AN494

An HC11-Controlled Multiband RDS Radio

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This application note describes the software and hardware features of the microcontroller (MCU) of a synthesized multiband radio which includes RDS (radio data system) decoding (FM, band II). It uses an MC68HC(7)11 MCU whose program can be on-chip or contained in an external EPROM (erasable programmable read-only memory). ROM versions are available.

Both LCD (liquid crystal display) and VFD (vacuum fluorescent display) 16-character dot matrix display modules can be used to display RDS and tuning information. Traffic messages, initiated by the reception of EON (enhanced other networks) data (group 14B) or TA = TP = 1 (traffic announcement = traffic program = 1) on the current frequency, are handled. The station carrying the TA is tuned for the duration of the message, followed by a return to the original frequency. A tuning knob employing an incremental encoder is supported.

Introduction

Figure 1 shows a block diagram of the application. The controller hardware and software are described in detail here. The other hardware is not covered to the same depth, because that varies between different implementations, the intention being to describe a controller which could

be added to an existing radio or to one which includes only one or two of the possible bands.

Separate FM and AM PLLs (phase-locked loop) are shown. This is not essential, but it reduces the amount of band switching necessary and simplifies hardware fault finding. The illustrated configuration corresponds to that used by the author for software development and debugging.

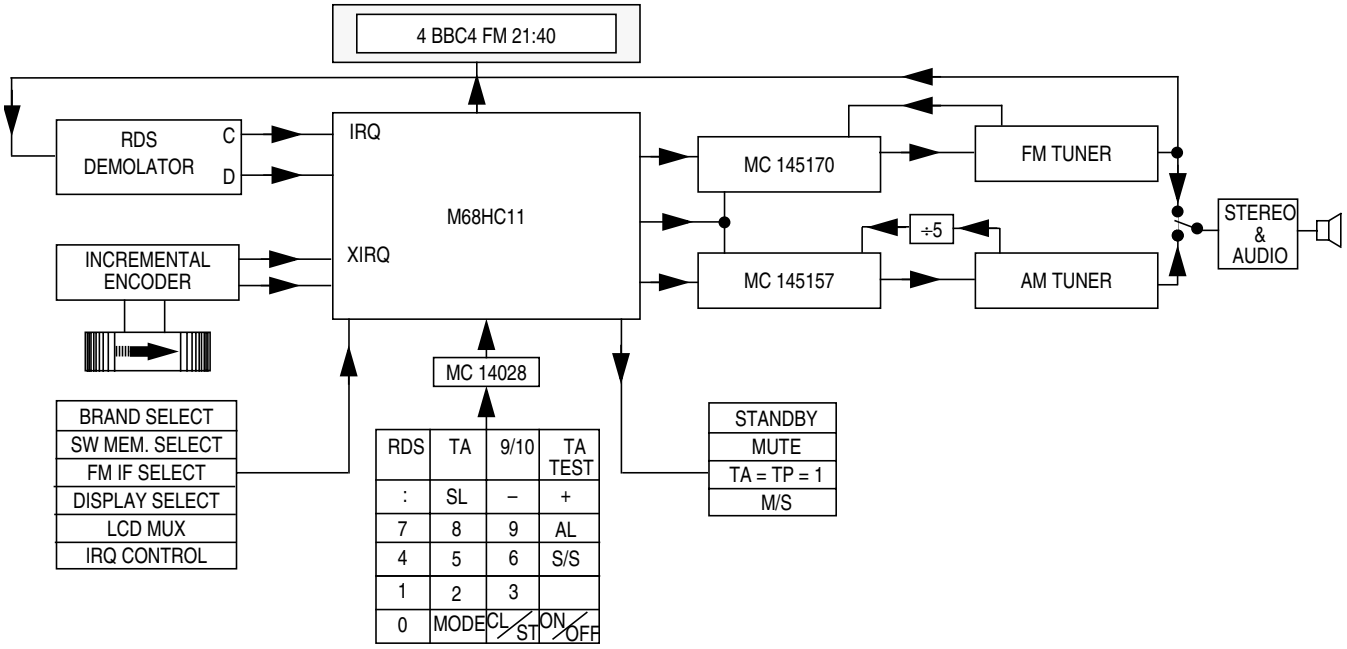


Figure 1. Main Block Diagram

The MCU used is the MC68HC(7)11. The MC68HC711K4 (K4) [and similar chips such as the MC68HC711P2 (P2) and MC68HC711PH8 (PH8)] can be used in expanded mode, but this application has been included in the ROM of an E32 and a PH8.

To use the ROMed parts in this application, the first three bytes of EEPROM (electrically erasable programmable ROM) should contain an extended jump to the appropriate start address. The E32 (ZC403311) requires $7E, $90, and $00 at addresses $B600, $B601, and $B602, while the PH8 (ZC428200 or ZC428202) requires $7E, $40, and $00 at

addresses $0D00, $0D01, and $0D02. This can be done using either PCbug11 or the BUFFALO (bit users fast friendly aid to logical operation) monitor (see reference 5). The E32 version uses all the input/output (I/O) and can, therefore, be used only in single-chip mode. The circuit diagram of the HC11E controller is shown in **Figure 3** and the circuit diagram of the K4/PH8 in **Figure 4**. The K4/PH8 version shows the additional hardware (within the dotted line) used to develop and debug the software on a K4 using PCbug11. This implementation uses two of the K4's chip selects to enable external memories allowing debug to be done with the code in RAM and the PCbug11 talker in an EPROM. This arrangement requires a further four I/O (input/output) lines, leaving 30 for use in the application. The description of the application, and the listed software, corresponds to the E32 ROMed version (ZC403311). Later sections list the port allocation and functional differences which apply to the PH8 ROMed versions (ZC428200 and ZC428202).

Forty programs (10 on FM, 10 on MW and 20 on SW) can be stored using the HC11E's on-chip EEPROM (the PH8 has 20 additional SW (shortwave) programs). Each contains frequency, an 8-character name [PS (program service) name on a station with RDS] and, on FM only, PI (program identification) code and a TA inhibit bit. For stations with no RDS (for example, all AM stations), the saved name can be manually entered. Programs saved with no name use their frequency instead. The SW banks are selected by an I/O line (two for the PH8). When the MCU is reset, or any of the band or memory select inputs are changed, the last used program in the selected band is tuned. This feature does not require that the MCU is permanently powered up, as this information is also stored in non-volatile EEPROM.

The keyboard uses an MC14028 decoder to minimize the number of I/O lines used. Either LCD or VFD 16-digit dot matrix displays can be used. The VFD display driver supported is the MSC7128, and the LCD driver the HD44780. This driver on its own provides a 16-way multiplexed LCD. In conjunction with an HD44100, it can facilitate an 8-way multiplexed higher contrast display. The input level on a port pin selects the appropriate type of multiplexing to match the display in use. To minimize the I/O activity, only one display is driven, the choice between LCD and VFD again being determined by an I/O line.

MC145170 and MC145157 PLLs are supported, using the same data and clock lines as the VFD driver, along with dedicated chip selects. The MC145157 requires an external prescaler for frequencies above 20 MHz, but the MC145170 has an on-chip 160-MHz capability.

A tuning knob can be included by using an incremental encoder. This can utilize either IRQ or XIRQ. As IRQ is used for the RDS clock, XIRQ is most appropriate for the tuning function. The possibility of using IRQ (see information described later) has been included to facilitate debug with PCbug11, which can employ XIRQ for its communication with the PC. Edges detected on the encoder execute the PS edit and alarm setup functions of the +/– (plus/minus) keys, depending on the direction of rotation. This provides a quick and convenient method of editing the PS name and changing the alarm time. A difference in function between the encoder and the +/– keys applies in normal mode. The program number is not affected by the tuning knob. In this mode, when the +/– keys control the program number, the tuning knob increments or decrements the frequency.

Two I/O lines are used to select the band. These lines are regularly monitored; if they change, the radio is retuned to the last used station in the selected band. **Table 1** shows the bands which are available.

- Band 2 is intended for single-conversion (low IF, intermediate frequency) MW or SW radios. The large step size of 9 or 10 kHz is suitable for MW rather than SW, but the small step size of 1 kHz is suitable for either SW or MW.
- Band 3 is for dual-conversion (10.7-MHz first IF) SW designs. The FM IF offset is selected as + or –, according to the level on port A, bit 2 (high: LO high; low: LO low).
- Bands 0 and 1 both are intended for VHF/FM, the difference between them being in the use of the M68HC11's IRQ pin. It is possible to use IRQ interrupts for both RDS and the tuning knob, as the two functions are not required simultaneously. To facilitate this, the band-select inputs affect the function performed when an edge is detected in the IRQ pin. When band 0 is selected, an RDS bit is read, but in any other band the incremental encoder function is performed. This enables automatic selection of function if bit 0

on port A is taken high when movement is detected from the shaft encoder. This facility can be disabled (RDS function only) by holding bit 3 of port A low. This should be done if XIRQ is being used for the tuning knob. As XIRQ is level-sensitive, some additional components are required to interface it with the incremental encoder. **Figure 2** shows a simple circuit which can be used for this purpose.

Table 1. Available Bands

Band	PA1	PA0	IF Offset	Step	Memory	Use	Prescaler MC145157 Only
0	0	0	+/–10,700	50, 10	10	VHF	10
1	0	1	+/–10,700	50, 10	10	VHF	10
2	1	0	455	9 (or 10), 1	10	MW/SW	—
3	1	1	10,700	5	20/40	SW	5

