is disconnected from power for a longer period of time. Similar to the accumulators on older PC mainboards, this will (1) destroy the NiCas and (2) make them leak! If you see a pack with the white, crystal-looking electrolyte leaked out, immediately replace it, since the acid can also destroy traces on the PCB. The cells used in the pack have a non-standard size. Simply use a pack of four standard AA/R6 cells and connect it via some inches of wire to the PCB. Even the smallest AA cells available these days have four times the capacity of the original cells, and there is plenty of space in the case to install the new pack somewhere.

Out of Tune

The second next common failure is a synthesizer crystal out of tune. This becomes notable by the tuner's exact-tuning display: though the correct frequency for a certain station is set, the exact-tuning indicator does not 'show green'. Typically, it will claim a mistune towards lower frequencies. Since the tuning principle is a PLL synthesizer with a closed loop, aging of analog components like the varicaps or OpAmps is out of question, the synthesizer's reference clock must be wrong - just by a couple ppm, but enough...

You may try swapping the crystal, but since you will need to readjust the oscillator anyway, you may try to get the old one back to the correct frequency: the crystal is stabilized with two small ceramic capacitors. Their purpose is to assure a correct start and a stable oscillation, and they also have the property of slightly reducing the crystals resonance frequency. They are located between the crystals's contacts and ground. Try reducing their values (one of them is adjustable, but that is usually not enough) or unsolder them. For example, I had an RT200 that came 'back into tune' after I removed C272...

Linked to the out-of-tune phenomenon is the tuner's incaopability to reliably receive in stereo; an RT200 going mono in the music's rhythm is not uncommon ;-)

Failed +5V Supply

In case the tuner starts acting 'funny' or the display stays dark altogether, it's worth to check the +5V supply of the microprocessor. If it is more than half a volt too low, try to swap the regulating transistor for the +5V supply, T236. Seems this transistor is slightly underdimensioned and may get 'cooked' over time. I usually replace it with a BD135 plus a small heatsink.

Broken Processor

Another failure I had so far was a broken microprocessor (which is a complete project on its own, see below), but this is surely not a standard failure and more due to incompetent handling/repair of the previous owner...

Spare Part Numbers

(taken from Telefunken's 1981-1991 Service Handbook and the Service Manual)

ICs, Transistors, Diodes		
IC201	IC TA7060 AP	339 575 227
IC202	IC HA12412	339 575 228
IC203	IC LB1450	339 575 278
IC204	IC LA1245	339 575 285
IC205	IC LB1426	339 575 279
IC206	IC TCA4500A	339 575 284
IC207	IC NJM4558D	339 575 087
IC208	IC MN6147	339 575 281
IC209	IC MN1455LF (IC209)	339 575 280
IC210	IC MC1741 (IC210)	339 575 123
IC211	IC MB74LS42 (IC211)	339 575 282
IC212	IC NJM7812A (IC212)	339 575 283
	transistor BF451	339 556 289
	transistor BC639	309 001 313

T204-207,209,224,228, 229,231,233,234,237, 238	transistor 2SC1815Y	339 556 292
T201	transistor 2SC380	339 556 052
T202	transistor 2SK212D	339 556 453
T203	transistor 2SK212C	339 556 454
T208-225,210-223,227, 230,232	transistor 2SA1015	339 556 216
T235	transistor 2SA1020	339 556 456
T236	transistor 2SD592	339 556 455
T101	transistor 3SK45B	339 556 456
T102,104	transistor 2SC535B	339 005 901
T103	transistor 2SC461B	339 005 925
D201-204,207,208	diode 1S446	309 327 925
D205,206	diode KV1225	339 529 322
D209-214,217,220-223, 304,305,501-504,506)	diode 1S1555	339 529 017
D215,216,218,224,225, 229,230,303	diode SR1K	339 529 101
D219	diode KB262	339 529 092
D226	diode DBA10B	339 529 368
D227	diode 05Z7,5X	339 529 317
D228	diode 05Z6,8Z	339 529 318
D301,302	diode 05Z16X	339 529 319
D101-104	diode 1SV53F2	339 529 314
D105	diode 1S2687C	339 529 315
D520,522,523	LED SR531D	339 529 323
D521	LED SG231D	339 529 320
D524-528	LED LN05202P	339 529 321
D503	LED SLP135B	339 529 324
	rectifier	339 520 051
Filters		
FL201,202	low-pass filter	339 368 014
CF201	ceramic filter 10.7MHz	339 367 116
CF202	ceramic filter 10.7MHz	339 368 016
CF204,205	ceramic filter	339 367 132
L201	coil 10.7MHz (L201)	339 347 039
L202	lowpass filter 195 kHz	339 367 117
L203	choke coil 2.2µH	339 348 655
L204	coil 3.3mH	339 347 045
	choke coil 220µH	339 347 038
L206	antenna coil	339 347 139
L207	oscillator coil 100µH	339 347 138
L208	coil	339 367 114
L209	coil	339 367 115

L210,211	choke coil 39µH	339 347 040
	symmetrical transformer	339 312 114
L101	coil	339 347 134
L102,104	coil	339 347 135
L105	coil	339 347 136
L108	oscillator coil	339 347 143
L106	coil	339 347 137
L107	coil	339 367 113
Misc. Electrical Parts		
	accumulator 4.8V	339 283 128
	key	339 442 121
	mains button w. rod	339 202 109
	push button	339 222 132
	push button	339 222 124
	push button, 2 fold	339 222 125
	push button, 3 fold	339 222 126
	tuning knob	339 222 123
J201	antenna socket	309 670 928
J202	DIN socket, 5 poles	339 540 114
J203	cinch socket	339 540 146
FLU201	digital display	339 335 108
FU201	fuse T2.5A	309 627 916
FU202,203	fuse T400mA	339 572 004
FU204	fuse T100mA	339 570 023
R220,267	var. res. 10KOhm	339 508 651
R246,279,286	var. res. 20KOhm	339 508 653
R355	var. res. 5KOhm	339 502 015
RY201	relay	339 360 108
S201	push button assembly	339 442 119
XTAL201	crystal 4.5MHz	339 349 154
	battery 4.8V/150mAh	339 168 006
	FM mixer board	339 337 145
C101,109,112	trimmer	339 510 061
C124	trimmer	339 510 062
	station buttons board, cpl.	339 337 137
	tact switch w/o diode	339 442 020
	tact switch w. diode	339 442 018
	scanning board, cpl.	339 442 130
	key assembly for it	339 442 120
	mains socket	339 480 107
	mains switch	339 442 121
	mains transformer	339 312 112
	mains cable	339 480 106
Misc. Mechanical Parts		
	cable binder	339 911 713

front plate, cpl.	339 132 128
side part f. front plate	339 232 125
frame f. tuning knob	339 222 145
button frame	339 222 144
buttons guiding, 8 fold	339 222 143
indicator window	339 272 128
display frame	339 337 142
push button holder	339 917 111
push button spring	339 917 110
housing, upper part	339 112 107
housing, rear panel	339 137 110
foot	339 062 112

Available Documents

- Manual
- Service Manual/Circuit Diagram

Goodies

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Replacing The Broken Microprocessor in a Telefunken RT200

Introduction

NOTE: This is a project for people who are absolutely crazy, like me. It took me altogether more than two months of work to do this project, not counting the hassle to find appropriate information (and realizing that I had to find out things myself). This report mostly has documentational purposes and there is probably noone who has an RT200 with the same problem and can use this text as a 1:1 guide. To do something like this, you need to have experience in reverse engineering devices, understanding both analog and digital electronics, building hardware, and programming embedded controllers. If you try something similar along the lines of this project, you are absolutely on your own and I might not be able to help you out. Especially, you are yourself responsible for anything you break. So for the moment, lean back, read, enjoy, and see if you can reuse some aspects for your projects.

The root of this project is one of my collecting passions, Telefunken Hifi components built in the late 70s/early 80s. The RT200 is an FM/AM Tuner with a built-in timer clock, i.e. you may use it to switch other devices on and off at preprogrammed times. Typically, those were the cassette deck and/or amplifier, either to wake yourself in the morning with a sound quality better than any alarm radio clock or make unattended recordings of radio programs.

I bought this RT200 for a few bucks at a flea market. Normally, there are few things in a synthesizer-based digital tuner that can break: no movable parts except for the buttons, no lamps to burn out, just a NiCd accumulator that may start to leak after a couple of years of operation. This RT200 however was perfectly dead: plug it in and you won't get any reaction to key presses, just a few cryptic symbols on the display.

Checking the parts that are usually broken in such a case (power supply, clock generator) revealed nothing, so it was clear that the central microprocessor chip had passed away. A truly uncommon event, so I guess this happened due to incompetent repair attempts by the previous owner.

Contents

Some Reverse Engineering

Since the tuner's PCB is single-sided, it is principally possible to reverse-engineer the device by following the traces, but at least in Germany, there is a much simpler way: go to www.schaltungsdienst.de, the web page of the Lange circuit service in Berlin. This company offers a unique service: it archives schematics and manuals for about any piece of audio/video equipment that was ever sold in Germany. Manufacturers usually only have schematics for the newer devices, but Lange always gets a copy of the schematic and stores it (hopefully) forever. It might even happen that when you ask a manuacturer for an older schematic, they will automatically forward your request to Lange. Of course this service is not free; expect about 20..40 DEM plus shipping, depending on the number of pages to copy. I however think that this is well worth the money, given the amount of time and nerves you save. Fortunately, this schematic already gives the pin functions of the central microprocessor IC (a Matsushita MN4500 by the way, but that doesn't help anyone...):

Pin No.	Name	Direction	Function
1	Vss	----	Ground
2	LW	Output	goes high if switched to long wave AM (unused on the RT200)
3	MW	Output	goes high if switched to medium wave AM
4	FM	Output	goes high if switched to FM
5	OUTLED OUT	Output	goes high to turn tuner on
6	MUT OUT	Output	goes high to mute the AF output
7	LATCH OUT	Output	controls data transfer to the synthesizer chip
8	DIGIT OUT 5	Output	row selectors for the display/keyboard matrix
9	DIGIT OUT 4	Output	"
10	DIGIT OUT 3	Output	"
11	DIGIT OUT 2	Output	"
12	DIGIT OUT 1	Output	"
13	DIGIT OUT 0	Output	"
14	KEY IN 0	Input	sense lines for the keyboard matrix
15	KEY IN 1	Input	"
16	KEY IN 2	Input	"
17	KEY IN 3	Input	"
18	STAT DET	Input	goes high when a signal of sufficient quality is received; needed for auto scan
19	PWR DET	Input	issues a 'reset pulse' after the main supply comes back
20	KEY IN 4	Input	sense lines for the keyboard matrix
21	KEY IN 5	Input	"
22	BCDOUT 0	Output	contols the decoder driving the station key LEDs
23	BCDOUT 1	Output	"
24	BCDOUT 2	Output	"
25	BCDOUT 3	Output	"
26	TEST	Input	unused input
27	RESET	Input	low-active reset for the CPU
28	GND	----	Ground
29	LOCKDET IN	Input	goes high when the synthesizer's PLL has synchronized to the programmed frequency

30	CLOCKIN	Input	250Hz clock from the syntesizer chip for the internal timer
31	SEGMENT OUT 0	Output	segment data for the display + addr/data for the synthesizer chip
32	SEGMENT OUT 1	Output	"
33	SEGMENT OUT 2	Output	"
34	SEGMENT OUT 3	Output	"
35	SEGMENT OUT 4	Output	"
36	SEGMENT OUT 5	Output	"
37	SEGMENT OUT 6	Output	"
38	SEGMENT OUT 7	Output	"
39	Vdd	----	5V supply voltage
40	CPU CLOCKIN	Input	CPU clock input (562.5kHz)

Luckily, these are all only digital functions and the processors works with a standard 5V supply and TTL levels, which simplifies the selection for a new processor:

Selecting a Microprocessor Platform

The microcontroller market offers lots of different families and variants of controllers. Some of them are well-known and for general-purpose use, some of them were designed with a specific application in mind. Since the synthesizer's PLL loop (see below) is completely done in the PLL chip, the main CPU's functionality mainly consists of driving the multiplexed display, querying the keys, running the internal clock for the timer and moving around some data - all not very advanced tasks even a 4-bit CPU could handle (I guess the original MN4500 is a 4-bit CPU!), but most 4-bit-CPUs are not general purpose and difficult to get or require expensive development systems, so let's settle with an 8-bit core. What other things do we need?