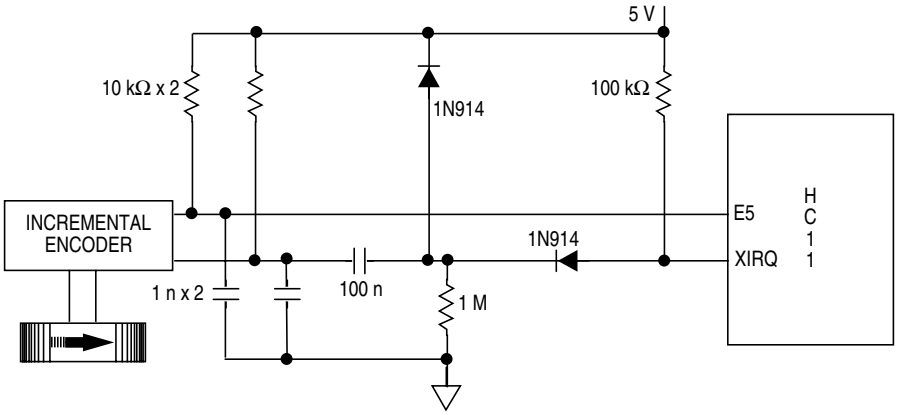


Figure 2. Incremental Encoder Interface Circuit

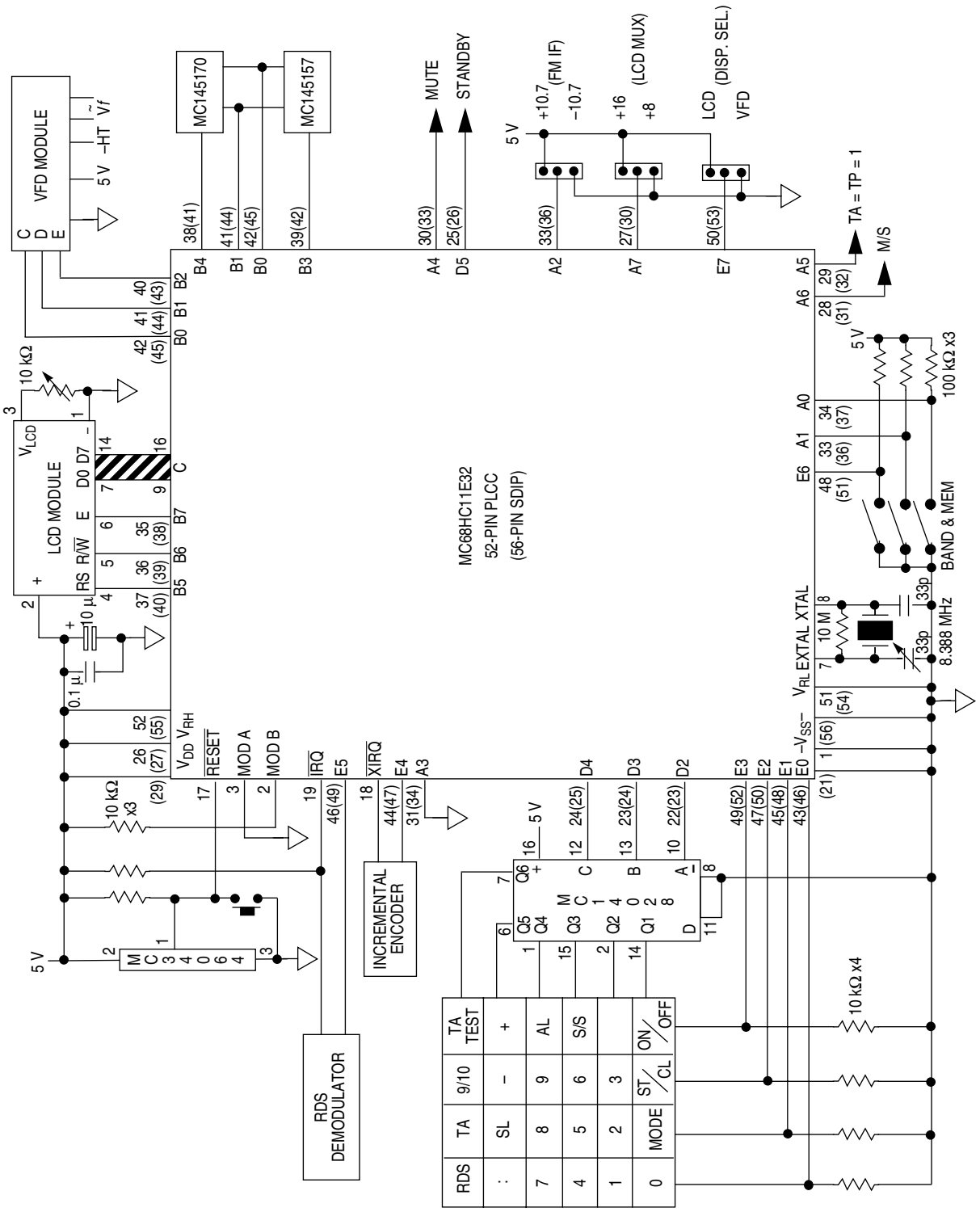


Figure 3. MC68HC11E32 Circuit

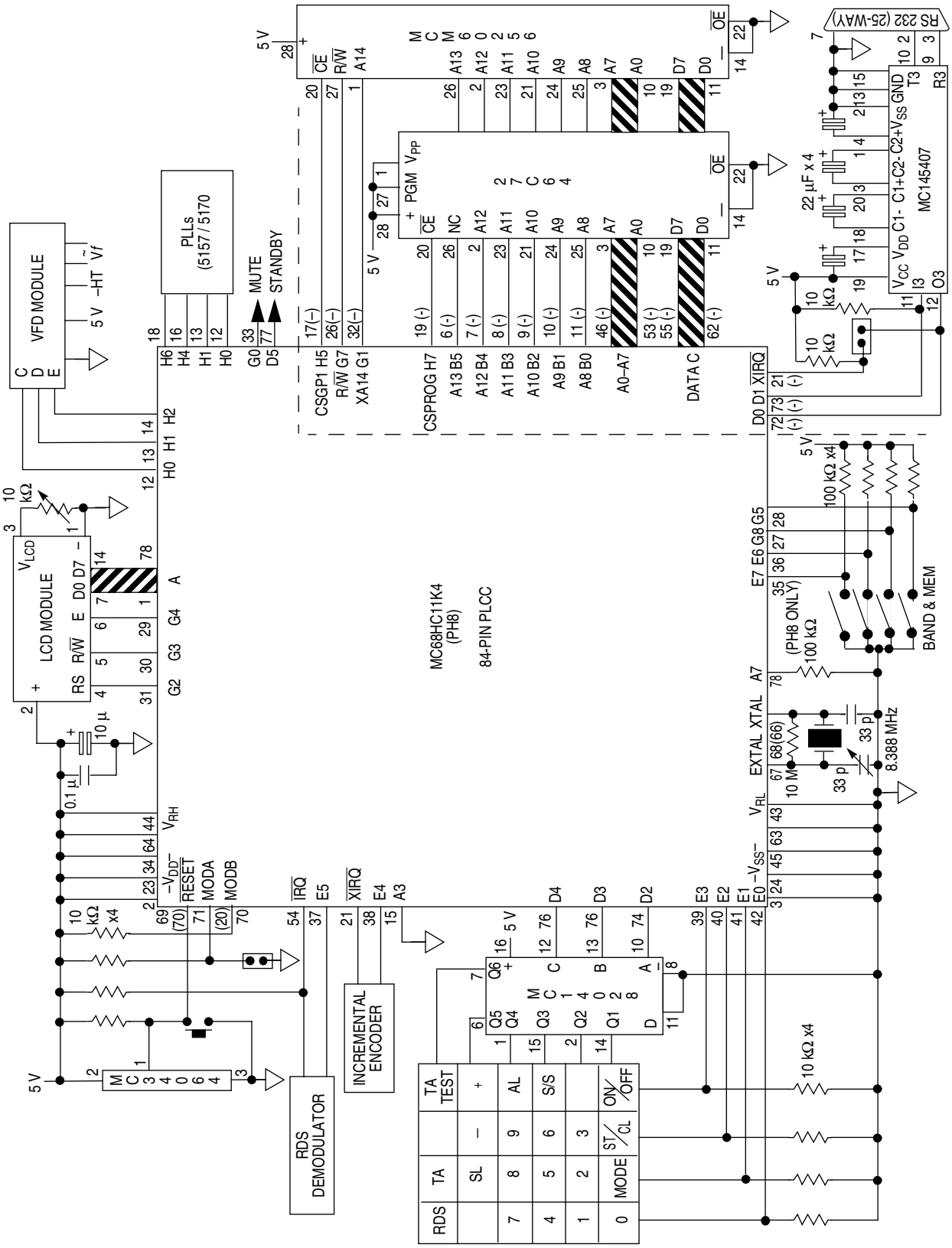


Figure 4. MC68HC11K4 and PH8 Circuit

Frequency Synthesis

Synthesis of the local oscillator (LO) in a superheterodyne radio provides many advantages over mechanical tuning. The main benefits are:

- Tuning accuracy
- Stability
- Storing of often-used frequencies.

The accuracy and stability result from the fact that the LO is phase-locked to a crystal oscillator. In conjunction with RDS, frequency synthesis provides the additional facility of allowing the radio to retune itself to a traffic announcement or news bulletin. A synthesizer can be retrofitted to most radios by replacing the tuning capacitor with a varicap diode. The voltage biasing the varicap is supplied by the synthesizer and also can be used to provide RF (radio frequency) tuning. Alternatively, manual preselector or no RF tuning can be employed.

Motorola's MC145157 and MC145170 synthesizers are two of a series offering a variety of options including serial or parallel interfacing and single or dual modulus prescaling. The MC145157 requires a prescaler for frequencies above 20 MHz but the MC145170 can handle input frequencies up to 160 MHz. The MC145157 has been included to retain compatibility with hardware developed for use with the MC68HC05B4 synthesizer described in ANE416 (reference 1).

Figure 5 shows the block diagram of the MC145170. It uses the Motorola bitgrabber system, whereby the number of bits sent determines the register which is written to. There is, therefore, no need for the control bit which is required by the MC145157.

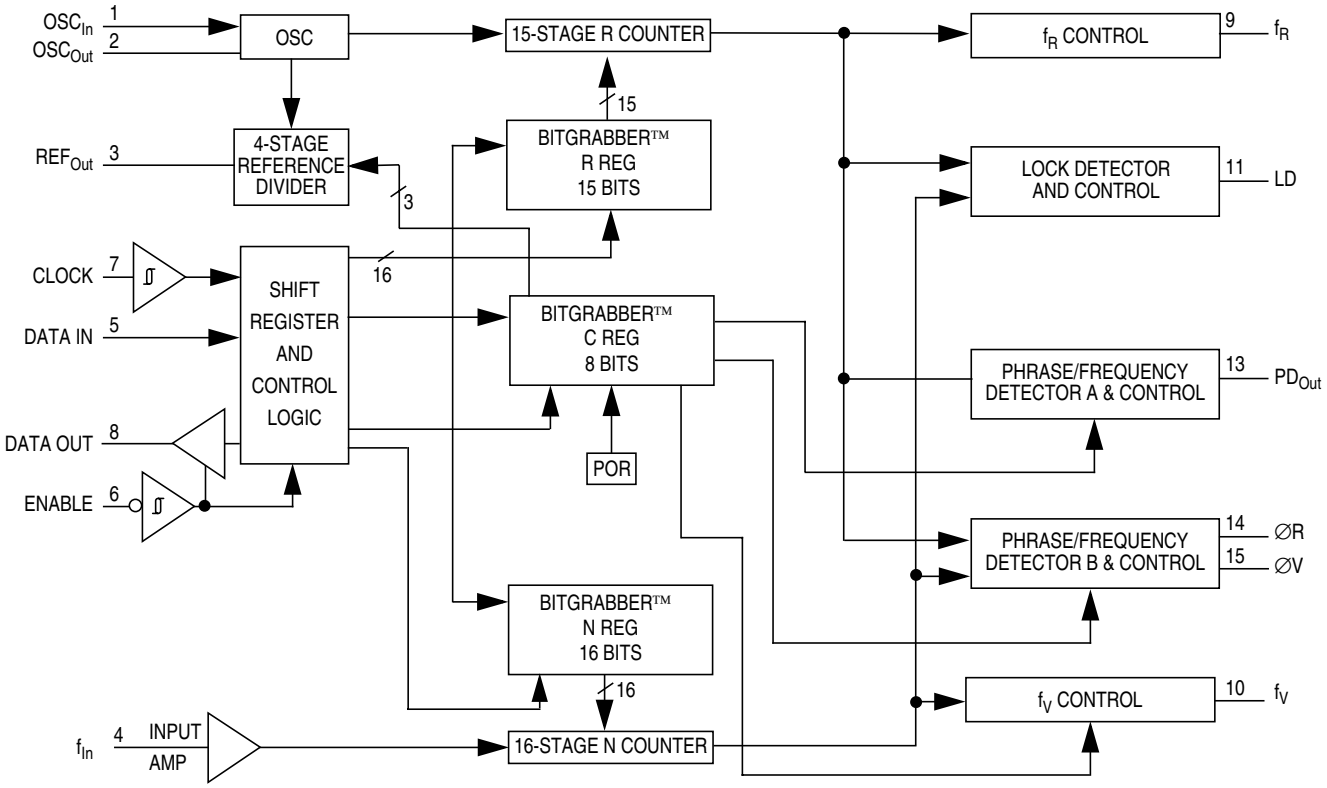


Figure 5. MC145170 Block Diagram

The reference counter divides the 8-MHz crystal oscillator (10 MHz for the MC145157) down to the reference frequency (in this case, 1 kHz for the MC145157 and 10 kHz for the MC145170) at which the comparison is made with the (also divided down) local oscillator. The filtered output of the phase comparator supplies the tuning voltage to the local oscillator. The numbers chosen as the divide ratios determine the frequency at which this oscillator stabilizes. The equation that follows shows the relationship between the various frequencies where P is the LO prescaler (MC145157 only). The received frequency can be changed by altering the LO divide ratio. The MCU takes care of the decimal-to-binary conversion, IF offset, and the other arithmetic required.

LO frequency = RF + IF = P x [(Xtal frequency) / (ref. divide ratio)] x LO divide ratio

The MC145157 is specified to operate up to 20 MHz, so prescaling is required on FM and SW (10.7-MHz IF). For this SW band, divide-by-5

prescaling is used; for FM, divide-by-10 is used. This increases the minimum step size to 10 kHz of FM, which is ideal for this band, and to 5 kHz on SW, which is suitable for almost all broadcast stations. The MC145170 does not require any prescaling even on the FM band and can use this to advantage by allowing the use of a higher reference frequency, making the low-pass filter design less critical.