- Must be available in CMOS, to allow operation from the built-in accumulator for power failures or for times when the tuner is not connected to a mains supply.
- Must be able to run with the slow 562.5kHz clock supplied by the synthesizer chip. Of course we could add an own oscillator, but I already said that there is no need for much compute power and the low clock helps keeping the power consumption low.
- Must be available without problems. Not yet another obscure chip ;-)
- Development tools must be available for free at best...

Summing up, I settled with a CPU family that is the most widely used family of 8-bit controllers: The 8051 family. Originally introduced by Intel, 8051 derivatives are available from more than a dozen of manufacturers. The two 'standard' ROMless components 8031 and 8032 are available from probably more than 10 different manufacturers. I finally settled for the 80C32, the variant with more internal RAM (needed for the stations' frequency storage) and a third timer (not needed here). By coincidence, I got an TS80C32X2 from Temic, formerly Telefunken Microelectronics. It has the nice capability of running in *X2 mode*, i.e. an internal frequency divider is turned off and the device runs at double speed with the same external clock. A very nice feature, especially considering the low external clock frequency.

The other stuff around the CPU is pretty basic: an address latch to demultiplex address and data lines, an EPROM for the code (the C32's internal RAM of 256 bytes is sufficient for this task), and some latches and bus drivers for additional parallel I/O: since the external memory interface eats a lot of I/O lines, an I/O expansion is necessary in some way. I could have used one of the more modern x51 variants with built-in flash EPROM and thereby get most of the processor's pins as I/O, but as I already mentioned, I have a strong preference for components that are *not* single-sourced.

The whole circuitry is built on a prototype card and wired with thin isolated copper wires, a popular method for prototypes. Needs a bit patience and requires accuracy...the connection to the tuner's mainboard is done via a ribbon cable with a crimped plug on one end and an IC socket on the mainboard; of course, I had to unsolder the broken processor and replace it with a socket. The DIL connector is in my case a simple IC socket with the cable soldered onto it wire by wire; there are however also crimpable connectors available for this end.

Basic Layout of the Software

As you may imagine, it is by far too complex to explain the firmware on a line-by-line basis at this place; I'm also not going to explain the basics of the 80C32's architecture at this place - there's plenty of literature available in the Internet about that. I will therefore describe the basic building blocks and line out how they work together:

Initialization

Of course, the first step after a power-on or a reset is the initialization. The interrupt-driven background processes have to be initialized, and some global memory cells are resetted to meaningful defaults.

Interrupt Routines

There are two interrupt-driven background processes that run on the CPU. At least on a standard C32 without X2 mode, they consume about 70% of the CPU time, which is no miracle given the low clock frequency. The remainder is however still fully sufficient for our purposes.

The first process runs at about 400 interrupts per second and is used to drive the flourescent display and read the keyboard matrix. As with most consumer electronics, the RT200's display is a 'dumb' display that does not the refresh by itself, so the processor has to do the multiplexing itself. It works in the following way: Initially, the CPU outputs the data for the leftmost digit to the SEGMENT OUT pins and pulls the DIGIT OUT 0 line low while DIGIT OUT 1..4 remain high; this way, the contents of the leftmost digit are displayed at the correct place. In the next cycle (==interrupt), the first digit is turned off, the data for the second digit outputted, and the second digit is turned on. This process continues until the last digit is done, and we jump back to the first digit. So at any point of time, only one digit is on, but if this done fast enough, you get the impression of a still display. Similar to a computer monitor, about 60..70 complete cycles are needed per second for a flicker-free display, which results in the interrupt frequency mentioned above for 6 digits.

The other regular process is an interrupt service routine triggered by the precise 250Hz delivered by the synthesizer chip. This clock is used to run a real-time clock needed for the time display and timer functionality. For each interrupt, a byte in memory is incremented. As soon as its value reaches 250, the seconds value is incremented. The rest should be clear ;-)

Since the keyboard matrix and display share their row select, is is only natuaral that the process mentioned first also scans the keyboard. If one row of the matrix is pulled low, any key that is pressed and connected to that row will generate a low level on the keyboard scan lines. The scanned values are stored in 6 consecutive memory cells, resulting in an image of the keyboard matrix stored in memory that gets updated regularly. The x51 family allows to assign either a low or a high priority to each interrupt source. In our case, the keyboard/display multiplexer gets a high priority, while the clock update process works with the standard (low) priority. This is necessary to allow the multiplexer to interrupt a running clock service routine. Especially when one or more counter(s) roll over, the clock update consumes more time and can significantly delay the next multiplex cycle (don't forget we have a rather slow 8032!) and result in a visible sort of 'flicker' resulting from some segments being turned on longer than others and therefore seeming to be brighter.

Main Loop

The RT200 has a row of buttons that release each other and define the current 'operating mode' of the tuner's 'user interface':

- Timer On: Normal tuner operation, timer function enabled;
- Timer Off: Normal tuner operation, timer function disabled;
- Timer Set: (Re)program timer settings;
- Timer Check: Recall/display timer settings;
- Timer Cancel: Erase timer settings;
- Clock Set: Set the timer's clock.

Once the system is initialized, the CPU contiuously queries which button is pressed and branches into the appropriate sub-handler. Normally, this handler immediately returns to the main loop once the appropriate actions are done, but it may decide to delay this return in case a multi-key entry (time or frequency) is made. Of course, such an entry is immediately terminated in case the operation mode changes, so the key input routines inside these handlers also regularly check the current mode.

The Timer Section

is not overly complex: The handler for the 'Timer On' and 'Timer Off' modes is basically the same. in 'Timer On' mode, this handler is additionally followed by another routine that compares the current time against the preprogrammed timer values and issues the appropriate on/off sequences when necessary. This check is only done if the seconds value is zero; i.e. there is no problem with the background interrupt process updating the time in the same moment this routine runs. Problems only would occur if the comparison took longer than a minute...

Programming the Synthesizer Chip

The probably hardest part was the programming of the synthesizer chip, the chip responsible for selecting the frequency to be received. Its function is to generate a freely programmable frequency that is mixed with the amplified and coarsely preselected signal from the antenna. When you mix two frequencies properly, you get as a result two new signals with a frequency of the sum resp. difference of both frequencies. In our case, only the difference is interesting. If we program the synthesizer with a frequency that is higher than the signal to be received by a fixed amount, the difference remains constant and the following circuits need not be tunable; they can be accurately adjusted for this frequency. This principle is called *Superhet Receiver* in contrast to a *Straight Receiver* where all circuits have to be tuned synchronously to the frequency of the station to be received. Though this is in theory doable, it becomes extremely difficult to keep more than two variable circuits 'in tune'. Two circuits is however not enough for a good selection, so practically all radio receivers, including the simplest pocket radios, are superhet-type receivers.

The synthesizer chip generates a variable frequency with a tunable oscillator whose frequency is divided and compared to a given reference clock. The difference signal is fed back to the oscillator's tuning circuitry. As soon as the oscillator is 'in tune' (i.e. the regulator doesn't have to correct any more), the oscillator outputs a frequency that is the reference clock *multiplied* by the divisor. So if we make the divisor programmable, we have an oscillator with a programmable frequency!

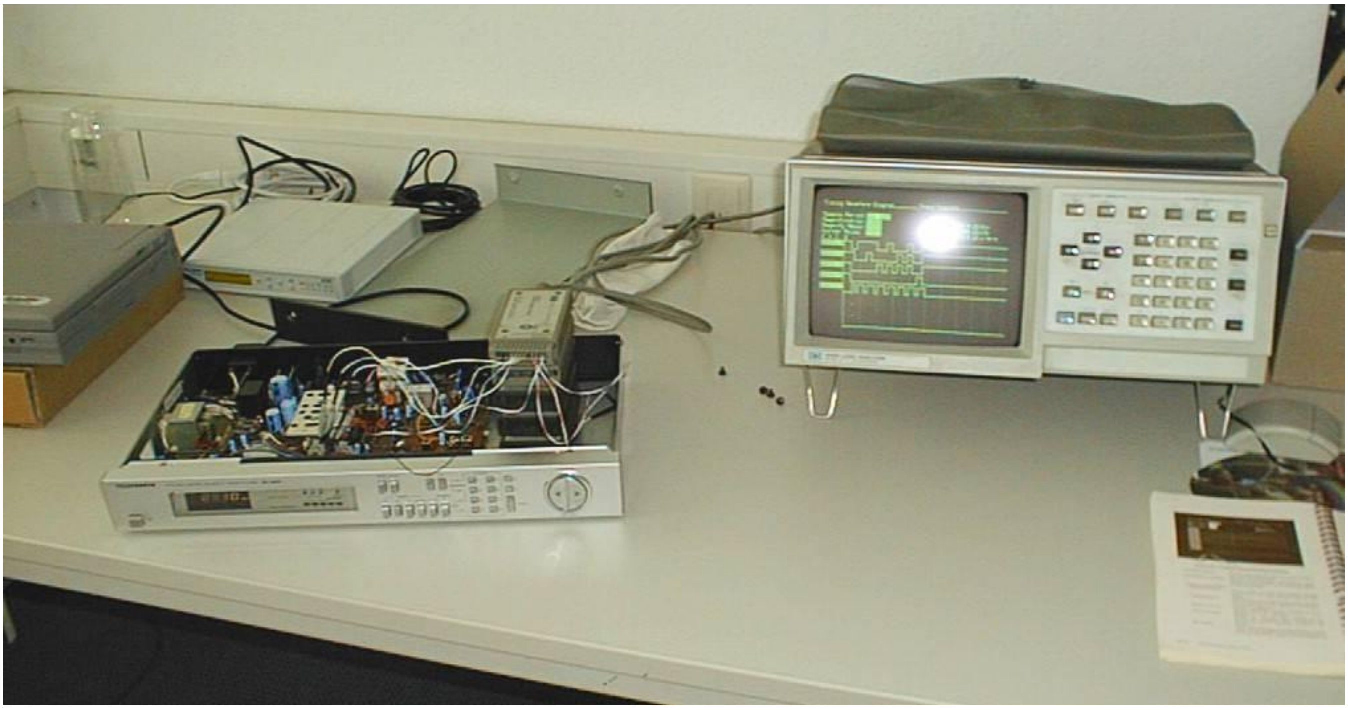
In case of the RT200, a Matsushita MN6147 is used that contains the reference oscillator, frequency comparator/regulator, and the programmable divider. The oscillator is an LC-circuit inside the RF frontend that contains a *Varicap* diode. A Varicap is a diode that operates in blocked direction and varies its parasitic capacitance according to a DC voltage applied to it.

From the schematic, we get the MN6147's pinout:

Pin No.	Name	Direction	Function
1	Vss	----	Ground
2	OSC OUT	Output	Goes high if PLL has locked
3	OSC1	----	Connect to 4.5 MHz crystal
4	OSC2	----	"
5	CLOCK1	Output	562.5 kHz clock for CPU
6	CLOCK2	Output	250 kHz clock for CPU timer
7	VCC CLOCK	----	+5V supply
8	PD OUT	Output	Output of Varicap voltage (externally amplified with 741 OpAmp)
9	LATCH CLOCK	Input	control signal from CPU
10	DAIN 3	Input	Data/Address input from CPU
11	DAIN 2	Input	"
12	DAIN 1	Input	"
13	DAIN 0	Input	"
14	VCC	----	+5V supply
15	AM LOIN	Input	Input from AM oscillator
16	FM LOIN	Input	Input from FM oscillator
17	SW/MW	Input	Select short or medium AM wave band (unused, tied low)
18	FM/AM	Input	Select AM or FM operation

Though this helps understanding the circuitry, it doesn't help us with out new firmware, since there is no information about *how to program* the synthesizer to a certain frequency. After a couple of phone calls with Panasonic/Matsushita Germany, it was clear that I would have had to contact the japanese mother company to get this piece of information (the people I spoke to however were quite friendly and trying to help me, I must add at this point!).