An important part of any PLL is the loop filter. The filter in **Figure 6** is an active filter using the double-ended phase detector outputs from the MC145170 feeding a CA3460 operational amplifier. This dual op-amp allows the simple double-ended low-pass filter to be followed by a second order Sallen and Key filter. An active filter has the added advantage of increasing the available voltage swing beyond the supply rail of the MC145170/MC145157.

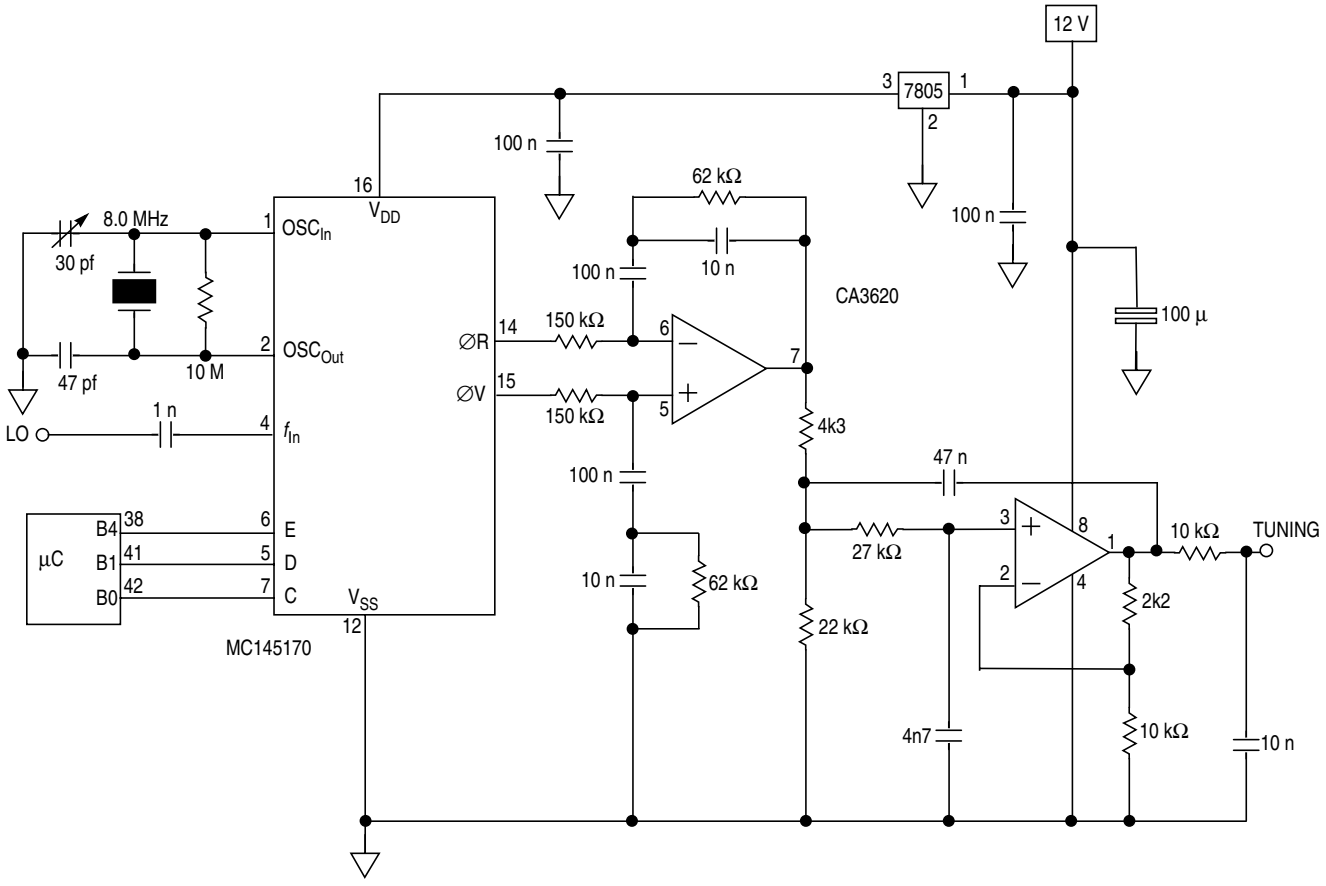


Figure 6. MC145170 Circuit

The combination of active filter and double-ended phase detector outputs makes it simple to select the correct relationship between voltage and frequency. Usually, the fixed side of the varicap diode is grounded, so increased voltage increases the frequency of the oscillator; in some oscillator designs, the fixed side may be taken to the supply rail, and increasing the voltage will decrease the frequency. With the filter design shown here, the choice can be made simply by swapping the phase detector outputs from the PLLs.

Radio Data System

The radio data system (RDS) adds a digital data capability to the FM VHF transmissions on band II (87.5 to 108 MHz). The specification is defined in CENELEC EN 50067 (formerly EBU Technical Document 3244, see reference 2). An MC68HC05E0 implementation of RDS is described in AN460, (reference 5). It monitors the RDS activity on the MPX signal of a VHF radio but is not able to tune the radio and, therefore, cannot, use AF (alternative frequencies) or EON data. This application can tune the radio and uses EON data to retune the radio when a traffic announcement is taking place on another frequency. An announcement is initiated by a packet 14B and the radio retunes if TAs are enabled. At the end of the TA, the original station is re-tuned. TAs are not active in standby mode (standby line high).

To transmit the data, a subcarrier is added at 57 kHz. This subcarrier is amplitude-modulated with the shaped bi-phase coded data signal. The subcarrier itself is suppressed to avoid data modulated cross-talk in phase-locked-loop stereo decoders and to maintain compatibility with the German ARI system which uses the same subcarrier frequency. Information is sent in groups of four 26-bit blocks. Each group of 104 bits is one of several types containing different information. It is up to the broadcaster to decide which features are transmitted as long as the specified format is adhered to and PI, PTY, and TP are included. Each group contains a different subset of the RDS features; a list of all currently defined features is shown in **Table 2**.

The retrieval of data is carried out by demodulation hardware, which generates clock and data signals that can be used by the MCU. Suitable devices which can perform this function include SAA6579, SAA7579T (plus an external filter), TDA7330, LA2231, and RDS hybrids.

Table 2. RDS Features

Feature	Information
PI	Program identification
PTY	Program type
PS	Program service name
RT	Radiotext
CT	Clock time and date
AF	Alternative frequencies
TA	Traffic announcement
TP	Traffic program
MS	Music/speech switch
DI	Decoder identification
PIN	Program item number
EON	Enhanced other networks
TDC	Transparent data channel
INH	In-house data

This application supports PI, PTY, PS, RT, CT, TP, TA, MS, DI, PIN, and EON. These features facilitate permanent display of the 8-digit station name (PS) and time (CT), and, on request, can display program type (PTY), radiotext data (RT), and the status of the other RDS information (see **Table 5**).

EON data can be displayed and used to switch to traffic announcements, but the retuning features associated with AF are not supported, as they are appropriate only for a radio intended for use in a vehicle. In a car radio, AF data would be used to tune the radio to the strongest signal carrying the selected service. PI is a 2-byte number which identifies the

country, coverage area, and service. It can be used by the control MCU but is not normally intended for display. A change in PI code causes the initialization of all RDS data as it indicates that the radio has been retuned. This application facilitates the display of the current PI code.

PTY is a 5-bit number which indicates the current program type. At present, 16 of these types are defined. Examples include "no programme type," "Current affairs," and "Pop music," although the actual syntax which is displayed is determined by the software of the controlling MCU. In this example, PTY can be displayed on request; **Table 3** shows the display used for each PTY code.

PS is the 8-character name of the station and is permanently displayed (except in standby mode). In the absence of RDS (for example, AM bands), the name can be entered manually. If none is entered, then the frequency is used as the station name when the program is stored in EEPROM.

Radiotext (RT) constitutes a string of up to 64 characters which give additional information regarding the service or program currently being transmitted. In this application, RT is displayed on request on the 16-digit dot matrix displays, using scrolling. The data often contains extra spaces to center the text on a 2 x 32 character display. As these are not appropriate for a 16-character scrolling display, the software reduces all sequences of two or more spaces to a single space.

CT (clock time and date) data is transmitted every minute on the minute and provides a very accurate clock, traceable to national standards. The (modified Julian) date and local time variation are also transmitted. Time is permanently displayed. In standby mode (see information later), the date is displayed instead of the PS name. The MJD number, which is the form in which the date is received, can also be displayed. The MCU converts this number into day-of-week, day-of-month, month and year.

AF would be used by a car radio to retune to the strongest signal carrying the selected service. AF data, along with TDC (transparent data channel) and INH (in-house data), is not used in this application.

TA and TP are flags. TP is set if the transmitter normally carries traffic information and TA is set if a traffic announcement is in progress. The

combination — TA = 1 and TP = 0 — is used to indicate that EON data is being used to supply information on other networks, including traffic announcements. A port line (port A, bit 5) is asserted (low) when TA = TP = 1. This can be used to demute or switch from another source (for instance, cassette when a TA occurs).

Table 3. PTY Types

PTY	Display
0	no program type
1	News
2	Current affairs
3	Information
4	Sport
5	Education
6	Drama
7	Culture
8	Science
9	Varied
10	Pop music
11	Rock music
12	Easy listening
13	Light classics
14	Serious classics
15	Other music
16–31	no program type

M/S is a single bit indicating either music or speech and is intended to be used to make a tone or volume adjustment to a radio's audio stage. The M/S bit is displayed on request. A port line (port A, bit 6) is asserted (low) when M/S = 1. This can be used to control external hardware.

Decoder information (DI) constitutes four bits indicating the type of transmission (mono, stereo, binaural, etc.). Currently, it is not in use in the United Kingdom, but it can be displayed as a number between 1 and 15.

Program item number (PIN) is used to identify the program currently being broadcast. The format is a 2-byte number which includes the scheduled time and date (day of month) of the start of the program. PIN can be displayed as four hexadecimal digits or fully decoded to day of month and time.

EON (enhanced other networks) replaces the older ON format. If type 14 groups are used to provide EON data, then type 3 groups (ON) will not be used. Type 14A groups are used to send information about other networks. The PS name and principal frequency of up to 16 other networks can be displayed. Type 14B groups are used to switch to traffic announcements; they include the PI code of the station carrying the announcement. This PI code is searched for in NVM, and the required station is tuned if it is stored in NVM. This method allows the user to select which TAs are allowed (they will not occur if the station is not in NVM or if its TA inhibit bit is set) and avoids attempts to jump to an announcement which is not relevant or not receivable with sufficient signal strength to be useful.

Keyboard

The keyboard has 23 keys. **Table 4** shows the layout and **Table 5** contains a summary of key functions against mode.

Table 4. Keyboard Layout

	PE0	PE1	PE2	PE3
Q6	RDS	Traffic	MW step	TA test
Q5	Time colon	Sleep	—	+
Q4	7	8	9	Alarm
Q3	4	5	6	Store
Q2	1	2	3	
Q1	0	Manual	Clear/Step	On/Off

The following functions are available.

On/Off

This key is intended as an on/off control for the radio. It sets a port line low for on and high for standby and can be used to control the power supply to the radio. Its status affects the behavior of other keys as described later in this application note.

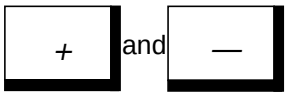
Sleep

When pressed, the 1-hour sleep timer starts, leaving the standby line low (radio on) until the sleep time has elapsed. At this time, the line is switched to the standby mode (high). In the normal display mode, the sleep timer running causes the decimal point to appear on the display modules' first character. The sleep timer can be cancelled by pressing ON/OFF. The sleep time can be reduced in increments of five minutes by repressing or holding down the SLEEP key.

Alarm

The alarm key selects the alarm display mode and toggles the alarm armed status. When the alarm is not armed, the legend ALARM-OFF is displayed. When it is armed, the alarm time is shown and adjustment of the alarm setup can be done by selecting the field (5/7 day, hours, or minutes) with the STORE/SET key. The selected field (hours or minutes) flashes and can be adjusted with the +/– keys or the tuning knob. The alarm setup display returns to normal three seconds after the last adjustment. If the radio is in standby mode and the alarm is set, the alarm time is displayed instead of the date. The radio will come fully on (standby line low) at the alarm time. After a 500-ms delay to allow power supplies to stabilize, the program which was tuned when the radio was last used is retuned. When set to the 5-day alarm, the alarm will not occur on Saturdays and Sundays.

Plus (+)
and Minus (–)



Pressing + or –, while in normal mode, increments or decrements the program number. The program number wraps round at 0 and 9. The mute line is set high before retuning and returned low 100 ms after the new frequency has been sent to the PLL. Changing the tuned program using the +/– keys (or the 0–9 keys) disables PS name clearing if RDS information is absent or contains multiple errors.

In PS-edit mode (see entry that follows), the + and – keys are used to change the character at the cursor position. This function is duplicated on the tuning knob incremental encoder. In the alarm setup mode, the + and – keys are used to change the alarm time as described earlier. The field which is currently selected for adjustment (using the STORE key) flashes. This function is duplicated on the tuning knob also.

In manual mode, these keys increment and decrement the current frequency in steps of 10 kHz or 50 kHz (FM) as selected by the CLEAR/STEP key. The default is 10 kHz. On the SW band, 1-kHz (455 kHz IF only) or 5-kHz steps are available; on the MW/LW band, 1- or 9-kHz steps are available. In the U.S.A., 10 kHz is appropriate instead of 9 kHz; this can be selected with a special key (see entry that follows). This function is duplicated on the tuning knob both in this mode and in normal mode. Use of the +/– keys (or the incremental encoder) to adjust the frequency enables PS name clearing if RDS information is absent or contains multiple errors. In normal mode, on the AM bands, use of the tuning knob displays the frequency in the PS name field, facilitating simultaneous display of frequency and time.

Store/Set

In normal modes (not manual or alarm), the store key selects the PS-edit mode in which the first character of the displayed PS-name flashes and can be changed by the + and – keys or the tuning knob. Subsequent presses of STORE move to the next character. A space is shown as a hyphen (–). This mode returns to the normal display mode 10 seconds after the last key press. This mode can be used to give a name to a station with no RDS PS name (all AM stations or an FM station with no RDS or with RDS or unusable quality). See the entry that follows for the method of saving this name in EEPROM. Entry of a PS name in this way requires that PS name clearing is disabled. This is achieved by changing the program number (by using the +/– or 0–9 keys). Fine tuning enables PS name clearing (see +/– key description). Direct frequency entry does not affect the PS name clearing status.

In the alarm setup mode, STORE selects what will be changed when the + or – keys or the tuning knob are used (5/7 day, hours, or minutes). Hours or minutes flash when they are selected.

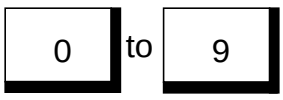
In manual mode, STORE enters a special manual store mode in which the 9–0 keys save, rather than recall, a program. After pressing STORE, the program number flashes to indicate this change of function. Alternatively, a second press of STORE saves the current tuning information into the current program number. The current frequency, PI code (FM), PS name, and TA inhibit flag (FM) are saved in EEPROM. The TA inhibit status can be changed using the TRAFFIC key (see entry that follows). If the PS edit mode has been used, then manual store mode should be used to save the entered PS name.

Manual

Select manual entry of frequency; a second press returns to normal mode if the tuned frequency has not been changed. If it has been changed, the second press retunes to the new frequency and an additional press is required to return to the normal mode. In manual mode, frequency is displayed instead of the time; the + and – keys or the tuning knob enable incrementing and decrementing of the current frequency. Direct entry of frequency can be made using 0–9 keys. In this mode, the STORE key enters the manual store mode in which the program number flashes, allowing storing of the tuned program and PS name into the current, or a different, program number. A second press of STORE saves the current frequency, PS name, PI code, and TA inhibit bit (FM) in EEPROM.

In manual mode, the TRAFFIC (TA) key controls the TA inhibit bit, which can be stored with each program. If the current station has its TP flag high, the least significant digit of the frequency will alternate with a decimal point. Pressing TP toggles the NVM inhibit bit. When inhibited, the decimal point between the MHz and kHz becomes a "–". A subsequent press of STORE saves this bit in NVM along with the frequency, PI code, and PS name.

0 to 9



These keys are used both for direct frequency entry and for recalling the 40 available programs. In all modes, except standby and manual, when a 0–9 key is pressed, the selected program is tuned. Changing the tuned program using the 0–9 keys (or the +/– keys) disables PS name clearing if RDS information is absent or contains multiple errors. In manual mode, these keys are used for the direct entry of frequency. After entering the required frequency, pressing MANUAL retunes to the new frequency.

The mute line is set high before retuning and returned low 100 ms after the new frequency has been sent to the PLL. In manual store mode, the program number flashes and the 0–9 keys save the tuned program into the selected program number in EEPROM.

RDS

RDS

The first press displays scrolling RT data. Subsequent presses display PTY code, PI code, TA and TP, PIN code (two formats), MJD, MS and DI, last TA PI code, the reason for returning from last TA and EON (up to 16 networks with their principal frequency). See **Table 5** for the display formats. The RDS key is operational in all modes except standby.

Traffic

TRAFFIC

Enable/disable traffic switching. When disabled, this is indicated by a decimal point in the 11th character of the dot matrix displays. Default at power-up is enabled. The TRAFFIC key works in all modes except standby. During manual mode and manual store mode, it toggles the TA inhibit status, which can subsequently be saved in NVM.

Clear/Step

CLEAR/STEP

Toggles between 10-kHz and 50-kHz steps on the FM band or between 1 and 9 kHz (or 10 kHz) on the MW band. There is no indication on the dot matrix displays. In manual mode, the displayed frequency is cleared to facilitate the entry of a new frequency. If the clear is followed by use of the + or – keys or the tuning knob, the original frequency is retained, allowing a change of step size only. In PS edit mode, the clear key clears the current PS name.

TA Test

TA TEST

Pressing TA test simulates the arrival of a group 14B. The PI code of the other network is embedded in the code (C5B1, Radio Clyde in the ROMed version).

Time Colon

TIME COLON

This key enables or disables the flashing colon in the time display. This can be used to prevent unnecessary I/O activity thus reducing RFI. Disabling the colon prevents 1-Hz updating, as the display modules are only updated if the data to be displayed has changed.

MW Step

MW STEP

This optional key selects 9- or 10-kHz steps on MW. Nine kHz is appropriate in Europe and 10 kHz in the United States. The default is 9 kHz, and the key need not be implemented if 10 kHz will never be required.

Table 5. Key Function by Mode

	On/Off	Sleep	Alarm	+/–	Store	Manual	TP	RDS	0–9	Clear
Standby (OFF)	mode normal (ON)	mode sleep (ON)	mode alarm	—	—	—	—	—	—	—
Normal (ON)	mode standby (ON)	"	"	+/– prog.	mode PS-edit	mode manual	toggle traffic enable flag	display RT PTY PI TA TP PIN hex PIN dec MJD M/S DI TA ret. TA PI EON (16)	tune prog.	toggle step 10/ 50 kHz
PS edit	"	"	"	+/– ASCII	next char.	"	"		"	"
ALARM off	"	"	mode alarm on	+/– prog.	—	"	"		"	"
ALARM on	"	"	mode alarm off	5/7 day toggle	mode setup	"	"		"	"
ALARM setup	"	"		+/– hour/min	hour/min toggle	"	"		"	"
MANUAL	"	"	mode alarm	+/– freq.	mode store	mode normal	toggle traffic enable NV bit		input freq.	"
MANUAL store	"	"	"	"	save prog.	"		"	save prog.	& clear freq.

Circuit

The circuit is in two distinct parts. The circuit for the MC145170 synthesizer is shown in **Figure 6**. The synthesizer board is the only part of the synthesizer controller which actually needs to be in (or close to) the radio. A local oscillator signal to supply the synthesizer should be taken from a low-impedance point so that the oscillator is not significantly loaded. Pulling of the oscillator frequency is not a problem as the PLL circuitry will compensate, but loading the tuned circuit itself is not recommended unless a high-impedance buffer is included. This prevents affecting the tuning range or the "Q" of the oscillator.

The MC145157 requires a divide-by-10 prescaler for FM and divide-by-5 for band 3. The MC145170 does not require prescaling. The standard LP1186 FM tuner does not have an LO take-off but a signal can be taken, without other modification, from the emitter of the oscillator BF195 (near the center of the PCB).

The Mullard LP1186 is unusual in having its local oscillator low. More recent tuners, for instance, the Larsholt 7254/55, almost always have their local oscillator above the tuned frequency. This selection can be made using port A, bit 2.

A 16-digit LCD (parallel) or VFD (serial) dot-matrix display module can be driven. The two display modules show the same data (within the limitations of their character ROMs). The VFD display driver supported is the MSC7128 and the LCD driver, the HD44780. On its own, this driver can be used to provide a 16-way multiplexed display, but an 8-way multiplexed higher contrast display is possible if the module also incorporates an HD44100. In an application which drives an LCD module (for instance, a ROMed PH8) and the module is not connected, a 10-k pulldown resistor should be added to bit 7 of port A. This prevents the software hanging up waiting for the busy line to go low.

Figure 3 and **Figure 4** show the circuit diagrams of the controllers. **Figure 3** gives the pin numbers for the 52-pin PLCC HC11E with the numbers for the 56-pin SDIP (if different) in brackets. With the E32, the display in use can be selected by the level on port E, bit 7 (high for LCD and low for VFD) and the LCD multiplexing by port A, bit 7 (high for

divide-by-16, low for divide-by-8). The SW bank is selected by the level on port E, bit 6.

Figure 4 shows pin numbers for the 84-pin PLCC K4, with the differences for the PH8 in brackets. Debug on the K4 using PCbug11 (reference 5) requires some additional hardware (within the dotted line) and port D bits 0 and 1 (SCI), port G bits 1 and 7 (XA14 and R/W), and port H bits 5 and 7 (CSGP1 and CSPROG), leaving 30 input/output (I/O) lines for use in the application. The display selections are not available on the PH8 ROMed versions, but there are four SW banks of 10 program memories; they are selected by port E, bits 6 and 7.

Since different demodulator devices can be used, the circuitry for the demodulator is not shown. The clock from the demodulator interrupts the microprocessor on each positive edge. At this time, a data bit is available and is read on bit 5 of port E.

Software

An assembled listing of part of the HC11E32 ROMed version (ZC403311) of the application is included. The software is in three modules and was assembled and linked using the Introl re-locatable assembler and linker. The first module is listed. It contains all the main control routines, including the main loop and keyboard scanning, and the function to be performed by each key.

The second module contains the RDS and display functions, while the third module is the 4-function, 9-digit integer BCD arithmetic required for the MJD date calculations.

The second and third modules are described and listed in AN495 (reference 4). EB419/D (reference 5) describes and lists additional debug code contained in the ROMed parts.

The code which is executed only on startup (power-on or reset) begins at the label START on the third page of the first module's listing, while the main loop starts at the label IDLE on the next page. The idle loop is quite long, as many functions and checks have to be carried out.

These include:

- Pacing the loop using the main timer
- Checking to see if the display needs updating or if a transient display has timed out
- Checking if alarm is armed and, if so, comparing its time with the current time
- Sleep timer operation
- Traffic announcement timing and return
- Keyboard scanning and selected function execution
- Incremental encoder execution
- Checking for changes in the band and memory selection inputs
- Timing band changes
- Updating TA = TP = 1 and M/S outputs

The keyboard subroutine (KBD) is executed at 64 Hz from the idle loop and checks to see if a key is pressed. If the same key is pressed on three consecutive tries, its function is performed. The remainder of the first module constitutes the subroutines performed by each key and the arithmetic and serial activity required to tune the synthesizers. The batch files used for linking the modules are shown as comments at the end of the listing, along with the pseudo-vectors required by PCbug11 during debug.