Since I also own a still working RT200, there was a simpler way of finding things out: take a working sample, tap onto the data and clock lines, and see what is happening when the frequency changes. I was able to use a digital logic analyzer from HP for this job:



Shown on the LA's display is the result of a single programming cycle. The synthesizer chip contains a couple of registers, each 4 bits wide. With a low-to-high transition of the clock line, a certain register is selected; with a high-to-low transition, data is written to the addressed register. So a single write operation consists of the following steps:

- Apply register address to data lines
- Pull clock line high
- Apply register data to data lines
- Pull clock line low again

The frequency to be programmed (remember this is 10.7 MHz resp. 450 kHz higher than the frequency ultimately to be tuned) is simply written in BCD code to the synthesizer's registers. Specifically:

- Write 0 to register 2
- For FM:
  - Write 1 to register 1
  - Write hundreds of MHz to register 3
  - Write tens of MHz to register 4
  - Write ones of MHz to register 5
  - Write hundreds of kHz to register 6
  - Write 2 to register 7 if +50 kHz, otherwise write 4
- For AM:
  - Write 2 to register 1
  - Divide frequency by 9
  - Write hundreds of kHz to register 3
  - Write tens of kHz to register 4
  - Write ones of kHz to register 5
  - Write 0 to register 6
  - Write 0 to register 7
- Write 7 to register 8

Note that in AM mode, you can only tune in 9 kHz steps!

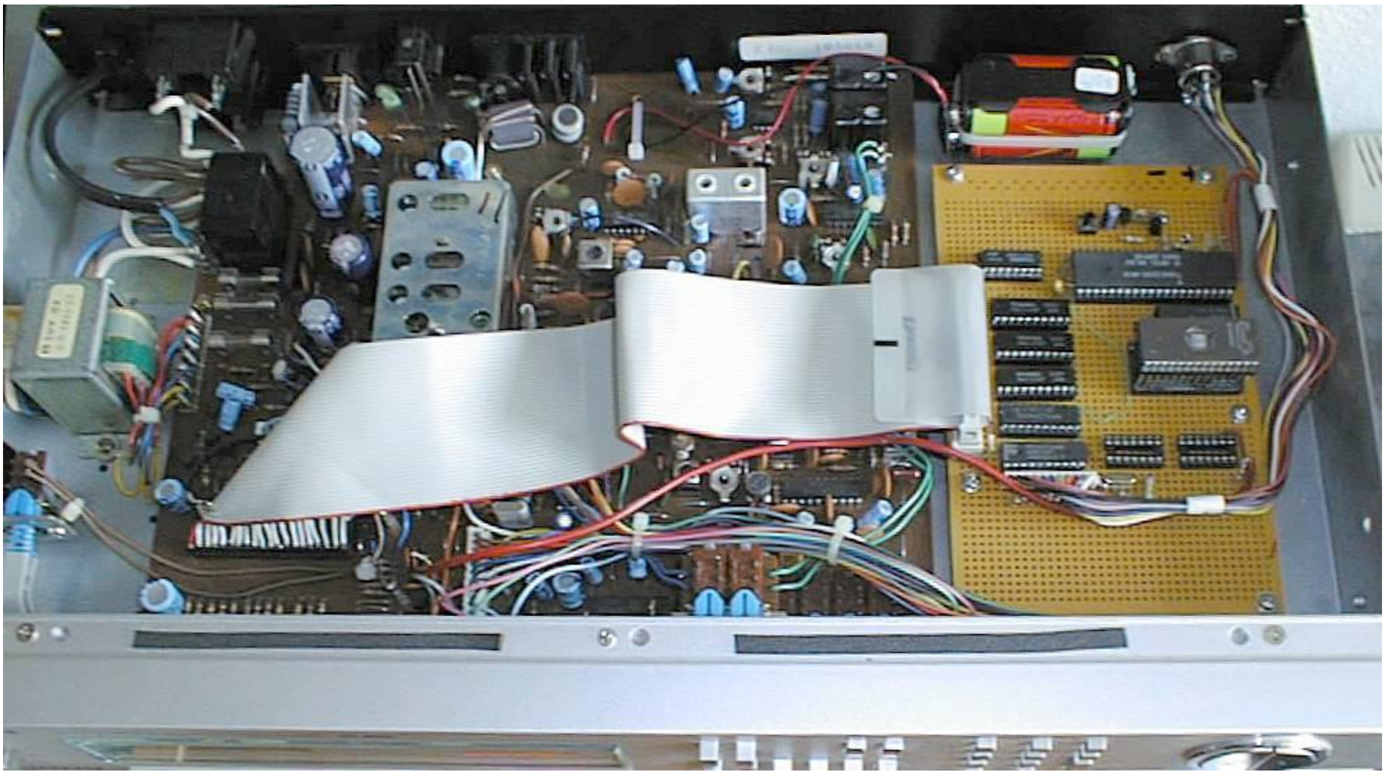
Adding a Remote Control Input

The larger brother of the RT200, the RT300, features a remote control input to control the tuner via the infrared remote control receiver in the RP300 pre-amplifier. Now that we have a firmware we can extend and modify easily, there is no reason not to add some nice features you had always been missing...

The RP300 contains a Siemens infrared receiver & decoder chip that outputs the code of the pressed button as a 6-bit-code (all bits zero means that no button is pressed). For the 'less intelligent' devices like the cassette deck or the record player, some logic decodes these codes into individual signal lines for the controllable functions. The tuner in contrast directly gets the 6-bit-code and has to do the decoding itself. The reason for this is simple: About 20 buttons of the remote control are assigned to the tuner, and you only have 8 pins in the used DIN connectors. Of course this also saves I/O pins at the tuner's processor, and what is more interesting: the tuner also can 'see' codes destined for other devices in the system and react on them. For example, if you turn the system off via the remote control, the tuner can also turn itself off automatically. And what is more interesting: The buttons on the RP300's front panel run via a virtual remote control whose signal is merged with the IR receiver's output, the tuner also can notice when you switch the signal source to 'Tuner' and turn itself on. Another goodie I added to display the selected signal source on the tuner's display for a few seconds. Adding the remote control input was relatively simple: the signal are fed into the system with an extended low-level keyboard scan routine. Whenever a higher-level routine queries the keyboard, this routine first checks the remote control input for a non-zero code and returns this code in case the code translates to a 'usable' button. Otherwise, the normal key matrix scan is initiated.

Actual Implementation

Below is a photo about how I installed the board in the RT200.



There is space in abundance in the right half of the cabinet, enough to install a standard Eurocard-sized prototype board (160x100mm). Since this was a singular project, I didn't feel the need for a real PCB (and the circuitry underwent quite a couple of changes...). a 40-wire ribbon cable connects the board to the socket of the old processor. I could have used one of these handy DIL connectors for the cable, but you know, it was Saturday and all shops were closed...Due to the low clock frequency, such a long cable is not a problem except for slight interferences during AM receival (who needs that in a Hifi tuner anyway...). All connections, including power supply, are made via this ribbon cable. The only other connector is the RP300 remote control input in the rear right corner.