The displays are only updated when there is a change in the displayed data. At 8 Hz, a check is made to see if any characters have changed; if there has been a change, the display update routine is executed. This is done to minimize interference caused by communication with the displays. The colon between the hours and minutes of the time display changes at 1 Hz. This can be disabled (colon permanently displayed) by using the time colon key. The display routine (MOD) is executed in the idle loop if the flag bit 3 of STAT2 is set. It is set every 125 ms by timer B interrupts. If flag bit 4 of STAT2 is set, the display is initialized, indicating no valid RDS data. The dot-matrix modules are then updated, if necessary, with new data. Each time, before anything is written to the LCD module, the subroutine WAIT is used; this checks that the controller

in the module is not busy. The different display formats are selected by checking the various flags and the relevant routine executed. The normal display permanently shows PS name and time. As the locations in RAM used for hours and minutes contain binary numbers, they are converted to BCD before being written to the relevant bytes in DISP. Once all 16 bytes in DISP have been loaded, loops are used to send the data to the display modules. The standby display (alarm not enabled) shows date and time. After a power-up, the display "Mon 0 inv 0:00" indicates that the date and time are invalid. The date and time will be correct once a valid RDS CT group has been received.

The VFD routine sends the same data as is shown on the LCD module to the serial VFD module. The display driver used has a different character set from the standard ASCII set used by the LCD module. The table VTAB is used to convert ASCII data into the required character in the VFD module. The small table INITF is used to send the required initialization bytes to the VFD module. This module does not require a busy check but does require a delay between successive bytes. This is satisfied by the wait loop within the serial output loop VFDL. The LCD and VFD routines are in the second software module (see reference 4).

Table 6. Display Formats

Display Mode		Format

Standby
Off
	Alarm off
	Alarm off, no CT
	Alarm on
		`Thu 12 May 21:35`
		`Mon 0 inv 0:00`
		`0659 alarm 21:35`

Normal
On
	With RDS PS name
	Without RDS
	Auto name
	Tuning knob (AM)
		`4 BBC 4 FM 21:40`
		`5 ---------- 21:40`
		`6 -- 9410 21:40`
		`6 -- 9415 21:40`

Alarm	Alarm off Alarm on/setup	`Alarm – OFF` `5-day alarm 0659`
Sleep		`Sleep 60 minutes`

Table 6. Display Formats (Continued)

Display Mode		Format
RDS	RT PTY PI TA & TP PIN (hex) PIN (decoded) MJD MS & DI last TA 1. 2. EON (16)	Kaleidoscope. . . . Culture PI code – C204 TP – 0 TA – 1 PIN no. – 655E 12th at 21:30 MJ day – 49484 M/S M DI 01 last TA PI C514 TA rtrn: EON PI BBC 3 FM 92.10 BBC Gael 103.70 BBC Nwcl 96.00 BBC Scot 94.30 BBC Scot 92.50 BBC Scot 94.70 BBC Scot 93.50 Classic 101.70 BBC Eng 107.90 BBC 1 FM 99.50 BBC 2 FM 89.90 ---------- ----------
Manual		6 Classic 101.70

Traffic Announcements

The radio can respond to EON-initiated traffic announcements if they are enabled by the TRAFFIC (TA) key. This status is indicated by a decimal point at the 11th character on the dot-matrix displays. A switch to a TA on another frequency will only occur if the station has previously been stored in NVM; the EON data which can be displayed using the RDS key is not used for TA switching. The PI code of the last TA (or attempted TA) can be displayed by pressing the RDS key eight times. A further press displays one of the TA return/inhibit messages shown here. TAs which are the result of TA = TP = 1 on the current frequency do not update the last TA PI or TA return/inhibit messages.

When a 14B group is received, the following occurs:

- Check traffic flag; if enabled, proceed; otherwise, set TA rtrn/inhb message to:
  TA inhb: flag — Traffic key inhibit flag (d.p. at the 11th character position)
- Search for TA PI code in NVM; if found, proceed; otherwise, set TA rtrn/inhb message to:
  TA inhb: EON PI — The PI code given in 14B is not in the NVM.
- Check station TA inhibit flag in NVM; if clear, proceed; otherwise, set TA rtrn/inhb message to:
  TA inhb: NVM — User inhibit of station using bit stored in NVM
- Retune to frequency stored in NVM against EON PI code. The PS name display changes to show the PS name of the service carrying the traffic announcement and the time display is replaced by the new frequency. If the service has its TP flag high, then the 10s of kHz digit will flash as in the manual mode display. After one second, check TP flag at the new frequency. If high, then proceed; otherwise, return to original frequency and set TA rtrn/inhb message to:
  TA rtrn: TP low — TP station does not have TP bit high.
- Check PI code at new frequency. If correct (same as 14B EON TA PI code), then proceed; otherwise, retune to original frequency and set TA rtrn/inhb message to:
  TA rtrn: PI code — PI code of TP station was not as expected.
- After an additional two seconds, start to monitor the TA flag; if high, remain on current frequency, if low, return to original frequency and set TA rtrn/inhb message to:
  TA rtrn: TA low — TA flag of TP station low. This is the normal return method.
- If, during a TA, the radio is manually retuned, the TA rtrn/inhb message is set to:
  TA rtrn:manual — User-initiated manual return

Table 7. MCU I/O

K4 and PH8		Function	E32	
Port A bits	0–7	LCD module data bus	Port C bits	0–7
Port B bits	0–7	High-order addresses (K4)	N/A	—
Port C bits	0–7	Data bus (K4)	N/A	—
Port D bits	0–1 2–4 5	Debug (PCbug11 or BUFFALO) Keyboard rows (via 14028 encoder) Standby (high:standby, low:on)	Port D bits	0–1 2–4 5
Port E bits	0–3 4 5 6 7	Keyboard columns Shaft direction (XIRQ) RDS data in or shaft direction (IRQ) Short-wave memory select 1 Short-wave memory select 2 (PH8 only)	Port E bits N/A	0–3 4 5 6 —
Port F bits	0–7	Low-order addresses	N/A	—
Port G bits	0 1 2–4 5–6 7	Mute XA14 (K4 only) LCD control lines (RS, R/W, and clock) Band select R/W (K4)	Port A bit N/A Port B bits Port A bits N/A	4 — 5–7 0–1 —
Port H bits	0–1 2 3 4 5 6 7	Serial clock/data for VFD and PLLs VFD chip enable (PH8: +/– 10.7 MHz) Port E, bit 5 input control MC145170 PLL chip enable CSGP1 (K4 only) MC145157 PLL chip enable CSPROG (K4 only)	Port B bits Port B bit Port A bit Port B bit N/A Port B bit N/A	0–1 2 3 4 — 3 —
N/A		FM IF select (+/– 10.7 MHz	Port A bit	2
N/A		TA = TP = 1	Port A bit	5
N/A		M/S = 1	Port A bit	6
N/A		LCD multiplex select (8/16)	Port A bit	7
N/A		Display module (LCD/VFD) select	Port E bit	7

Setup and Testing

An effective method of fault finding a PLL circuit is to initially do the tuning with a potentiometer, leaving the output of the filter disconnected from the VCO. As the radio is tuned through the frequency setup in the synthesizer, the filter output should switch from one extreme to the other. Until this test passes, it is not useful to close the loop, as it is difficult to distinguish the cause of a problem from its effects.

Check operation of the MC34064 LVI circuit. As the supply voltage is lowered, it should pull the reset pin low. This should occur between 4.70 and 4.50 volts. Adjust trimmer on the EXTAL pin of the M68HC711 for accurate timekeeping in the absence of RDS CT information. (Radio should be detuned or tuned to a station known not to provide RDS.) The trimmer on pin 2 of the PLL chip (MC145157 or MC145170) should be adjusted to provide an accurate reference frequency. This adjustment can be made simply to tuning to a strong broadcast of known frequency and adjusting for optimum reception or symmetric adjacent-channel response.

PH8 ROMed Application

The ROMed PH8s (ZC428200 and ZC428202) differ from the described E32 version of this application as follows:

1. 40 short-wave programs can be stored instead of 20. These are accessed by the use of a second memory-select line (port E, bit 7).
2. There is no display selection; both LCD and VFD signals are generated. If an LCD module is not connected, a pulldown on port A, bit 7 should be included (see **Figure 4**).
3. LCD multiplexing is fixed at divide-by-8.
4. Traffic announcement (retune to TA frequency) is not fully implemented in the ZC428200.

5. Time colon FLASH defeat key is not implemented; the display modules are always updated at 8 Hz.
6. TA = TP = 1 and M/S outputs are not implemented.
7. 10-kHz MW steps are not available (no 9/10 key).
8. +/–10.7-MHz IF selection (FM) is carried out on port H, bit 2 which is read after reset but before it is set up as an output. A pullup or pulldown resistor will determine the IF selection (pullup for LO high and pulldown for LO low) without affecting the pin's subsequent function as an output (VFD chip enable).
9. The 500-ms delay at switch-on between the standby line moving and the PLLs being retuned is not implemented.
10. The sleep d.p. flashes during operation of the sleep timer.

References

1. *A Radio Synthesizer Using the MC68HC05B4*, Motorola document order number ANE416/D
2. CENELEC EN 50067, *Specifications of the Radio Data System (RDS)*, formerly EBU technical document 3244
3. *An RDS Decoder Using the MC68HC05E0*, Motorola document order number AN460/D
4. *RDS Decoding for an HC11 Controlled Radio*, Motorola document order number AN495/D
5. *ROMed HC11E32 and HC11PH8 Including BUFFALO Monitor and PCbug 11 Talker*, Motorola document order number EB419/D

Code Listing

```
*************************************************************
*                                                           *
*             MC68HC11E32 RDS multiband radio.              *
*                                                           *
*         Used with RDSE.S11, FNCE.S11 & RDRAME.S11.        *
*                                                           *
*    P. Topping                      3rd April '94          *
*************************************************************

            IMPORT      SDATA,TINTB,INITD,MOD,CLOCK,MJDAT,WAIT,CLREON,CBCD, PROC, TFCC

            EXPORT      DCON2,NEW,CLTR,SHAFT

            LIB         RDRAME.S11

PORTA       EQU         $00                 PORT A ADDRESS
PORTB       EQU         $04                 "    B  "
PORTC       EQU         $03                 "    C  "
PORTD       EQU         $08                 "    D  "
PORTE       EQU         $0A                 "    E  "
PORTCD      EQU         $07                 PORT C DATA DIRECTION REG.
PORTDD      EQU         $09                 "    D  "      "        "
TMSK2       EQU         $24
PACTL       EQU         $26
OPTION      EQU         $39
INIT        EQU         $3D

RBO         EQU         $1000               REGISTER BLOCK OFFSET
PPROG       EQU         $3B                 EEPROM CONTROL REGISTER
ND          EQU         9                   No. DIGITS

            SECTION.S .RAM1,COMM

BMJD        RMB         3                   BINARY MJD
Q           RMB         9                   WORKING NUMBER 1 - RDS
TMQ         RMB         9                   SCRATCH
R           RMB         9                   WORKING NUMBER 2 - RDS
TMP         RMB         9                   MULT. OVER. OR DIV. REMAINDER
R           RMB         9                   WORKING NUMBER 3 - RDS
MJD         RMB         9                   MODIFIED JULIAN DAY NUMBER
YR          RMB         9                   YEAR
MNTH        RMB         2                   MONTH
DOM         RMB         2                   DATE
DOW         RMB         1                   DAY OF WEEK

*****************************************
*                                       *
*           RAM allocation, RDS & radio.*
*                                       *
*****************************************

DIST        RMB         1                   TRANSIENT DISPLAY, TIMEOUT,COUNTER
SLEPT       RMB         1                   SLEEP TIMER MINUTES COUNTER
RDSTO       RMB         1                   RDS TIMEOUT COUNTER
PSNP        RMB         1                   PS DISPLAY POINTER
DAT         RMB         4                   SERIAL DATA BUFFER
TMPGRP      RMB         8                   TEMPORARY GROUP DATA
GROUP       RMB         8                   COMPLETE GROUP DATA
PTY         RMB         1                   PROGRAM-TYPE CODE (CURRENT)
PTYCMP      RMB         1                   PROGRAM TYPE CODE (PTY SCAN)
PI          RMB         2                   PROGRAM IDENTIFICATION CODE
PION        RMB         2                   PROGRAM IDENTIFICATION CODE (EON)
PIN         RMB         2                   PROGRAM ITEM NUMBER
LEV         RMB         1                   VALID BLOCK LEVEL
BIT         RMB         1                   BIT LEVEL
ITMP1       RMB         1                   TEMP BYTE FOR USE IN IRQ
SYN         RMB         2                   SYNDROME
```

```
CONF        RMB         1                   SYNDROME CONFIDENCE
TH32        RMB         1                   TICS (SECONDS/32)
TH8         RMB         1                   EIGHTHS OF SECONDS
SEC         RMB         1                   SECONDS
MIN         RMB         1                   MINUTES
OUR         RMB         1                   HOURS
AMIN        RMB         1                   ALARM MINUTES
AOUR        RMB         1                   ALARM HOURS
DISP1       RMB         1                   RT DISPLAY POINTER #1
DISP2       RMB         1                   RT DISPLAY POINTER #2
                        6
RQ          RMB         6                   WORKING BCD NUMBER 1 RADIO
RP          RMB         6                   "       "    "    2  "
RR          RMB         2                   "       "    "    3  "
W1          RMB         2                   W
W2          RMB         2                   O
W3          RMB         2                   R
W4          RMB         2                   K
W5          RMB         2                   I
W6          RMB         2                   N
W7          RMB         2                   G
KEY         RMB         1                   CODE OF PRESSED KEY
KOUNT       RMB         1                   KEYBOARD COUNTER
DIG2        RMB         1                   2nd DIGIT TIMEOUT COUNTER
CARRY       RMB         1                   BCD CARRY
COUNT       RMB         1                   LOOP COUNTER
NUM1        RMB         2                   1ST No. POINTER (ADD & SUBTRACT)
NUM2        RMB         2                   2ND No. POINTER (ADD & SUBTRACT)
LED         RMB         1                   STATION NUMBER
SMEM        RMB         2                   CURRENT FREQUENCY
REARET      RMB         1                   LAST TA REASON FOR RETURN
RTDIS       RMB         1                   RDS DISPLAY TYPE
DI          RMB         1                   DECODER IDENTIFICATION
SCHAN       RMB         1                   SCAN CHANNEL
*****************************************
*                                       *
*           Flags, & pages 1-2.         *
*                                       *
*****************************************

STAT        RMB         1                   0: MODE 1: STATION, 0: FREQ
*                                           1: STEP 1: 50KHz, 0: 10KHz
*                                           2: CLRQ 1: CLEAR IF NO. KEYED
*                                           3: TIMER MS BIT TOGGLE (64 Hz)
*                                           4: RDS DATA CLEARING ENABLE
*                                           5: KEY FUNCTION PERFORMED
*                                           6: KEY REPEATING
*                                           7: NOT JUST POWERED UP
STAT2       RMB         1                   0: VALID SYNDROME
*                                           1: VALID GROUP
*                                           2: RT DISPLAY
*                                           3: UPDATE DISPLAY
*                                           4: CLEAR DISPLAY
*                                           5: SPACE FLAG
*                                           6: NOT ON PROGRAM (AM)
*                                           7: TA RETUNE DONE
STAT3       RMB         1                   0: NOT ON PROGRAM (FM)
*                                           1: TEXTA/TEXTB BIT (RT)
*                                           2: TA FLAG
*                                           3: TP FLAG
*                                           4: SHAFT DIRECTION
*                                           5: SHAFT ROTATION
*                                           6: UPDATE DATE
*                                           7: SHAFT INTERRUPTS
STAT4       RMB         1                   0: DISPLAY (OR TA SWITCH) TRANSIENT
*                                           1: SLEEP TIMER RUNNING
*                                           2: TRAFFIC ENABLED
*                                           3: ALARM DISPLAY
*                                           4: ALARM ARMED
*                                           5: ALARM SET-UP
*                                           6: ALARM HOURS (SET-UP)
*                                           7: VALID GROUP 14B RECEIVED
STAT5       RMB         1                   0: BAND CHANGE TIMEOUT
*                                           1: RDS DISPLAYS
*                                           2: SLEEP DISPLAY
*                                           3: M/S 0: M, 1: S
```

```
*                                               4: RETUNE FLAG (FREQUENCY MODE)
*                                               5: TA INHIBIT FLAG (NVM)
*                                               6: STORE MODE
*                                               7: WEEKDAY ONLY ALARM

STAT6       RMB         1                       BAND/BANK (,MW STEP,COLON, ,A1,A0,,E6)
BCTO        RMB         1                       BAND CHANGE TIMEOUT
SCNT        RMB         1                       SHAFT DETENT COUNTER

            SECTION .RAM2,COMM
EON         RMB         256
            SECTION .RAM3,COMM                  EON DATA (16 NETWORKS)
DISP        RMB         16                      LCD MODULE BUFFER
DISPP       RMB         16                      CURRENT LCD MODULE CONTENTS
PSN         RMB         8
RT          RMB         69                      RADIOTEXT
            SECTION .ROM1
STRST       JMP         START                   RESET VECTOR
TMRB        JMP         TINTB                   RTI
IRQ         JMP         SDATA                   IRQ

****************************************
*                                      *
*     Reset routine - set-up ports etc.      *
*                                      *
****************************************

START       LDAA        #$01
            STAA        INIT                    REGISTERS AT $1000
            LDAA        #$10                    ENABLE EEPROM WRITE (NOT CONFIG)
            STAA        $1035

            LDAA        #$30                    IRQ EDGE SENSITIVE
            STAA        $1039
            LDAA        #$03                    32Hz RTI (8.388MHz XTAL)
            STAA        $1026                   PORTA, BITS 3 & 7 INPUTS
            LDAA        #$40                    ENABLE REAL TIME INTERRUPTS
            STAA        $1024
            LDAA        #$00                    DWOM = 0, PORTD PUSH-PULL
            STAA        $1028

            LDS         #$02FF                  INITIALISE STACK POINTER

            LDY         #$1000                  0,1:   BAND INPUTS (FM, FM, MW, SW), 2: FM IF
            LDAA        #$10                    3:     IRQ CONTROL, 4: MUTE, 5: TA=TP=1
            STAA        PORTA,Y                 6:     M/S=1, 7: 8/16 LCD MUX

H2L         LDAA        #$00                    0,1:   SERIAL CLOCK/DATA, 5,6,7: LCD CONTROL
            STAA        PORTB,Y                 2,3,4: LATCH SIGNALS (VFD, 5157 & 5170)

            CLR         PORTC,Y
            LDAA        #$FF                    0-7:   LCD PARALLEL BUS
            STAA        PORTCD,Y

            CLR         PORTD,Y                 0,1:   SCI (DEBUG)
            LDAA        #$3C                    2-4:   KEYBOARD OUTPUTS
            STAA        PORTDD,Y                5:     STANDBY

*           PORTE                               0-3:   KEYBOARD INPUTS, 4: SHAFT INPUT (XIRQ)
*             "                                 5:     RDS/SHAFT INPUT, 6: SW BANK, 7: LCD/VFD

****************************************
*                                      *
*         INITIALISE LCD AND RAM.            *
*                                      *
****************************************

            JSR         DBOUNC                  WAIT 15ms
            LDAA        #$30
            JSR         CLOCK                   INITIALISE LCD
            JSR         DBOUNC                  WAIT 15ms
            LDAA        #$30
            JSR         CLOCK                   INITIALISE LCD

            LDX         #BMJD                   INITIALISE PAGE 0 RAM
CLOOP       CLR         0,X
```

```
            INX
            CPX         #SCNT+1                 MORE ?
            BNE         CLOOP
            BSET        STAT4,$04               ENABLE TRAFFIC SWITCHING - DEFAULT ?
            BSET        STAT,$01                STATION MODE

            LDAA        #$30
            JSR         CLOCK                   INITIALISE LCD
            JSR         WAIT
            LDAA        #$30                    /8 DISPLAY
            BRCLR       PORTA,Y,$80,M8
            LDAA        #$38                    /16 DISPLAY
M8          JSR         CLOCK                   LATCH IT
            JSR         WAIT
            LDAA        #$08                    SWITCH DISPLAY OFF
            JSR         CLOCK                   LATCH IT
            JSR         WAIT
            LDAA        #$01                    CLEAR DISPLAY
            JSR         CLOCK                   LATCH IT
            JSR         INITD                   INITIALISE RDS DATA & DISPLAY
            JSR         CLREON                  AND EON DATA

*           Initialise interrupt JMPs

JRT1        EQU         $00EB                   E32 BUFFALO RAM JUMP TABLE
JIRQ        EQU         $00EE                   "    "      "    "    "
JXIRQ       EQU         $00F1                   "    "      "    "    "

            LDAA        #$7E
            STAA        JRTI
            STAA        JIRQ
            STAA        JXIRQ
            LDD         #TINTB
            STD         JRTI+1                  RTI
            LDD         #SDATA
            STD         JIRQ+1                  IRQ
            LDD         #SHAFTX
            STD         JXIRQ+1                 XIRQ

            LDAA        #$00                    ENABLE IRQ & XIRQ
            TAP

            *******************************
            *                             *
            *           Idle loop.        *
            *                             *
            *******************************

IDLE        LDY         #$1000
            BRSET       STAT,$08,TBH
            BRSET       $0E,Y,$80,*
            BSET        STAT,$08
            BRA         NO2D
TBH         BRCLR       $0E,Y,$80,*
            BCLR        STAT,$80

NO2D        BRCLR       STAT4,$01,NOPS          DISPLAY TRANSIENT ?
            LDAA        DIST
            BNE         NOPS                    YES, TIMED OUT ?
            JSR         CLTR

NOPS        BRCLR       STAT2,$08,NDU           DISPLAY UPDATE REQUIRED ?
            JSR         MOD                     YES, DO IT
            BCLR        STAT2,$08               AND CLEAR FLAG

NDU         BRCLR       PORTD,Y,$20,FULON       STANDBY ?

NOTSNZ      BRSET       STAT4, $10,NNT2         STANDBY, ALARM ARMED ?
NTJ2        JMP         NT2

NNT2        BRCLR       STAT5,$80,NWA           YES, WEEKDAY ALARM ONLY ?
            LDAA        DOW                     YES
            CMPA        #4                      SATURDAY OR
            BHI         NT2J                    SUNDAY ?