Program Source

The program's assembler sources are available . To assemble them, you need my own cross assembler AS,

```
;***************************************************************************
;                                                                          *
; RT200 Firmware                                                           *
;                                                                          *
; Changes:                                                                 *
;   2000-08-30  /AArnold - hour digit 3..9 immediately jumps to hours ones *
;                        - clear AM+FM after entering start time           *
;   2000-09-04  /AArnold - begun decrementing frequency                    *
;   2000-09-05  /AArnold - begun programming synthesizer                   *
;   2000-09-10  /AArnold - tuning works :-)                                *
;   2000-09-11  /AArnold - added usage of program keys                     *
;   2000-09-12  /AArnold - autorepeat up/down                              *
;   2000-09-13  /AArnold - started digital frequency input                 *
;   2000-09-14  /AArnold - added search + PLL lock inputs                  *
;                        - mute during PLL adjustment                      *
;   2000-09-16  /AArnold - mute during freq. wrap                          *
;   2000-09-17  /AArnold - bail out during AM freq input,search            *
;                        - symbolically calculate delays                   *
;   2000-09-22  /AArnold - turn off station LED before search              *
;                        - switch to 256 Byte RAM                          *
;   2000-09-28  /AArnold - add remote control handling                     *
;   2000-09-30  /AArnold - remote control decoder                          *
;   2000-10-01  /AArnold - display other input sources                     *
;                        - remote ctrl off always turns off                *
;   2000-10-03  /AArnold - added step functionality                        *
;   2000-10-07  /AArnold - only check timer once a minute                  *
;   2000-10-15  /AArnold - version 1.0                                     *
;   2000-11-12  /AArnold - do not overwrite band info when tuner is        *
;                          already off                                     *
;   2001-03-02  /AArnold - fix typos in clearing once on/off times (damn!) *
;                          add copyright string                            *
;                          version 1.1                                     *
;                                                                          *
;***************************************************************************

                cpu     8052

temic           equ     1

                include "stddef51.inc"
                include "bitfuncs.inc"

                if      temic
ckcon           equ     08fh
                endif

;---------------------------------------------------------------------------
; macros:

regbank         macro   no              ; register selection
                if      no & 1
                 setb    rs0
                elseif
                 clr     rs0
                endif
                if      no & 2
                 setb    rs1
                elseif
                 clr     rs1
                endif
                endm
```

```
proc            macro   name            ; procedure frame
                section name
                public  name
name            label   $
                endm

endp            macro
                endsection
                endm

ljnz            macro   dest
                jz      skip
                ljmp    dest
skip:
                endm

ljc             macro   dest
                jnc     skip
                ljmp    dest
skip:
                endm

;---------------------------------------------------------------------------
; constants

rawclk          equ     562500          ; input clock to CPU (4.5 MHz / 8)
timeclk         equ     250             ; TOD clock
timeperiod      equ     1000/timeclk
digits          equ     6               ; # of digits in display
delval          function time,time/timeperiod

disprate        equ     68              ; desired display refresh rate in Hz
                if      temic
t0rate           equ     rawclk/6/digits/disprate ; -->timer 0 reload value
                else
t0rate           equ     rawclk/12/digits/disprate ; -->timer 0 reload value
                endif

                                        ; operation modes given by switches
                enum    mode_cset,mode_check,mode_tset,mode_cancel,mode_on,mode_off

                enum    reg0,reg1,reg2,reg3,reg4,reg5,reg6,reg7

KEY_UP          equ     14              ; misc. keys
KEY_DOWN        equ     15
KEY_AM          equ     9               ; why this double-mapping???
KEY_FM          equ     8
KEY_PHONO       equ     10
KEY_AUX         equ     11
KEY_TAPE        equ     12
KEY_TUNER       equ     13
KEY_REMOFF      equ     16
KEY_STORE       equ     17
KEY_FREQINP     equ     18
KEY_OFF         equ     19
KEY_STEP        equ     20
KEY_NONE        equ     0ffh

NUMPROGS        equ     8               ; reduce to 4 for 8031

MIN_FM          equ     0845h           ; frequency ranges:
MIN_FM1         equ     (MIN_FM|8000h)-1
MAX_FM          equ     1130h
MAX_FM1         equ     MAX_FM|8000h
DEF_FM          equ     0875h

MIN_AM          equ     0504h
```

```
MIN_AM1         equ     0495h
MAX_AM          equ     1710h
MAX_AM1         equ     1719h
DEF_AM          equ     0522h

;----------------------------------------------------------------------------
; data definitions

ON              bit     p1.7            ; control bits: turn device on
FM              bit     p1.6            ; switch AM prt on
AM              bit     p1.5            ; switch FM part on
MUTE            bit     p1.4            ; mute audio output
LATCHCLK        bit     p1.3            ; clock to synthesizer
LED             bit     p1.2            ; diagnostic LED
LOCK            bit     p1.1            ; PLL lock input
STATION_DET     bit     p1.0            ; station detection from strength indicator

PORT_AUX        equ     0               ; 4-2-10 decoder
PORT_ROW        equ     1               ; display+kbd row selection
PORT_COL        equ     2               ; display data
PORT_KBD        equ     0               ; keyboard sense
PORT_REM        equ     1               ; remote control data

                segment data
                org     20h

dispdata:       db      digits dup (?)  ; segment data is bit-addressable
__dig0          sfrb    dispdata+0
STORE           bit     __dig0.2
MHZ             bit     __dig0.4
KHZ             bit     __dig0.7
__dig2          sfrb    dispdata+2
dig2dot         bit     __dig2.0
__dig3          sfrb    dispdata+3
dig3dot         bit     __dig3.0
auxdata:        db      ?               ; data for LED 0..9 port

; things that need not be bit-addressable

clk_msec:       db      ?               ; current time
clk_sec:        db      ?
clk_min:        db      ?
clk_hour:       db      ?

time_permon:    db      ?,?             ; timer values
time_permoff:   db      ?,?
time_onceon:    db      ?,?
time_onceoff:   db      ?,?
prog_perm:      db      ?               ; program to turn on for permanent timer
prog_once:      db      ?               ; program to turn on for one-shot timer

; an FM program contains the frequency in BCD coding.  Since the 100s position
; is only one bit wide, we use the upmost bit for the +50kHz step and the
; upmost nibble remains in the valid BCD range.
;
; for example, 94.80 is stored as 0948h, 100.55 is stored as 9005h
;
; an AM program also contains the frequency in BCD coding, it is just a bit
; simpler since the 4-digit kHz value perfectly fits onto 2 bytes :-)
;
; for example, 522 is stored as 0522h, 1611 is stored as 1611h

am_progs:       db      NUMPROGS dup (2 dup (?)) ; stored programs
fm_progs:       db      NUMPROGS dup (2 dup (?))

am_prog:        db      2 dup (?)       ; current programs
fm_prog:        db      2 dup (?)
```

```
currband:       db      ?               ; AM/FM selected ?

keydata:        db      digits dup (?)  ; input from keyboard matrix


lastkey:        db      ?               ; last key read

firstdel:       db      ?

stack:          org     0d0h            ; reserve 48 bytes of stack
                db      30h dup (?)

;-----------------------------------------------------------------------------
; reset/interrupt vectors

                segment code
                org     0               ; reset entry
start:          ljmp    resinit

                org     3               ; IE0 entry (250 Hz signal)
                ljmp    clkserve

                org     0bh             ; TF0 entry (display multiplexer)
                ljmp    dispmux

;-----------------------------------------------------------------------------
; store date & time here for identification

                org     20h
                db      "RT200 Firmware (C) 2001 Alfred Arnold"
                db      " Build Date - Time : ",date," - ",time

;-----------------------------------------------------------------------------
; since we want the copyright info in plain text, we have to redefine the
; character set afterwards!

                charset 'E',10          ; shrunk charset
               charset 'r',11
               charset 'o',12
               charset 'n',13
               charset 'S',14
               charset 'y',15
                charset 'C',16
                charset 'A',17
                charset 'P',18
                charset 'h',19
                charset 'U',20
                charset 'X',21

;-----------------------------------------------------------------------------
; reset initialization

resinit:        mov     sp,#stack       ; set start of stack

                setb    ON              ; turn tuner off
                setb    MUTE
                clr     AM
                clr     FM
                clr     LATCHCLK
                setb    LED

                if      temic           ; turn on TEMIC X2 mode
                mov     ckcon,#1
                endif

                regbank 1               ; preset variables for dispmux handler:
```

```
                mov     r2,#1           ;  row shifter
                mov     r1,#dispdata    ;  data pointer displ-matrix
                mov     r0,#keydata     ;  data pointer kbd-matrix
                regbank 0

                setb    it0             ; IE0 is level-triggered
                setb    ex0             ; enable external interrupt 0
                clr     px0             ; 250 Hz interrupt has lower priority

                mov     tmod,#32h       ; T1 stopped, T0 in mode 2, no gate
                mov     th0,#(256-t0rate) ; set display mux interrupt rate
                setb    tr0             ; turn or timer 0
                setb    et0             ; interrupts on for timer 0
                setb    pt0             ; high priority

                clr     a               ; preinit clock
                mov     clk_msec,a
                mov     clk_sec,a
                mov     clk_min,a
                mov     clk_hour,a

                mov     r0,#4           ; preinit timer values to invalid times
                mov     r1,#time_permon
initimer:       mov     @r1,a
                inc     r1
                setb    acc.7           ; (meaning bit 7 in hours is set )
                mov     @r1,a
                clr     acc.7
                inc     r1
                djnz    r0,initimer

                mov     a,#0fh          ; preinit timer programs
                mov     prog_perm,a
                mov     prog_once,a

                mov     fm_prog,#lo(DEF_FM) ; preinit FM programs to 87.5 MHz
                mov     fm_prog+1,#hi(DEF_FM)
                mov     r0,#NUMPROGS
                mov     r1,#fm_progs
initfm:         mov     @r1,#lo(DEF_FM)
                inc     r1
                mov     @r1,#hi(DEF_FM)
                inc     r1
                djnz    r0,initfm

                mov     am_prog,#lo(DEF_AM) ; preinit AM programs to 522 kHz
                mov     am_prog+1,#hi(DEF_AM)
                mov     r0,#NUMPROGS
                mov     r1,#am_progs
initam:         mov     @r1,#lo(DEF_AM)
                inc     r1
                mov     @r1,#hi(DEF_AM)
                inc     r1
                djnz    r0,initam

                mov     currband,#40h   ; initially on FM

                mov     r0,#dispdata    ; init display segment+keyboard status
                mov     r1,#keydata
                mov     r2,#6
                clr     a
iniloop:        mov     @r0,a
                mov     @r1,a
                inc     r0
                inc     r1
                djnz    r2,iniloop
                mov     a,#15
                mov     auxdata,a       ; clear aux port

                mov     lastkey,#KEY_NONE ; no key previously read

                setb    ea              ; enable interrupts

;----------------------------------------------------------------------------
; main loop

main:
                call    getmode         ; get operation mode
                cjne    a,#mode_off,nooff
                call    oper
                ljmp    main
nooff:          cjne    a,#mode_on,noon
                call    chktimer        ; additionally check timer when 'on'
                call    oper
                ljmp    main
noon:           cjne    a,#mode_cset,nocset
                call    cset
                ljmp    main
nocset:         cjne    a,#mode_tset,notset
                call    tset
                ljmp    main
notset:         cjne    a,#mode_check,nocheck
                call    check
                ljmp    main
nocheck:        cjne    a,#mode_cancel,nocancel
                call    cancel
                ljmp    main
nocancel:       call    dummy
                ljmp    main

;---------------------------------------------------------------------------
; normal operation mode: display clock/frequency, check timer, operate keys

                proc    oper

                jnb     ON,showfreq
                call    dispclk         ; off->display time of day
                sjmp    keyin
showfreq:       call    dispfreq        ; on->show frequency

keyin:          mov     b,#delval(800)  ; standard timeout for first time
                call    readkey         ; input available?
                ljc     terminate

                cjne    a,#KEY_AM,no_am ; switch to AM ?
               jnb     AM,do_am       ; if AM is already selected,
               call    freqinp_am     ; then frequency input...
               ljc     terminate
                setb    MUTE            ; ...and program if OK
                call    setfreq
               ljmp    terminate
do_am:          call    switchon_am
                ljmp    terminate
no_am:

                cjne    a,#KEY_FM,no_fm ; switch to FM ?
               jnb     FM,do_fm       ; if FM is already selected,
               call    freqinp_fm     ; then frequency input...
                ljc     terminate
                setb    MUTE            ; ...and program if OK
                call    setfreq
                ljmp    terminate
do_fm:          call    switchon_fm
                ljmp    terminate
```

```
no_fm:

                cjne    a,#KEY_OFF,no_off ; switch on/off?
                jb      ON,pwr_on       ; depends on current state
                call    switchoff       ; switch off
                ljmp    terminate
pwr_on:         call    switchon
                ljmp    terminate
no_off:

                cjne    a,#KEY_REMOFF,no_remoff ; switch off ?
                call    switchoff
                ljmp    terminate
no_remoff:

                cjne    a,#KEY_TUNER,no_tuner ; switch on ?
                call    switchon
                sjmp    terminate
no_tuner:

                cjne    a,#KEY_AUX,no_aux ; switch to aux ?
                mov     dptr,#str_aux
                call    write
                mov     a,#delval(900)
                call    delay
                sjmp    terminate
no_aux:

                cjne    a,#KEY_TAPE,no_tape ; switch to tape ?
                mov     dptr,#str_tape
                call    write
                mov     a,#delval(900)
                call    delay
                sjmp    terminate
no_tape:

                cjne    a,#KEY_PHONO,no_phono ; switch to phono ?
                mov     dptr,#str_phono
                call    write
                mov     a,#delval(900)
                call    delay
                sjmp    terminate
no_phono:

                cjne    a,#KEY_UP,no_up ; tune up ?
                jb      ON,skip_up      ; not if turned off
                call    tuneup          ; otherwise do it
skip_up:        sjmp    terminate
no_up:

                cjne    a,#KEY_DOWN,no_down ; tune down ?
                jb      ON,skip_down    ; not if turned off
                call    tunedown        ; otherwise do it
skip_down:      sjmp    terminate
no_down:

               cjne    a,#KEY_STORE,no_store ; store to program?
               jb      ON,skip_store  ; not if turned off
                call    storeprg        ; do it
skip_store:     sjmp    terminate
no_store:

                cjne    a,#KEY_STEP,no_step ; step up a program ?
                mov     a,auxdata       ; get currently selected program
                anl     a,#15           ; only bits 0..3 relevant
                jnb     acc.3,step1     ; when >=8, no program was selected
                mov     a,#7            ; in such case, start from beginning
```

```
step1:          inc     a               ; go to next program
                anl     a,#7            ; possibly wrap
                sjmp    doprog          ; rest like direct selection
no_step:

                call    key2num         ; check for numbers 0..9
                jc      terminate       ; no-->ignore key
                dec     a               ; number: ignore 0 at this point
               clr     c              ; program selection ?
               subb    a,#NUMPROGS
               mov     b.7,c
                clr     c
               add     a,#NUMPROGS    ; restore key value
               jnb     b.7,no_selprg  ; when not in range...
doprog:         mov     b,currband
                jb      b.5,sel_am      ; select AM program ?
               call    switchon_fm_prg ; select FM program
               sjmp    terminate
sel_am:        call    switchon_am_prg ; select AM program
               sjmp    terminate
no_selprg:

terminate:      ret
                endp

;----------------------------------------------------------------------------
; additionally check timer in operation mode

                proc    chktimer

                mov     a,clk_sec       ; only check when hh:mm has just changed,
                jz      goon            ; i.e. seconds are zero
                ret
goon:
                mov     r0,clk_min      ; first save time
                mov     r1,clk_hour

                mov     a,r0            ; repetitive turn on?
                cjne    a,time_permon,no_permon
                mov     a,r1
                cjne    a,time_permon+1,no_permon
                mov     a,prog_perm     ; yes-->
                sjmp    turnon

no_permon:      mov     a,r0            ; repetitive turn off?
                cjne    a,time_permoff,no_permoff
                mov     a,r1
                cjne    a,time_permoff+1,no_permoff
                sjmp    turnoff         ; yes-->

no_permoff:     mov     a,r0            ; single turn on?
                cjne    a,time_onceon,no_onceon
                mov     a,r1
                cjne    a,time_onceon+1,no_onceon
                mov     time_onceon,#0  ; yes-->clear time
                mov     time_onceon+1,#80h
                mov     a,prog_once
                sjmp    turnon

no_onceon:      mov     a,r0            ; single turn off?
                cjne    a,time_onceoff,no_onceoff
                mov     a,r1
                cjne    a,time_onceoff+1,no_onceoff
                mov     time_onceoff,#0  ; yes-->clear time
                mov     time_onceoff+1,#80h
                sjmp    turnoff
```

```
no_onceoff:     ret                     ; end without hits...

turnon:         mov     c,acc.7         ; turn on: select range
                clr     acc.7           ; remove range flags from program #
                clr     acc.6
                jc      turnon_fm

                call    switchon_am_prg ; turn on AM program
                ret

turnon_fm:      call    switchon_fm_prg ; turn on FM program
                ret

turnoff:        call    switchoff       ; turn device off
                ret
                endp

;----------------------------------------------------------------------------
; setting the clock:

                proc    cset

                setb    ON              ; turn tuner off
                setb    MUTE
                clr     AM
                clr     FM

                mov     auxdata,#15     ; not needed here

                call    readnum         ; is a number available ?
                jc      idle            ; no --> display time

                mov     r3,#mode_cset   ; get rest of time
                call    readtime
                jc      idle            ; success?

                mov     clk_sec,#0      ; clear seconds (avoids rollovers while
writing m+h)
                mov     clk_hour,r5     ; store hours
                mov     clk_min,r4      ; store minutes

idle:           call    dispclk         ; show (possibly new) time
terminate:      ret
                endp

;----------------------------------------------------------------------------
; setting the timer:

                proc    tset

                setb    ON              ; turn tuner off
                setb    MUTE
                clr     AM
                clr     FM

                mov     r2,#0           ; we start with the first value (perm on)
                mov     a,r2            ; display this
                mov     auxdata,a

                call    clrdisp         ; erase display
                mov     dispdata+2,#1   ; show just a dot

loop:           clr     AM              ; AM+FM LEDs are only on during
                clr     FM              ; time/prog entry
                call    getmode         ; are we still in timer setting mode ?
                xrl     a,#mode_tset
                ljnz    terminate       ; no-->exit
                call    readkey         ; try to read a key
                jc      loop            ; none found -> back to beginning

                cjne    a,#KEY_UP,noup  ; step one setting further ?
                mov     a,r2            ; yes->increment pointer
                inc     a
stepdisp:       anl     a,#3
                mov     r2,a
                mov     auxdata,a       ; and display it
                sjmp    loop

noup:           cjne    a,#KEY_DOWN,nodown ; step one setting back ?
                mov     a,r2            ; yes->decrement pointer
                dec     a
                sjmp    stepdisp        ; rest as usual..

nodown:         call    key2num         ; now check whether this is a number?
                jc      loop            ; if no, forget this keypress finally

                mov     r3,#mode_tset   ; read rest of time
                call    readtime
                jc      loop            ; no success reading ?

                mov     a,r2            ; is this a start time?
                jb      acc.0,storetime ; yes: we have to read station#

                mov     r6,#0           ; initialize station #
                mov     a,clk_msec      ; init timer comparator: comp. bit 6&7
                anl     a,#0e0h         ; results in roughly 125 msec cycle
                add     a,#20h
                mov     r7,a

                clr     AM              ; start selection with FM
                setb    FM
rngloop:        call    getmode         ; read program type
                xrl     a,#mode_tset
                jnz     terminate
                call    readkey
                jc      rngrun
                cjne    a,#KEY_AM,no_am ; only AM/FM allowed
                mov     r6,#40h         ; AM?
                sjmp    progstart
no_am:          cjne    a,#KEY_FM,rngrun
                mov     r6,#80h         ; FM?
                sjmp    progstart
rngrun:         mov     a,clk_msec      ; time to toggle?
                anl     a,#0e0h
                xrl     a,r7
                jnz     rngloop         ; no-->
                mov     a,r7            ; calculate next time
                add     a,#20h
                mov     r7,a
                cpl     AM              ; toggle AM/FM display
                cpl     FM
                sjmp    rngloop

progstart:      mov     a,r6            ; display range selection
                rlc     a
                mov     FM,c
                rlc     a
                mov     AM,c
                mov     auxdata,#80h    ; start running display at 1
                mov     r1,#0
progloop:       call    getmode         ; read program number
                xrl     a,#mode_tset
                jnz     terminate
                call    readnum         ; number entered?
                jc      numrun          ; no-->
                dec     a               ; must be in range 0..7
                jb      acc.3,numrun
                orl     a,r6            ; otherwise merge into station marker
                mov     r6,a
                mov     a,r2            ; calculate address of station marker
                rr      a               ; we know that bit 0 was 0!
                add     a,#prog_perm
                mov     r0,a
                mov     a,r6            ; store station to RAM
                mov     @r0,a
                anl     a,#7            ; display in number LEDs
                orl     a,#80h
                mov     auxdata,a
                sjmp    storetime       ; go on storing time
numrun:         mov     a,clk_msec      ; time to increment aux display?
                anl     a,#0e0h
                xrl     a,r7
                jnz     progloop        ; no->
                mov     a,r7            ; calculate next time
                add     a,#20h
                mov     r7,a
                mov     a,auxdata       ; increment display
                inc     a
                jnb     acc.3,nwrap
                mov     a,#80h
nwrap:          mov     auxdata,a
                sjmp    progloop

storetime:      mov     a,r2            ; success: calculate address
                rl      a
                add     a,#time_permon  ; of time to write
                mov     r0,a
                mov     a,r4            ; save time
                mov     @r0,a
                inc     r0
                mov     a,r5
                mov     @r0,a

                call    clrdisp         ; clear display again
                mov     dispdata+2,#1

                mov     a,r2            ; go on with next time
                inc     a
                ljmp    stepdisp

                ljmp    loop            ; shouldn't be reached

terminate:      mov     auxdata,#15     ; turn LEDs off afterwards
                clr     AM
                clr     FM
                ret
                endp

;----------------------------------------------------------------------------
; recall timer values

                proc    check

                setb    ON              ; turn tuner off
                setb    MUTE
                clr     AM
                clr     FM

                mov     auxdata,#15     ; turn LEDs off
                call    readnum         ; wait for a number to be entered
                jc      normal          ; none->display time, abort

                dec     a               ; map 1..4->0..3
                clr     c
                subb    a,#4            ; is number in range?
                jnc     normal          ; no -> ditto

dloop:          add     a,#4            ; otherwise restore number...
                mov     r2,a            ; ...save it...
                rl      a               ; ...compute address of time...
                add     a,#time_permon
                mov     r0,a
                call    disptime        ; ...display time
                mov     dispdata+5,#0   ; don't forget to clear!

                mov     a,r2            ; restore number
                rrc     a               ; compute address of program
                clr     c
                add     a,#prog_perm
                mov     r0,a
                mov     a,@r0           ; fetch value
                mov     c,acc.7         ; display AM/FM
                mov     FM,c
                mov     c,acc.6
                mov     AM,c
                anl     a,#3fh          ; mask range bits out
                setb    acc.7           ; no blinking!
                mov     auxdata,a

wloop:          call    getmode         ; wait loop: still in check mode ?
                xrl     a,#mode_check
                jnz     normal          ; no->bail out

                call    readnum         ; otherwise wait for key as usual
                jc      wloop
                dec     a
                clr     c
                subb    a,#4
                jnc     wloop

                sjmp    dloop           ; and display when next key is correct

normal:         call    dispclk         ; none/terminate: display time
                mov     auxdata,#15     ; turn LEDs off
                clr     AM
                clr     FM

                ret
                endp

;----------------------------------------------------------------------------
; delete timer values

                proc    cancel

                setb    ON              ; turn tuner off
                setb    MUTE
                clr     AM
                clr     FM

                mov     auxdata,#15     ; turn LEDs off
                call    readnum         ; wait for a number to be entered
                jc      normal          ; none->display time, abort

                dec     a               ; map 1..4->0..3
                clr     c
                subb    a,#4            ; is number in range?
                jnc     normal          ; no -> ditto

                push    acc
                call    clrdisp         ; erase display after first numer entry
                mov     dispdata+2,#1   ; show just a dot
                pop     acc

dloop:          add     a,#4            ; otherwise restore number..
                setb    acc.7           ; ..turn LED continuously on..
                mov     auxdata,a
                clr     acc.7           ; ..compute address..
                rl      a
                add     a,#time_permon
                mov     r0,a

                clr     a               ; ..erase value
                mov     @r0,a
                setb    acc.7
                inc     r0
                mov     @r0,a

wloop:          call    getmode         ; wait loop: still in check mode ?
                xrl     a,#mode_cancel
                jnz     normal          ; no->bail out

                call    readnum         ; otherwise wait for key as usual
                jc      wloop
                dec     a
                clr     c
                subb    a,#4
                jnc     wloop

                sjmp    dloop           ; and display when next key is correct

normal:         call    dispclk         ; none/terminate: display time
                mov     auxdata,#15     ; turn LEDs off

                ret
                endp

;---------------------------------------------------------------------------
; intermediate dummy for unimplemented modes

dummy:          call    segtranslate
                mov     dispdata+1,a
                clr     a
                mov     dispdata+2,a
                mov     dispdata+3,a
                mov     dispdata+4,a
                mov     dispdata+5,a
                ret

;---------------------------------------------------------------------------
; display time of day

                proc    dispclk
                mov     a,clk_sec       ; seconds runner...
                mov     b,#6
                div     ab
                mov     a,b
                mov     r2,#80h         ; ...is a running segment
                jz      noshift         ; avoid 'zero' shift!
                xch     a,r2
shloop:         rr      a
                djnz    r2,shloop
                mov     r2,a
noshift:        mov     dispdata+5,r2
```

```
                mov     dispdata+0,#0   ; no special digits

                mov     r0,#clk_min     ; rest of time as usual
                call    disptime
                ret
                endp

;------------------------------------------------------------------------------
; 250 Hz interrupt: drives clock, runs aux port

clkserve:       setb    p3.4
                push    acc             ; save registers
                push    psw
                push    dpl
                push    dph
                regbank 2

                mov     r0,#clk_msec    ; ptr to clock values
                inc     @r0             ; increment millisecond counter
                mov     a,@r0
                xrl     a,#timeclk      ; rollover ?
                jnz     noroll
                mov     @r0,#0          ; yes -->
                inc     r0              ; points to seconds
                inc     @r0             ; increment seconds
                mov     a,@r0
                xrl     a,#60           ; second rollover ?
                jnz     noroll
                mov     @r0,#0          ; yes -->
                inc     r0              ; points to minutes
                inc     @r0             ; increment minutes
                mov     a,@r0
                xrl     a,#60           ; minute rollover ?
                jnz     noroll
                mov     @r0,#0          ; yes -->
                inc     r0              ; points to hours
                inc     @r0             ; increment hours
                mov     a,@r0
                xrl     a,#24           ; hour rollover ?
                jnz     noroll
                mov     @r0,#0          ; yes -->

noroll:         mov     dptr,#PORT_AUX  ; update aux port
                mov     a,clk_msec      ; get bit 7 of milliseconds
                orl     a,auxdata       ; turn on if either bit 7 set
                jnb     acc.7,dclear
                mov     a,auxdata
                sjmp    auxwrite
dclear:         mov     a,#15
auxwrite:       movx    @dptr,a         ; write the data

                pop     dph
                pop     dpl
                pop     psw
                pop     acc
                clr     p3.4
                reti