NWA         LDAA        AOUR                    NO, COMPARE ALARM HOURS
            CMPA        OUR                     WITH TIME
```

```
            BNE         NT2J                SAME ?
            LDAA        AMIN                YES, COMPARE ALARM MINUTES
            CMPA        MIN                 WITH TIME
            BNE         NT2J                SAME ?
            LDAA        SEC                 ONLY ALLOW WAKE-UP IN FIRST SECOND
            BNE         NT2                 TO PREVENT SWITCH-OFF LOCKOUT
ONAG        BCLR        PORTD,Y,$20         YES, SWITCH ON,
            JSR         DEL500              WAIT 500ms,
            BCLR        PORTA,Y,$10         DEMUTE
            JSR         P5170               AND TUNE (5170 & 5157)

FULON       BRCLR       STAT4,$02,FLN       SLEEP TIMER RUNNING ?
            LDAA        SLEPT               YES
            BNE         FLN                 TIME TO FINISH ?
            BCLR        STAT4,$02           YES, CLEAR FLAG,
            BSET        PORTD,Y,$20         SWITCH OFF
            BSET        PORTA,Y,$10         AND MUTE

            *******************************
            *                             *
            *         Idle loop (cont.).  *
            *                             *
            *******************************

FLN         BRCLR       STAT4,$80,NT1       14B FLAG HIGH ?
            BRSET       STAT2,$80,NT2       YES, BIT AGREES ?
            BSET        STAT2,$80           NO, SET BIT
            CLR         REARET
            LDAA        #25                 LOCK OUT RETURN
            STAA        DIST                FOR 3 SECONDS
            BSET        STAT4,$01           SET DISPLAY TRANSIENT FLAG
            BSET        PORTA,Y,$10         MUTE
            JSR         DBNC                WAIT 150 ms
            JSR         RETUNE2             AND RETUNE
            BRCLR       STAT4,$80,NWWS      PI CODE NOT IN EON LIST ?
            JSR         DEL500              WAIT 500ms
*           BRCLR       PORTE,Y,$10,SOK     SIGNAL OK ?
*           LDAA        #2
*           STAA        REARET
*           BRA         NT1
SOK         JSR         DEL500              WAIT 500ms
            BRSET       STAT3,S08,TPOK      TP OK?
            LDAA        #5
            STAA        REARET
            BRA         NT1
TPOK        LDAA        PI                  YES, CHECK PI CODE
            CMPA        PION
            BNE         PINOK1
            LDAA        PI+1
            CMPA        PION+1              AGAINST PI (EON)
            BEQ         NT2                 IF OK STAY SWITCHED
PINOK1      LDAA        #3
            STAA        REARET

NT1         BRCLR       STAT2,$80,NT2       14B FLAG LOW, BIT AGREES ?
            BCLR        STAT4,$80           MAKE SURE 14B CANCELLED
            BSET        PORTA,Y,$10         MUTE
            JSR         DBNC                WAIT 150 ms
NWWS        BCLR        STAT2,$80           CLEAR FLAG
            LDAA        LED                 SELECTED PROG.
            JSR         RETUNE2             AND RETURN TO ORIGINAL PROGRAM

NT2         JSR         KBD                 READ KEYBOARD
            JSR         KEYP                EXECUTE KEY
            BRCLR       STAT3,$20,NSRO      SHAFT ROTATION PENDING ?
            BCLR        STAT3,$20           YES, CLEAR FLAG
            BRSET       STAT3,$10,ANTI      DIRECTION ?
            JSR         PINC2               CLOCKWISE, INCREMENT
            BRA         NSRO
ANTI        JSR         PDEC2               ANTI-CLOCKWIRE, DECREMENT
NSRO        BRCLR       STAT3,$40,NRDSP     UPDATE DATE ?
            JSR         MJDAT               YES, CONVERT FROM MJD

            *****************************************
            *                                       *
            *           Idle loop (cont.).          *
```

```
            * Retune if band or SW bank inputs changed. *
            *                                           *
            *********************************************
NRDSP       LDY         #$1000
            BRCLR       STAT,$80,BTO          JUST POWERED UP ?
            BRCLR       PORTA,Y,$01,L5        NO, A0 LOW ?
            BRSET       STAT6,$04,CG6         NO, HIGH, BIT AGREES ?
            BSET        STAT6,$04             NO, MAKE IT HIGH
            BRSET       STAT6,$08,BTO         BAND ONE ?
            BSET        STAT3,$80             YES, SHAFT INTERRUPTS
            BRA         CHE                   AND NOTHING ELSE TO DO

L5          BRCLR       STAT6,$04,CG6         YES, A0 LOW, BUT AGREES ?
            BCLR        STAT6,$04             NO, MAKE IT LOW
            BRSET       STAT6,$08,BTO         BAND ZERO ?
            BCLR        STAT3,$80             YES, RDS INTERRUPTS
            BRA         CHE                   AND NOTHING ELSE TO DO

CG6         BRCLR       PORTA,Y,$02,L6        A1 LOW ?
            BRSET       STAT6,$08,CHE         NO, HIGH, BIT AGREES ?
            BSET        STAT6,$08             NO, MAKE IT HIGH
            BRA         BTO

L6          BRCLR       STAT6,$08,CHE         YES, A1 LOW, BIT AGREES ?
            BCLR        STAT6,$08             NO, MAKE IT LOW
            BRSET       STAT6,$04,BTO         BAND ZERO ?
            BCLR        STAT3,$80             YES, RDS INTERRUPTS
            BRA         BTO

CHE         BRSET       STAT6,$0C,BD3         BAND 3 ?
            BRA         OK6

BD3
CE6         BRCLR       PORTE,Y,$40,E6L       NO, E6 LOW ?
            BRSET       STAT6,$01,OK6         NO, HIGH, BIT AGREES ?
            BSET        STAT6,$01             NO, MAKE IT HIGH
            BRA         BTO

E6L         BRCLR       STAT6,$01,OK6         YES, E6 LOW, BIT AGREES ?
            BCLR        STAT6,$01             NO, MAKE IT LOW

BTO         BSET        STAT,$80              SET POWER-UP FLAG,
            LDAA        #10
            STAA        BCTO                  INITIALISE
            BSET        STAT5,$01             AND START BAND-CHANGE TIMEOUT

            *******************************
            *                             *
            *       Idle loop (cont.).    *
            *                             *
            *******************************

OK6         BRCLR       STAT5,$01,ARI         TIMEOUT RUNNING?
            DEC         BCTO                  YES, DECREMENT COUNT
            BNE         ARI                   FINISHED ?
            BCLR        STAT5,$01             YES, CLEAR FLAG
            BSR         RCLP                  AND RECALL LAST USED PROG. No.
            BRCLR       STAT6,$0C,ARI         BAND 0 ?
            BSET        STAT3,$80             NO, SHAFT INTERUPTS

ARI         BRSET       STAT3,$0C,TATP        TA=TP=1 ?
            BSET        PORTA,Y,$20
            BRA         IOOK
TATP        BCLR        PORTA,7,$20           YES, A5 LOW

IOOK        BRSET       STAT5,$08,MSH         M/S=1 ?
            BSET        PORTA,Y,$40
            BRA         IDLJ
MSH         BCLR        PORTA,Y,$40           YES, A6 LOW

IDLJ        JMP         IDLE

RCLP        BSET        PORTA,Y,$10           MUTE
            LDAB        #120
            JSR         READ1                 GET STORED PROG. No.
            STAA        LED
```

```
            JMP         RETUNE2                 PROGRAM 145170/57

            *******************************
            *                             *
            *     Shaft rotation interrupts. *
            *                             *
            *******************************

SHAFT       BRSET       PORTE,Y,$20,SEM         IRQ,SHAFT I/O HIGH (E5) ?
            BCLR        STAT3,$10               NO, CLEAR DIRECTION BIT
            BRA         TEM
SEM         BSET        STAT3,$10               YES, SET DIRECTION BIT
TEM         BSET        STAT3,$20               SET FLAG TO INDICATE ROTATION
            RTI

SHAFTX      BRSET       PORTE,Y,$10,XEM         XIRQ, SHAFT I/O HIGH (E4) ?
            BCLR        STAT3,$10               NO, CLEAR DIRECTION BIT
            BRA         YEM
XEM         BSET        STAT3,$10               YES, SET DIRECTION BIT
YEM         BSET        STAT3,$20               SET FLAG TO INDICATE ROTATION
            RTI

            *******************************
            *                             *
            *       Keyboard routine.       *
            *                             *
            *******************************

KBD         CLR         W1
            LDY         #$1000
            LDX         #7
KEY1        LDAB        W1
            ADDB        #$04                    SELECT COLUMN
            STAB        W1
            LDAB        PORTD,Y
            ANDB        #$20                    PRESERVE OTHER PORTD DATA
            ADDB        W1
            STAB        PORTD,Y
            LDAA        PORTE,Y                 READ KEYBOARD
            BITA        #$0F                    ANY INPUT LINE HIGH ?
            BNE         L1
            DEX                                 NO, TRY NEXT COLUMN
            BNE         KEY1                    LAST COLUMN ?
            CLR         KEY                     YES, NO KEY PRESSED
            BRA         EXIT
L1          LDAB        W1
            LSLB
            LSLB
            LDAA        PORTE,Y                 READ KEYBOARD
            ANDA        #$0F
            ABA
            CMPA        KEY                     SAME AS LAST TIME ?
            BEQ         EXIT
            STAA        KEY                     NO, SAVE THIS KEY
            CLR         KOUNT
EXIT        INC         KOUNT                   YES, THE SAME
            LDAA        KOUNT
            BRCLR       STAT,$40,NRML           REPEATING ?
            LDAB        PSNP                    YES
            BEQ         NOTCH                   CHARACTER CHANGE ?
            CMPA        #8                      YES, REPEAT AT 8 Hz
            BRA         GON2
NOTCH       CMPA        #16                     NO, REPEAT AT 4 Hz
            BRA         GON2
NRML        CMPA        #3                      NO, 3 THE SAME ?
            BLO         KCLC                    IF NOT DO NOTHING
            BEQ         GOON                    IF 3 THEN PERFORM KEY FUNCTION
            CMPA        #47                     MORE THAN 3, MORE THAN 47 (750mS) ?
GON2        BHI         GOON2                   TIME TO DO SOMETHING ?
            LDAA        KEY                     NO
            BEQ         RKEY                    KEY PRESSED ?
            CLC
            RTS                                 YES BUT DO NOTHING
GOON2       LDAA        KEY
            CMPA        #$54                    DEC. PROG.
            BEQ         GOON3
```

```
            CMPA        #$58                INC.PROG.
            BEQ         GOON3
            CMPA        #$52                SLEEP
            BNE         DNT2                IF NOT A REPEAT KEY, DO NOTHING
GOON3       BSET        STAT,$40            SET REPEAT FLAG
            CLR         KOUNT
GOON        LDAA        KEY
            BEQ         RKEY                SOMETHING TO DO ?
            SEC                             YES, SET C
            RTS
RKEY        BCLR        STAT,$20            NO, CLEAR DONE FLAG
DNT2        BCLR        STAT,$40            CLEAR REPEAT FLAG
            CLR         KOUNT               CLEAR COUNTER
KCLC        CLC
DNT         RTS

            ********************************
            *                              *
            *         Execute key.         *
            *                              *
            ********************************

KEYP        BCC         DNT                 ANYTHING TO DO ?
KEYP2       LDAA        KEY                 YES, GET KEY
            CMPA        #$54                DEC. PROG. (M)
            BEQ         RPT
            CMPA        #$58                INC. PROG. (S)
            BEQ         RPT
            CMPA        #$52                SLEEP
            BEQ         RPT
            BRSET       STAT,$20,DNT        NOT A REPEAT KEY, FLAG SET ?

RPT         CLRB
RJ          LDX         #CTAB
            ABX
            LDAA        0,X                 FETCH KEYCODE
            CMPA        KEY                 THIS ONE ?
            BEQ         PJ                  YES
            CMPA        LAST                NO, LAST CHANCE ?
            BEQ         DNT                 YES, ABORT
            ADDB        #4                  NO TRY THE NEXT KEY
            BRA         RJ
PJ          BSET        STAT,$20
            JSR         1,X
            JMP         P5170

            ********************************
            *                              *
            *     Keyboard jump table.     *
            *                              *
            ********************************

CTAB        FCB         $11                 0
            JMP         DIGIT
            FCB         $21                 1
            JMP         DIGIT
            FCB         $22                 2
            JMP         DIGIT
            FCB         $24                 3
            JMP         DIGIT
            FCB         $31                 4
            JMP         DIGIT
            FCB         $32                 5
            JMP         DIGIT
            FCB         $34                 6
            JMP         DIGIT
            FCB         $41                 7
            JMP         DIGIT
            FCB         $42                 8
            JMP         DIGIT
            FCB         $44                 9
            JMP         DIGIT
            FCB         $48                 ALARM
            JMP         ALARM
            FCB         $38                 STORE/SET
            JMP         SAVE
```

```
            FCB         $18                 ON/OFF
            JMP         ONOFF
            FCB         $14                 CLEAR/STEP
            JMP         CLEAR
            FCB         $12                 MODE (PROG./FREQ.)
            JMP         MODE
            FCB         $52                 SLEEP TIMER START
            JMP         SLEEP
            FCB         $54                 DEC. PROG./FREQ./CHAR.
            JMP         PDEC
            FCB         $58                 INC. PROG./FREQ./CHAR.
            JMP         PINC
            FCB         $61                 RDS DISPLAYS
            JMP         RTDSP
            FCB         $62                 TRAFFIC ENABLE (TOGGLE)
            JMP         TPEN