;------------------------------------------------------------------------------
; Timer 0 interrupt: drives display/keyboard multiplexer

dispmux:        setb    p3.5
                push    acc             ; save registers
                push    psw
                push    dpl
                push    dph
                regbank 1
                mov     dph,#0          ; only use port 0..3

                mov     dpl,#PORT_COL   ; clear display
                mov     a,#0ffh
                movx    @dptr,a

                mov     dpl,#PORT_ROW   ; select row
                mov     a,r2
                cpl     a
                movx    @dptr,a

                mov     dpl,#PORT_COL   ; output display data
                mov     a,@r1
                cpl     a
                movx    @dptr,a

                mov     dpl,#PORT_KBD   ; get kbd status
                movx    a,@dptr
                cpl     a
                mov     @r0,a

                inc     r0              ; next row
                inc     r1
                mov     a,r2
                rl      a
                jnb     acc.6,nowrap    ; back to beginning?
                mov     a,#1            ; yes-->
                mov     r1,#dispdata
                mov     r0,#keydata
nowrap:         mov     r2,a            ; write row bit back

                pop     dph
                pop     dpl
                pop     psw             ; restore registers
                pop     acc
                clr     p3.5
                reti                    ; return - IE0 is cleared automatically

;----------------------------------------------------------------------------
; get operation mode

                proc    getmode
                push    reg0
                mov     a,keydata       ; coded in first row of keyboard data
                anl     a,#3fh          ; omit bits 6&7
               mov     r0,#8          ; assume bit 7 is set (never happens...)
loop:           rlc     a               ; bit to test --> carry
               jc      bset           ; bail out if set
                djnz    r0,loop         ; otherwise go on...
               mov     r0,#mode_off+1 ; default assumption
bset:          dec     r0             ; correct value
                mov     a,r0            ; return in A
                pop     reg0
               ret
                endp

;----------------------------------------------------------------------------
; get status of autoscan switch
; Status = 1 or 0 in C

                proc    getautoscan

                mov     a,keydata+4     ; switch status is in row 4...
                mov     c,acc.5         ; ...bit 5
                ret
                endp

;----------------------------------------------------------------------------
; are we in on/off mode?
; C = 0 if yes

                proc    chkonoff
                call    getmode         ; get current mode
                clr     c               ; default: yes
                cjne    a,#mode_on,no_on; dispatch
                sjmp    yes
no_on:          cjne    a,#mode_off,no_off
                sjmp    yes
no_off:         setb    c               ; other mode
yes:            ret
                endp

;----------------------------------------------------------------------------
; store current frequency to memory

                proc    storeprg

                mov     auxdata,#15     ; clear num display
                setb    STORE           ; turn store LED on
storeloop:      call    chkonoff        ; bail out of input loop?
                jc      skip_store
                call    readnum         ; otherwise get number of program
                jc      storeloop
                dec     a               ; transform 1.. --> 0.. , 0 will be sieved out
as 0FFh
                clr     c
                subb    a,#NUMPROGS     ; in allowed range?
                mov     b.7,c
                clr     c
                add     a,#NUMPROGS
                jnb     b.7,storeloop
                setb    acc.7           ; found a valid number: show in display
                mov     auxdata,a
                clr     acc.7           ; for address computation
                rl      a
                jb      AM,store_am     ; AM/FM division
                add     a,#fm_progs     ; store FM program
                mov     r0,a
                mov     a,fm_prog
                mov     @r0,a
                inc     r0
                mov     a,fm_prog+1
                mov     @r0,a
                sjmp    skip_store
store_am:       add     a,#am_progs     ; store AM program
                mov     r0,a
                mov     a,am_prog
                mov     @r0,a
                inc     r0
                mov     a,am_prog+1
                mov     @r0,a
skip_store:     clr     STORE           ; LED off again
                ret

                endp

;----------------------------------------------------------------------------
; turn on/off:

                proc    switchon_am_prg ; with program number in A

                push    reg0            ; needed for addressing
                setb    acc.7           ; show program # on aux display
                mov     auxdata,a
                clr     acc.7
                rl      a               ; 2 bytes/entry
                add     a,#am_progs
                mov     r0,a            ; transfer data
                mov     a,@r0
                mov     am_prog,a
                inc     r0
                mov     a,@r0
                mov     am_prog+1,a
                pop     reg0
                sjmp    doswitch

                public  switchon_am

switchon_am:    mov     auxdata,#15     ; entry without program set
doswitch:       clr     FM              ; switch on & to AM
                setb    AM
                setb    MUTE
                clr     ON

                mov     a,p1            ; save AM+FM flag
                anl     a,#01100000b
                mov     currband,a

                call    setfreq         ; program synthie after turning on

                ret

                endp


                proc    switchon_fm_prg ; with program number in A

                push    reg0            ; needed for addressing
                setb    acc.7           ; show program # on aux display
                mov     auxdata,a
                clr     acc.7
                rl      a               ; 2 bytes/entry
                add     a,#fm_progs
                mov     r0,a            ; transfer data
                mov     a,@r0
                mov     fm_prog,a
                inc     r0
                mov     a,@r0
                mov     fm_prog+1,a
                pop     reg0
                sjmp    doswitch

                public  switchon_fm

switchon_fm:    mov     auxdata,#15     ; entry without program set
doswitch:       clr     AM              ; switch on & to FM
                setb    FM
                setb    MUTE
                clr     ON

                mov     a,p1            ; save AM+FM flag
                anl     a,#01100000b
                mov     currband,a

                call    setfreq         ; program synthie after turning on

                ret

                endp
                proc    switchon        ; switch on to AM or FM, whichever was last

                mov     a,currband      ; what was selected?
                jb      acc.6,switchon_fm
                sjmp    switchon_am

                ret                     ; never reached...

                endp


                proc    switchoff       ; switch off

                jb      ON,nosave       ; when tuner is already off, P1 band info is
invalid
                mov     a,p1            ; save AM+FM flag
                anl     a,#01100000b
                mov     currband,a
nosave:
                clr     AM
                clr     FM
                setb    MUTE
                setb    ON
                mov     auxdata,#15

                ret

                endp

;-----------------------------------------------------------------------------
; get a pressed key
; returns character in A, when C is clear, otherwise C is set

                proc    readkey

                push    reg0
                push    reg1
                push    reg2
                push    dpl
                push    dph

                call    kstat           ; get current key status
                jc      nokey_clr       ; if nothing present, exit immediately

                mov     r2,a            ; save keycode
                xrl     a,lastkey       ; equal to last key?
                jz      autorep         ; yes-->to possible auto repeat
                mov     a,#delval(40)   ; new key: wait 40ms for debouncing
                sjmp    waitchk

autorep:        mov     a,r2            ; repeat only for up/down
                cjne    a,#KEY_UP,noup
                mov     a,#delval(60)   ; repeat rate
                sjmp    waitchk
noup:           cjne    a,#KEY_DOWN,nokey_nclr
                mov     a,#delval(60)

waitchk:        call    delay           ; wait for the given time...
                call    kstat           ; ...and check key status again
                jc      nokey_clr       ; key released in meantime?
                xrl     a,r2            ; still the same?
                jnz     nokey_clr       ; no-->completely reset

yeskey:         mov     a,r2            ; we now have the keycode - at last!
                mov     lastkey,a       ; save for next time
                clr     c               ; signal key found
                sjmp    fin

nokey_clr:      mov     lastkey,#KEY_NONE ; clear buffer of last key
nokey_nclr:     setb    c               ; no key found
fin:            pop     dph
                pop     dpl
                pop     reg2
                pop     reg1
                pop     reg0
                ret

                proc    kstat           ; subroutine: get key status

                mov     dptr,#PORT_REM  ; first check remote control
                movx    a,@dptr
                anl     a,#3fh          ; only bits 0..5 relevant
                jz      norem           ; value 0 --> no signal from RP300
                call    remtranslate    ; otherwise translate to keycode
                jb      acc.7,norem     ; bit 7 set --> unused code
                clr     c               ; otherwise we have a code
                ret

norem:          mov     r0,#keydata+1   ; otherwise check key matrix
loop1:          mov     a,@r0           ; get data of a row
                anl     a,#0fh          ; keys only in lower nibble
                jnz     found1          ; is a bit set? yes-->
                inc     r0              ; otherwise, go to next loop
                cjne    r0,#keydata+6,loop1 ; all rows checked?
                setb    c               ; yes --> nothing found
                ret

found1:         mov     r1,a            ; save value
                mov     a,r0            ; calculate relative row address
                clr     c
                subb    a,#keydata+1
                rl      a               ; 4 keys per row
                rl      a
                mov     r0,a            ; save first part

                mov     a,r1            ; now add the bit position
                orl     a,#8            ; avoid infinite loop!
loop2:          rrc     a
                jc      found2          ; bail out if found
                inc     r0              ; otherwise check next bit
                sjmp    loop2

found2:         clr     c               ; return with result
                mov     a,r0
                ret

                endp

                endp

;---------------------------------------------------------------------------
; get a number
; returns digit in A, when C is clear, otherwise C is set

                proc    readnum

                call    readkey         ; try to get a key
                jc      done            ; give up ?

                call    key2num

done:           ret
```

```
                endp

;---------------------------------------------------------------------------
; read a time to R4(m):R5(h)
; gets first entered number in a, mode in r3

                proc    readtime

                push    reg0

                mov     r4,a
                call    clrdisp         ; first clear display
                setb    dig2dot         ; set decimal dot at this point
                mov     a,r4

                cjne    a,#0,n_1_0      ; digit must be between 0..2
                sjmp    firstgood
n_1_0:          cjne    a,#1,n_1_1
                sjmp    firstgood
n_1_1:          cjne    a,#2,skiptens   ; if not, take this as 1s of hours

firstgood:      mov     r0,a            ; save 10s of hours
                call    segtranslate    ; display them
                mov     dispdata+1,a
                mov     a,r0            ; calculate hours so far
                mov     b,#10
                mul     ab
                mov     r5,a            ; save them here
                sjmp    loop2           ; go to one's hours entry

skiptens:       mov     r4,a
                clr     a               ; no tens entered:
                mov     r5,a
                call    segtranslate    ; display 10s of hour as 0
                mov     dispdata+1,a
                mov     a,r4            ; restore ones
                sjmp    skipones

loop2:          call    getmode         ; bail out ?
                xrl     a,r3
                jnz     fail
                call    readnum         ; get second number
                jc      loop2
skipones:       mov     r0,a            ; save it temporarily
                add     a,r5            ; compute hours
                clr     c               ; >= 24 ?
                subb    a,#24
                jnc     loop2           ; yes --> not allowed
                mov     a,r0            ; otherwise, display 1s of hours
                call    segtranslate
                inc     a               ; don't forget dot
                mov     dispdata+2,a
                mov     a,r5            ; and add to 10s of hours
                add     a,r0
                mov     r5,a

loop3:          call    getmode         ; bail out ?
                xrl     a,r3
                jnz     fail
                call    readnum         ; get third number
                jc      loop3
                clr     c               ; must be <= 5
                subb    a,#6
                jnc     loop3           ; otherwise discard
                add     a,#6            ; revert subtraction
                mov     r0,a            ; save temporarily
                call    segtranslate    ; display
                mov     dispdata+3,a
                mov     a,r0            ; store to minutes
                mov     b,#10
                mul     ab
                mov     r4,a

loop4:          call    getmode         ; bail out?
                xrl     a,r3
                jnz     fail
                call    readnum         ; get last number
                jc      loop4
                mov     r0,a
                call    segtranslate
                mov     dispdata+4,a
                mov     a,r0
                add     a,r4            ; all digits 0..9 valid :-)
                mov     r4,a            ; save back to minutes
                clr     c               ; end with success

done:           pop     reg0
                ret

fail:           setb    c               ; end without success
                sjmp    done

                endp

;----------------------------------------------------------------------------
; convert key in A to number in A

                proc    key2num

                clr     c               ; numeric keys have values from 0..9
                subb    a,#10           ; i.e. we should get a borrow now
                cpl     c               ; if not...
                jc      done            ; ...forget it

                add     a,#11           ; keys 1..9 are now correct
                mov     b,#10           ; now get the 10->0 with a modulo op
                div     ab
                mov     a,b
                clr     c               ; done

done:           ret
                endp

;----------------------------------------------------------------------------
; clear numeric display

                proc    clrdisp

                clr     a               ; no comment ;-)
                mov     dispdata+1,a
                mov     dispdata+2,a
                mov     dispdata+3,a
                mov     dispdata+4,a
                mov     dispdata+5,a
                clr     KHZ
                clr     MHZ

                ret
                endp

;----------------------------------------------------------------------------
; write message at (DPTR) to display
```

```
                proc    write

                push    reg0
                call    clrdisp         ; clear other stuff
                mov     r0,#dispdata+1  ; points to leftmost digit
loop:           clr     a               ; get a byte from string
                movc    a,@a+dptr
                jz      done            ; terminate at NUL
                call    segtranslate    ; otherwise translate...
                mov     @r0,a           ; ...and print
                inc     dptr            ; next char
                inc     r0              ; next digit
                mov     a,r0            ; end of display reached?
                cjne    a,#dispdata+6,loop
done:           pop     reg0
                ret

                endp

;----------------------------------------------------------------------------
; display a time stored at (R0)

                proc    disptime

                inc     r0              ; bit 7 of hours set ?
                mov     a,@r0
                dec     r0
                jb      acc.7,invtime

                clr     KHZ             ; no frequency display!
                clr     MHZ

                mov     a,@r0           ; display minutes
                mov     b,#10
                div     ab
                call    segtranslate
                mov     dispdata+3,a
                mov     a,b
                call    segtranslate
                mov     dispdata+4,a
                inc     r0
                mov     a,@r0           ; display hourss
                mov     b,#10
                div     ab
                jz      suppress        ; suppress leading 0 for hours
                call    segtranslate
suppress:       mov     dispdata+1,a
                mov     a,b
                call    segtranslate
                setb    acc.0           ; dot between hour + min
                mov     dispdata+2,a

                ret

invtime:        clr     a               ; clear display for invalid time
                mov     dispdata+1,a
                mov     dispdata+3,a
                mov     dispdata+4,a
                setb    acc.0
                mov     dispdata+2,a

                ret

                endp

;----------------------------------------------------------------------------
; display frequency
```

```
                proc    dispfreq
                jb      AM,amdisp       ; display AM or FM
                call    dispfm
                sjmp    done
amdisp:         call    dispam
done:           ret
                endp

;---------------------------------------------------------------------------
; display AM frequency

                proc    dispam

                mov     a,am_prog+1     ; get higher byte
                mov     b,#16           ; split into digits
                div     ab
                jz      zero            ; suppress leading 0
                call    segtranslate    ; display 10s..
zero:           mov     dispdata+1,a
                mov     a,b             ; ..1s..
                call    segtranslate
                mov     dispdata+2,a

                mov     a,am_prog       ; get lower byte
                mov     b,#16           ; split into digits
                div     ab
                call    segtranslate    ; display 10s..
                mov     dispdata+3,a
                mov     a,b             ; ..1s..
                call    segtranslate
                mov     dispdata+4,a

                mov     dispdata+5,#0   ; unused place

                clr     MHZ
                setb    KHZ

                ret

                endp

;---------------------------------------------------------------------------
; display FM frequency

                proc    dispfm

                mov     a,fm_prog+1     ; get higher byte
                clr     acc.7           ; clear 50kHz step
                mov     b,#16           ; split into digits
                div     ab
                jz      zero            ; suppress leading 0
                call    segtranslate    ; display 100s..
zero:           mov     dispdata+1,a
                mov     a,b             ; ..10s..
                call    segtranslate
                mov     dispdata+2,a

                mov     a,fm_prog       ; get lower byte
                mov     b,#16           ; split into digits
                div     ab
                call    segtranslate    ; display 1s..
                setb    acc.0
                mov     dispdata+3,a
                mov     a,b             ; ..0.1s..
                call    segtranslate
                mov     dispdata+4,a
                mov     a,fm_prog+1     ; display .05 step
                mov     c,acc.7
                clr     a
                mov     acc.0,c
                mov     acc.2,c
                call    segtranslate
                mov     dispdata+5,a    ; unused place

                clr     KHZ
                setb    MHZ

                ret

                endp

;----------------------------------------------------------------------------
; tune up: manually increment with optional auto-repeat, search

                proc    tuneup

                public  doauto_up

                mov     auxdata,#15     ; surely not a set program any more!
                call    getautoscan     ; shall we search ?
                jc      doauto_up       ; yes-->

                call    freq_up         ; one manual step up
                call    setfreq
                call    dispfreq
                mov     firstdel,#13    ; leave about 13 steps out until repeat starts
uploop:         call    readkey         ; still up key pressed ?
                jc      terminate
                xrl     a,#KEY_UP
                jnz     terminate
                mov     a,firstdel      ; still in delay phase ?
                jz      dostep
                dec     a               ; yes-->
                mov     firstdel,a
                sjmp    uploop
dostep:         setb    MUTE            ; mute in repeat mode
                call    freq_up         ; one repeat step
                call    setfreq
                call    dispfreq
                sjmp    uploop

terminate:      ret

doauto_up:      call    getautoscan     ; auto scan terminated ?
                jnc     terminate       ; yes-->bail out
                call    chkonoff        ; tuner still on?
                jc      terminate       ; no-->bail out
                call    readkey         ; key pressed ?
                jc      nokey
                cjne    a,#KEY_UP,noup  ; further up key inputs ignored
                sjmp    nokey
noup:           cjne    a,#KEY_DOWN,terminate ; key up changes search direction
                sjmp    doauto_dn
nokey:          setb    MUTE            ; search loop: silence
                call    freq_up         ; one step up
                call    dispfreq
                call    setfreq
                mov     a,#delval(100)  ; wait a moment for tuner to sync
                call    delay
                jb      STATION_DET,terminate ; stop if found
                sjmp    doauto_up       ; otherwise go on
                endp

;----------------------------------------------------------------------------
; tune down: manually increment with optional auto-repeat, search

                proc    tunedown

                public  doauto_dn

                mov     auxdata,#15     ; surely not a set program any more!
                call    getautoscan     ; shall we search ?
                jc      doauto_dn       ; yes-->

                call    freq_down       ; one manual step down
                call    setfreq
                call    dispfreq
                mov     firstdel,#13    ; leave about 13 steps out until repeat
downloop:       call    readkey         ; still down key pressed ?
                jc      terminate
                xrl     a,#KEY_DOWN
                jnz     terminate
                mov     a,firstdel      ; still in delay phase ?
                jz      dostep
                dec     a               ; yes-->
                mov     firstdel,a
                sjmp    downloop
dostep:         setb    MUTE            ; mute in repeat mode
                call    freq_down       ; one repeat step
                call    setfreq
                call    dispfreq
                sjmp    downloop

terminate:      ret

doauto_dn:      call    getautoscan     ; auto scan terminated ?
                jnc     terminate       ; yes-->bail out
                call    chkonoff        ; tuner still on?
                jc      terminate       ; no-->bail out
                call    readkey         ; key pressed ?
                jc      nokey
                cjne    a,#KEY_DOWN,nodown ; further key inputs ignored
                sjmp    nokey
nodown:         cjne    a,#KEY_UP,terminate ; key up changes search direction
                sjmp    doauto_up
nokey:          setb    MUTE            ; search loop: silence
                call    freq_down       ; one step up
                call    dispfreq
                call    setfreq
                mov     a,#delval(100)  ; wait a moment for tuner to sync
                call    delay
                jb      STATION_DET,terminate ; stop if found
                sjmp    doauto_dn       ; otherwise go on

                endp

;----------------------------------------------------------------------------
; increment frequency

                proc    freq_up

                jb      FM,incfm        ; differentiate AM/FM

                mov     a,am_prog       ; increment lower part
                add     a,#9
                da      a
                mov     am_prog,a
                jnc     amdone
                mov     a,am_prog+1     ; optionally increment upper part
                add     a,#1
                da      a
                mov     am_prog+1,a

amdone:         mov     a,am_prog       ; hit upper limit?
                cjne    a,#lo(MAX_AM1),done
                mov     a,am_prog+1
                cjne    a,#HI(MAX_AM1),done

                mov     am_prog,#LO(MIN_AM)    ; yes-->set to lower limit
                mov     am_prog+1,#HI(MIN_AM)

                setb    MUTE            ; we don't want to hear the PLL sync in this
case!

                sjmp    done

incfm:          mov     a,fm_prog+1     ; first toggle 50kHz flag
                cpl     acc.7
                mov     fm_prog+1,a
                jb      acc.7,fmdone    ; if bit goes to 1, no carry

                mov     a,fm_prog       ; otherwise increment next frequency digit
                add     a,#1
                da      a
                mov     fm_prog,a
                jnc     fmdone          ; done if no carry

                mov     a,fm_prog+1     ; otherwise increment upper byte
                add     a,#1
                da      a
                mov     fm_prog+1,a

fmdone:         mov     a,fm_prog       ; hit upper limit?
                cjne    a,#lo(MAX_FM1),done
                mov     a,fm_prog+1
                cjne    a,#HI(MAX_FM1),done

                mov     fm_prog,#LO(MIN_FM)    ; yes-->set to lower limit
                mov     fm_prog+1,#HI(MIN_FM)

                setb    MUTE            ; we don't want to hear the PLL sync in this
case!

done:           ret

                endp

;---------------------------------------------------------------------------
; decrement frequency

                proc    freq_down

                jb      FM,decfm        ; differentiate AM/FM

                mov     a,am_prog       ; decrement lower part
                clr     c
                subb    a,#9
                call    da_s
                mov     am_prog,a
                jnc     amdone

                mov     a,am_prog+1     ; optionally decrement upper part
                clr     c
                subb    a,#1
                call    da_s
                mov     am_prog+1,a

amdone:         mov     a,am_prog       ; hit lower limit?
                cjne    a,#lo(MIN_AM1),done
                mov     a,am_prog+1
                cjne    a,#HI(MIN_AM1),done

                mov     am_prog,#LO(MAX_AM)    ; yes-->set to upper limit
                mov     am_prog+1,#HI(MAX_AM)

                setb    MUTE            ; we don't want to hear the PLL sync in this
case!

                sjmp    done

decfm:          mov     a,fm_prog+1     ; first toggle 50kHz flag
                cpl     acc.7
                mov     fm_prog+1,a
                jnb     acc.7,fmdone    ; if bit goes to 0, no carry

                mov     a,fm_prog       ; otherwise decrement next frequency
                clr     c
                subb    a,#1
                call    da_s
                mov     fm_prog,a
                jnc     fmdone          ; done if no carry

                mov     a,fm_prog+1     ; otherwise decrement upper byte
                clr     c
                subb    a,#1
                call    da_s
                mov     fm_prog+1,a

fmdone:         mov     a,fm_prog       ; hit lower limit?
                cjne    a,#lo(MIN_FM1),done
                mov     a,fm_prog+1
                cjne    a,#HI(MIN_FM1),done

                mov     fm_prog,#LO(MAX_FM)    ; yes-->set to upper limit
                mov     fm_prog+1,#HI(MAX_FM)

                setb    MUTE            ; we don't want to hear the PLL sync in this
case!

done:           ret

                endp

;----------------------------------------------------------------------------
; digital input of FM frequency

               proc    freqinp_fm

               call    clrdisp                ; preinitialize display
               setb    MHZ
                mov     auxdata,#15
                setb    dig3dot
               mov     r5,#0                  ; need preinit for different branches

loop1:          call    chkonoff                ; bail out ?
                ljc     badval
                call    readnum                 ; get first digit
               jc      loop1
               cjne    a,#0,no0               ; is this 0 or 1 ?
               sjmp    ishund
no0:           cjne    a,#1,isten
```

```
                sjmp    ishund

isten:          orl     a,r5                    ; tens: store digit
                mov     r5,a
                anl     a,#15
                call    segtranslate            ; display
                mov     dispdata+2,a
                sjmp    loop3

ishund:         swap    a                       ; 0 or 1: store as 100s
                mov     r5,a
                swap    a                       ; display 100s
                call    segtranslate
                mov     dispdata+1,a

loop2:          call    chkonoff                ; bail out ?
                jc      badval
                call    readnum                 ; get tens of MHz
                jc      loop2
                sjmp    isten                   ; go on as in other case

loop3:          call    chkonoff                ; bail out ?
                jc      badval
                call    readnum                 ; get ones
                jc      loop3
                swap    a                       ; store them
                mov     r4,a
                swap    a                       ; display them
                call    segtranslate
                inc     a                       ; don't forget dot!
                mov     dispdata+3,a

loop4:          call    chkonoff                ; bail out ?
                jc      badval
                call    readnum                 ; get 100s of kHz
                jc      loop4
                orl     a,r4                    ; merge in
                mov     r4,a
                anl     a,#15                   ; display
                call    segtranslate
                mov     dispdata+4,a

loop5:          call    chkonoff                ; bail out ?
                jc      badval
                call    readnum                 ; get opt. 50 kHz step
                jc      loop5
                mov     b,a                     ; save last digit
                jz      no50                    ; no 50 kHz step ?
                cjne    a,#5,loop5              ; ignore everyting but 0 and 5
                mov     a,r5                    ; otherwise set 50 kHz flag
                setb    acc.7
                mov     r5,a

; since the LSB (the 50kHz step) is by default in the upmost bit, comparison
; becomes simpler when we rotate everything one digit left

no50:           mov     a,b                     ; display last digit
                call    segtranslate
                mov     dispdata+5,a
                mov     a,#lo(MIN_FM)           ; compute lower bound
                mov     b,#hi(MIN_FM)
                call    lrot16
                mov     r0,a
                mov     r1,b
                mov     a,r4                    ; rotate comparison value
                mov     b,r5
                call    lrot16
                call    sub16                   ; compare values
                jc      badval                  ; C=1 -> not good

                mov     a,#lo(MAX_FM1)          ; compute upper bound
                mov     b,#hi(MAX_FM1)
                call    lrot16
                mov     r0,a
                mov     r1,b
                mov     a,r4                    ; rotate comparison value
                mov     b,r5
                call    lrot16
                call    sub16                   ; compare values
                jnc     badval                  ; C=0 -> not good

                clr     c                       ; everything fine:
                mov     a,r4                    ; store to current frequency
                mov     fm_prog,a
                mov     a,r5
                mov     fm_prog+1,a
                ret

badval:         mov      dptr,#str_error          ; respond that that was invalid
                call     write
                mov      a,#delval(800)           ; leave err msg visible a bit
                call     delay
                setb    c                       ; not good...
                ret

                endp

;----------------------------------------------------------------------------
; digital input of AM frequency

                proc    freqinp_am

                call    clrdisp                 ; preinitialize display
                setb    KHZ
                mov      auxdata,#15
                mov     r5,#0                   ; need preinit for different branches
                mov     r3,#0

loop1:          call     chkonoff                 ; bail out ?
                ljc      badval
                call     readnum                  ; get first digit
                jc      loop1
                cjne    a,#0,no0                ; is this 0 or 1 ?
                sjmp    isthou
no0:            cjne    a,#1,ishund
                sjmp     isthou

ishund:         orl     a,r5                    ; hundreds: store digit
                mov     r5,a
                anl     a,#15
                call    segtranslate            ; display
                mov      dispdata+2,a
                sjmp    loop3

isthou:         swap    a                       ; 0 or 1: store as 1000s
                mov     r5,a
                swap    a                       ; display 1000s
                call    segtranslate
                mov      dispdata+1,a

loop2:          call     chkonoff                 ; bail out ?
                jc       badval
                call     readnum                  ; get hundreds of kHz
                jc      loop2
```

```
               sjmp    ishund                 ; go on as in other case

loop3:          call    chkonoff                ; bail out ?
                jc      badval
                call    readnum                 ; get tens
               jc      loop3
               swap    a                      ; store them
               mov     r4,a
               swap    a                      ; display them
               call    segtranslate
                mov     dispdata+3,a

loop4:          call    chkonoff                ; bail out ?
                jc      badval
                call    readnum                 ; get 1s of kHz
               jc      loop4
               orl     a,r4                   ; merge in
               mov     r4,a
               anl     a,#15                  ; display
               call    segtranslate
                mov     dispdata+4,a

                mov     r0,#lo(MIN_AM)          ; compare lower bound
                mov     r1,#hi(MIN_AM)
               mov     a,r4                   ; get comparison value
               mov     b,r5
               call    sub16                  ; compare values
               jc      badval                 ; C=1 -> not good

               mov     r0,#lo(MAX_AM1)        ; compare upper bound
               mov     r1,#hi(MAX_AM1)
               mov     a,r4                   ; rotate comparison value
               mov     b,r5
               call    sub16                  ; compare values
               jnc     badval                 ; C=0 -> not good

               mov     a,r4                   ; build digit sum (must be dividable by
9)
               mov     b,#16
               div     ab
               add     a,b
               mov     r3,a
               mov     a,r5
               mov     b,#16
               div     ab
               add     a,b
               add     a,r3
               mov     b,#9                   ; check if remainder 0
                div     ab
               mov     a,b
               jnz     badval

               clr     c                      ; everything fine:
               mov     a,r4                   ; store to current frequency
               mov     am_prog,a
               mov     a,r5
               mov     am_prog+1,a
               ret

badval:         mov     dptr,#str_error         ; respond that that was invalid
                call    write
                mov     a,#delval(800)          ; leave err msg visible a bit
                call    delay
                setb    c                       ; not good...
               ret

               endp
```

```
;---------------------------------------------------------------------------
; program current frequency into synthesizer

                proc    setfreq

                clr     ea              ; we need the display lines for the synthie
                                        ; at this point, therefore clear diaplay

                mov     dptr,#PORT_ROW  ; blank display
                mov     a,#0ffh
                movx    @dptr,a

                mov     dptr,#PORT_COL  ; bits 0..3 contain register address/data

                jb      AM,do_am        ; program for AM ?

                mov     r0,#1           ; constant value for FM
                mov     a,fm_prog       ; add the 10.7 MHz IF to frequency
                add     a,#07h
                da      a
                mov     r4,a            ; save 100s of kHz
                swap    a               ; save 1s of MHz
                mov     r3,a
                mov     a,fm_prog+1     ; addition of upper part
                addc    a,#01h
                da      a
                mov     r5,#4           ; assume no 50 kHz offset
                jnb     acc.7,no50
                mov     r5,#2           ; otherwise different value for reg 7
no50:           clr     acc.7           ; remove +50 flag
                mov     r2,a            ; save 10s of MHz
                swap    a               ; save 100s of MHz
                mov     r1,a
                sjmp    do_it           ; skip to programming

do_am:          mov     r0,#2           ; constant value for AM
                mov     a,am_prog       ; add the 450 kHz IF to frequency
                add     a,#50h
                da      a
                mov     r4,a            ; save LSB temporarily
                mov     a,am_prog+1     ; add MSBs
                addc    a,#04h
                da      a
                call    dec2bin         ; now start division by 9: first step
                mov     b,#9
                div     ab
                mov     r1,a            ; -->100s result
                mov     a,r4            ; build next part of division: remainder|10s
                anl     a,#0f0h
                orl     a,b
                swap    a
                call    dec2bin
                mov     b,#9
                div     ab
                mov     r2,a            ; -->10s result
                mov     a,r4            ; build last part of division: remainder|1s
                anl     a,#0fh
                swap    a
                orl     a,b
                swap    a
                call    dec2bin
                mov     b,#9
                div     ab
                mov     r3,a            ; remainder should be 0 now ;-)
                mov     r4,#0           ; constant values for AM
                mov     r5,#0
```

```
do_it:          mov     a,#2            ; first, set register 2 to 0
                lcall   setsyn
                setb    LATCHCLK
                mov     a,#0
                lcall   setsyn
                clr     LATCHCLK

                mov     a,#1            ; next, value for reg 1
                lcall   setsyn
                setb    LATCHCLK
                mov     a,r0
                lcall   setsyn
                clr     LATCHCLK

                mov     a,#3            ; next, value for reg 3
                lcall   setsyn
                setb    LATCHCLK
                mov     a,r1
                lcall   setsyn
                clr     LATCHCLK

                mov     a,#4            ; next, value for reg 4
                lcall   setsyn
                setb    LATCHCLK
                mov     a,r2
                lcall   setsyn
                clr     LATCHCLK

                mov     a,#5            ; next, value for reg 5
                lcall   setsyn
                setb    LATCHCLK
                mov     a,r3
                lcall   setsyn
                clr     LATCHCLK

                mov     a,#6            ; next, value for reg 6
                lcall   setsyn
                setb    LATCHCLK
                mov     a,r4
                lcall   setsyn
                clr     LATCHCLK

                mov     a,#7            ; next, value for reg 7
                lcall   setsyn
                setb    LATCHCLK
                mov     a,r5
                lcall   setsyn
                clr     LATCHCLK

                mov     a,#8            ; finally, set register 8 to 7
                lcall   setsyn
                setb    LATCHCLK
                mov     a,#7
                lcall   setsyn
                clr     LATCHCLK

done:           setb    ea              ; reenable ints

                mov     a,#delval(999)  ; wait max. 1 sec for PLL to sync
               call    nexttime
               mov     b,a
syncloop:       jb      LOCK,didsync    ; PLL has found frequency
               mov     a,clk_msec     ; otherwise, test for timeout
               xrl     a,b
                jnz     syncloop        ; go on testing if not timed out
                mov     dptr,#str_nosyn ; print sync error
                call    write
                mov     a,#delval(800)
               call    delay

didsync:       clr     MUTE           ; turn Audio on again

                ret

setsyn:         anl     a,#15           ; mask nibble
                add     a,#2            ; correct value
                movc    a,@a+pc         ; read from table
                movx    @dptr,a         ; write to port
                ret                     ; done
                db      00h,80h,40h,0c0h; table for bit mirroring
                db      20h,0a0h,60h,0e0h
                db      10h,90h,50h,0d0h
                db      30h,0b0h,70h,0f0h

                endp

;---------------------------------------------------------------------------
; delay by (A) ticks (1 tick = 4ms @ 250Hz)

                proc    delay
                push    reg0
                inc     a               ; first assure we don't wait too few
                add     a,clk_msec      ; compute target value
                mov     r0,a            ; save this
                add     a,#6            ; is the target value between 250..255 ?
                jnc     loop
                mov     r0,a            ; yes->wrap it
loop:           mov     a,clk_msec      ; wait for target value
                xrl     a,r0
                jnz     loop
                pop     reg0
                ret
                endp

;---------------------------------------------------------------------------
; calculate target tick value, taking 249->0 rollover into account

                proc    nexttime
                push    reg0
                forward nowrap
                inc     a               ; first assure we don't wait too few
                add     a,clk_msec      ; compute target value
                mov     r0,a            ; save this
                add     a,#6            ; is the target value between 250..255 ?
                jnc     nowrap
                mov     r0,a            ; yes->wrap it
nowrap:         mov     a,r0
                pop     reg0
                ret
                endp

;---------------------------------------------------------------------------
; decimal adjustment after subtraction

                proc    da_s

                mov     b,psw           ; save C+AC
                mov     c,ac            ; first process lower nibble
                call    donibble
                mov     b.6,c
                swap    a               ; then process upper nibble
                mov     c,b.7
                call    donibble
                mov     b.7,c
                swap    a
                mov     psw,b           ; get carry results
                ret

donibble:       jc      do              ; always do when carry set
                jnb     acc.3,nodo      ; don't do for 0..7
                jb      acc.2,do        ; do for C..F
                jnb     acc.2,nodo      ; don't do for 8..9
                                        ; -->do for A..B
do:             clr     c               ; correction value
                subb    a,#6
                setb    c
                ret

nodo:           clr     c               ; no correction
                ret

                endp

;---------------------------------------------------------------------------
; conversion BCD --> BIN:

                proc    dec2bin

                push    acc             ; save temporarily
                swap    a               ; extract 10s digit
                anl     a,#0fh
                mov     b,#10           ; multiply up
                mul     ab
                mov     b,a             ; save temp result
                pop     acc             ; extract ones
                anl     a,#0fh
                add     a,b             ; assemble result

                ret

                endp

;---------------------------------------------------------------------------
; 16-bit-rotation of B:A :

               proc    lrot16

               rlc     a              ; rot lower half, bit into cary
               xch     a,b            ; rot upper half
               rlc     a
               xch     a,b
               mov     acc.0,c        ; correct bit that wrapped

               ret

               endp

;---------------------------------------------------------------------------
; 16-bit-subtraction of B:A - R1:R0 :

               proc    sub16

               clr     c              ; lower half
               subb    a,r0
               xch     a,b            ; upper half
               subb    a,r1
               xch     a,b
               ret

               endp

;---------------------------------------------------------------------------
; segment translation; 0-9
;
; Bits:     7
;          2 6
;           1
;          3 5
;           4

segtranslate:   inc     a
                movc    a,@a+pc
                ret
                db      0fch,060h,0dah  ; 7-segment codes for decimals 0..9
                db      0f2h,066h,0b6h
                db      0beh,0e0h,0feh
                db      0f6h
                db      09eh,00ah,03ah  ; e,r,o
                db      02ah,0b6h,076h  ; n,S,y
                db      09ch,0eeh,0ceh  ; C,A,P
                db      02eh,07ch,06eh  ; h,U,X

;---------------------------------------------------------------------------
; segment translation; 0-9/A-F

hextranslate:   inc     a
                movc    a,@a+pc
                ret
                db      0fch,060h,0dah  ; 7-segment codes for decimals 0..9
                db      0f2h,066h,0b6h
                db      0beh,0e0h,0feh
                db      0f6h
                db      0eeh,03eh,01ah  ; 7-segment codes for hex A..F
                db      07ah,09eh,08eh

;---------------------------------------------------------------------------
; remote control decoder

                proc    remtranslate

                anl     a,#3fh          ; only bit 0..5 relevant
                inc     a
                movc    a,@a+pc
                ret

                db      80h,00h,01h,02h,03h,04h,05h,06h
                db      07h,08h,09h,KEY_STEP,KEY_FREQINP,80h,80h,80h
                db      80h,80h,80h,KEY_TAPE,KEY_TUNER,KEY_PHONO,KEY_AUX,80h
                db      80h,80h,80h,KEY_TAPE,80h,80h,80h,80h
                db      80h,80h,80h,80h,KEY_REMOFF,80h,80h,80h
                db      80h,80h,80h,80h,80h,80h,80h,80h
                db      80h,80h,80h,80h,80h,80h,80h,80h
                db      KEY_DOWN,KEY_UP,80h,KEY_STORE,80h,80h,80h,80h

                endp

;---------------------------------------------------------------------------
; string constants
; hint: these are not ASCII-coded, we use a 'squeezed' set since anyway only
; a few characters are printable on a 7-segment display

str_error:      db      "Error",0
str_nosyn:      db      "noSyn",0
str_tape:       db      "CASS",0
```

```
str_phono:      db      "Phono",0
str_aux:        db      "AUX",0

;----------------------------------------------------------------------------

                end
```

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The Macroassembler AS

Main Page

Latest released version is 1.41r8 (1999-07-11)
Latest -current version is 1.42Bld54 (2006-12-19)
For Mailing List for AS Users, see bottom of this page

Patrick Conrad has provided a Belorussian translation of these pages. Many thanks for his efforts! Click here for his translation.

AS is a portable macro cross assembler for a variety of microprocessors and -controllers. Though it is mainly targeted at embedded processors and single-board computers, you also find CPU families in the target list that are used in workstations and PCs.

AS is completely free, i.e. you may use it for any commercial or non-commercial purpose without having to pay for it. If your really like AS, I encourage you to either send a bit of money to Greenpeace or a bottle of your favourite wine to me. If you want to integrate AS or parts of it into other projects, please contact me; since I really appreciate GNU and its targets, I think that someone who uses parts of AS or extends it should return something into the "freeware pool"; it's just a matter of fairness!

You may already have noticed that I did not pay much attention to the outer appearance of these pages; The reasons are manifold:

- Lack of time;
- Laziness ;->
- Better readability with Lynx