            FCB         $64                 MW STEP 9/10kHz (TOGGLE)
            JMP         T910
            FCB         $51                 COLON CONTROL
            JMP         TFCC
LAST        FCB         $68                 TA TEST
            JMP         TEST

            *******************************
            *                             *
            *          Alarm key.         *
            *                             *
            *******************************

ALARM       BRCLR       STAT4,$08,ADON      ALARM DISPLAY ON ?
            BRCLR       STAT4,$10,ALOF      YES, ALARM ON ?
            BCLR        STAT4,$10           YES, SWITCH OFF
            BRA         UDCNT
ALOF        BSET        STAT4,$10           NO, SWITCH ON
            BRA         UDCNT

ADON        JSR         CLTR                NO, ENABLE ALARM DISPLAY
            BSET        STAT4,$08           ALARM DISPLAY FLAG
UDCNT       BCLR        STAT4,$20           CANCEL SET-UP
            LDAA        #25                 3 SECONDS TIMEOUT
            STAA        DIST
            BSET        STAT4,$01           SET DISPLAY TRANSIENT FLAG
ABOA        RTS

            *******************************
            *                             *
            *          On/off key.        *
            *                             *
            *******************************

ONOFF       JSR         CLTR                CLEAR DISPLAY TRANSIENTS
            BCLR        STAT4,$82           CANCELL SLEEP TIMER & TA SWITCH FLAG
            BCLR        STAT5,$40           CANCEL STORE MODE

            BRCLR       PORTD,Y,$20,ALRON   ON ?
SODM        BCLR        PORTD,Y,$20         NO, SWITCH ON
            JSR         DEL500              WAIT 500ms
            BCLR        PORTA,Y,$10         AND DEMUTE
            RTS
ALRON       BSET        PORTD,Y,$20         YES, SWITCH OFF
            BSET        PORTA,Y,$10         AND MUTE
            RTS

            *******************************
            *                             *
            *        PS name clear.       *
            *                             *
            *******************************

PSC         LDX         #PSN
            LDAA        #$FF
CPSL        STAA        0,X
            INX
            CPX         #PSN+8
            BNE         CPSL
            RTS
```

```
                ********************************
                *                              *
                *              TP.             *
                *                              *
                ********************************

TPEN            BRSET        PORTD,Y,$20,HIGH       STANDBY ?
                BRSET        STAT,$01,NS1           NO, NORMAL MODE ?
                BRSET        STAT5,$20,TAEH         NO, FREQ. MODE, NVM DISABLE FLAG SET ?
                BSET         STAT5,$20              NO, SET IT
                RTS
TAEH            BCLR         STAT5,$20              YES, CLEAR IT
HIGH            RTS

NS1             BRCLR        STAT4,$04,TPOF         NORMAL MODE, TRAFFIC ON ?
                BCLR         STAT4,$04              YES, DISABLE
                RTS
TPOF            BSET         STAT4,$04              NO, ENABLE
                RTS

                ********************************
                *                              *
                *          Sleep timer.        *
                *                              *
                ********************************

SLEEP           BRSET        STAT5,$04,DECS         ALREADY SLEEP DISPLAY ?
                BRSET        STAT4,$02,STR          NO, SLEEP TIMER ALREADY RUNNING ?
INSLP           LDAA         #60                    NO, INITIALISE SLEEP TIMER
SLEP            STAA         SLEPT
                BSET         STAT4,$02              START SLEEP TIMER
STR             JSR          CLTR                   YES, CLEAR DISPLAY TRANSIENTS
                BSET         STAT5,$04              SLEEP DISPLAY
                BRA          SLPTOK                 NO DECREMENT IF FIRST TIME
DECS            LDAA         SLEPT                  DECREMENT SLEEP TIMER
                SUBA         #5
                STAA         SLEPT
                BMI          INSLP

SLPTOK          LDAA         #25
                STAA         DIST
                BSET         STAT4,$01              START DISPLAY TRANSIENT
                BRSET        PORTD,Y,$20,SODM       ALREADY ON ?
                BCLR         PORTA,Y,$10            YES, JUST DEMUTE
                RTS

                ********************************
                *                              *
                *       Number entry routine.  *
                *                              *
                ********************************

DIGIT           BRSET        PORTD,Y,$20,AB03       STANDBY ?
                JSR          CLTR                   NO, CLEAR DISPLAY TRANSIENTS
                LSRB
                LSRB
                BRSET        STAT,$01,SKP           STATION MODE ?
                BRSET        STAT5,$40,SKP          NO, STORE MODE ?
                BSET         STAT5,$10              NO, SET RETUNE FLAG (FREQUENCY MODE)
                BLCR         STAT5,$20              AND CLEAR TA INHIBIT BIT (NVM)
                STAB         W3
                BRCLR        STAT,$04,SHIFT         CLEAR Q ?
                BCLR         STAT,$04               YES, CLEAR FLAG
                JSR          CLQ                    AND CLEAR Q
SHIFT           BSR          DR1                    W1: MSD, W2: LSD
                LDX          W1
AGS             LDAA         1,X                    MOVE ALL DIGITS
                STAA         1,X                    UP ONE PLACE
                INX
                CPX          W2
                BNE          AGS                    DONE ?
                LDAA         W3                     YES, RECOVER NEW DIGIT
                STAA         0,X                    AND PUT IT IN LSD
                RTS
```

```
SKP         BSET        PORTA,Y,$10           MUTE
            TBA
            STAA        LED
            JMP         RETUNE

            ******************************
            *                            *
            *  Save pointers & 500ms delay. *
            *                            *
            ******************************

DR1         LDX         #RQ                   STORE POINTERS
            STX         W1
            LDAB        #5
            ABX
            STX         W2
ABO3        RTS

DEL500      LDX         #255
            JSR         SKDB
            LDX         #255
            JMP         SKDB

            ******************************
            *                            *
            *    Increment key (& knob).     *
            *                            *
            ******************************

PINC2       BRSET       STAT4,$20,ALSU1       ALARM SET-UP ?
            BRSET       STAT4,$08,TOG57       NO, ALARM DISPLAY ?
            BRSET       PORTD,Y,$20,DMI       NO,STANDBY ?
            LDAB        PSNP
            BNE         PSN0                  NO,PS EDIT MODE ?
            JMP         UP                    NO, STEP UP

PINC        BRSET       STAT4,$20,ALSU1       ALARM SET-UP ?
TOG57J      BRSET       STAT4,#08,TOG57       NO, ALARM DISPLAY ?

            BRSET       PORTD,Y,$20,DMI       NO, STANDBY ?
            BRSET       STAT,$01,NACS         NO, FREQ. MODE ?
            JMP         UP                    YES, STEP UP

            ******************************
            *                            *
            *  Alarm inc. (hours/minutes).   *
            *                            *
            ******************************

ALSU1       BRSET       STAT4,$40,IHR         YES, SET-UP HOURS ?
            LDAA        AMIN                  NO, MINUTES
            CMPA        #59
            BHS         TOOH
            INC         AMIN
            BRA         T5S
TOOH        CLR         AMIN
            BRA         T5S
IHR         LDAA        AOUR
            CMPA        #23
            BLO         HTOH
            CLR         AOUR
            BRA         T5S
HTOH        INC         AOUR
T5S         LDAA        #80                   10 SECOND TIMEOUT
            STAA        DIST
            BSET        STAT4,$01             SET DISPLAY TRANSIENT FLAG
            BCLR        PORTA,Y,$10           DEMUTE
DMI         RTS

NACS        LDAB        PSNP
            BEQ         CONTI                 NO, PS EDIT MODE ?
```

```
            ******************************************
            *                                        *
            *  P-S Edit inc. (ASCII) and 5/7 day toggle  *
            *                                        *
            ******************************************

PSN0        LDX         #PSN-1
            ABX
            LDAA        0,X                 YES
            INCA                            INCREMENT ASCII VALUE
            CMPA        #$20                SPACE
            BLS         MAK20               LESS OR EQUAL ?
            CMPA        #$2E                NO, .
            BLS         MAK2E               LESS OR EQUAL ?
            CMPA        #$30                NO, 0
            BLO         MAK30               LESS ?
            CMPA        #$39                NO, 9
            BLS         CNTB                LESS OR EQUAL ?
            CMPA        #$41                NO, A
            BLO         MAK41               LESS ?
            CMPA        #$5A                NO, Z
            BLS         CNTB                LESS OR EQUAL ?
            CMPA        #$61                NO, a
            BLO         MAK61               LESS ?
            CMPA        #$7A                NO, z
            BLS         CNTB                LESS OR EQUAL ?
MAK20       LDAA        #$20                MAKE SPACE
            BRA         CNTB
MAK2E       LDAA        #$2E                MAKE .
            BRA         CNTB
MAK30       LDAA        #$30                MAKE 0
            BRA         CNTB
MAK41       LDAA        #$41                MAKE A
            BRA         CNTB
MAK61       LDAA        #$61                MAKE a
CNTB        STAA        0,X
            LDAA        #80
            JMP         OUTCH

TOG57       BRCLR       STAT4,$10,DMI       ALARM ARMED ?
            BRCLR       STAT5,$80,A7        YES, 7-DAY ALARM ?
            BCLR        STAT5,$80           NO, MAKE IT 7 DAY
            BRA         T5S
A7          BSET        STAT5,$80           YES, MAKE IT 5 DAY
            BRA         T5S

            *******************************
            *                             *
            *  Program number increment.  *
            *                             *
            *******************************

CONTI       BSET        PORTA,Y,$10         MUTE
            BSET        STAT2,$08           PROG. No. INCREMENT, UPDATE DISPLAY
            LDAA        LED
            BRSET       STAT2,$80,IOK       IF SWITCHED TO TA DON'T INCREMENT
            INCA                            NEXT PROG.
            CMPA        #9                  TOO HIGH ?
            BLS         IOK
            CLRA                            YES, BACK TO ZERO
IOK         STAA        LED
            JMP         RETUNE

            *******************************
            *                             *
            *      Decrement key (& knob).  *
            *                             *
            *******************************

PDEC2       BRSET       STAT4,$20,ALSU2     ALARM SET-UP ?
            BRSET       STAT4,$08,TOG57     NO, ALARM DISPLAY ?
            BRSET       PORTD,Y,$20,DMD     NO, STANDBY ?
            LDAB        PSNP
            BNE         PSN1                NO, PS EDIT MODE ?
            JMP         DOWN                NO, STEP DOWN
```

```
PDEC        BRSET       STAT4,$20,ALSU2       ALARM SET-UP ?
            BRSET       STAT4,$08,TOG57       NO, ALARM DISPLAY ?
            BRSET       PORTD,Y,$20,DMD       NO, STANDBY ?
            BRSET       STAT,$01,NACS2        NO, FREQ. MODE ?
            JMP         DOWN                  YES, STEP DOWN

            ******************************
            *                            *
            *   Alarm dec. (hours/minutes).*
            *                            *
            ******************************

ALSU2       BRSET       STAT4,$40,IHRD        YES, SET-UP HOURS ?
            TST         AMIN                  NO, MINUTES
            BEQ         MZ
            DEC         AMIN
            BRA         T5SD
MZ          LDAA        #59
            STAA        AMIN
            BRA         T5SD
IHRD        TST         AOUR
            BNE         HZ
            LDAA        #24
            STAA        AOUR
HZ          DEC         AOUR
T5SD        LDAA        #80                   10 SECOND TIMEOUT
            STAA        DIST
            BSET        STAT4,$01             SET DISPLAY TRANSIENT FLAG
            BCLR        PORTA,Y,$10           DEMUTE
DMD         RTS

NACS2       LDAB        PSNP
            BEQ         CONTD                 PS EDIT CHARACTER CHANGE ?

            ******************************
            *                            *
            *      P-S Edit dec. (ASCII).  *
            *                            *
            ******************************

PSN1        LDX         #PSN-1
            ABX
            LDAA        0,X                   YES
            DECA                              DECREMENT ASCII VALUE
            CMPA        #$20                  SPACE
            BLS         MKE7A                 LESS OR EQUAL ?
            CMPA        #$2E                  NO, .
            BLS         MKE20                 LESS OR EQUAL ?
            CMPA        #$30                  NO, 0
            BLO         MKE2E                 LESS ?
            CMPA        #$39                  NO, 9
            BLS         CNTS                  LESS OR EQUAL ?
            CMPA        #$41                  NO, A
            BLO         MKE39                 LESS ?
            CMPA        #$5A                  NO, Z
            BLS         CNTS                  LESS OR EQUAL ?
            CMPA        #$61                  NO, a
            BLO         MKE5A                 LESS ?
            CMPA        #$7A                  NO, z
            BLS         CNTS                  LESS OR EQUAL ?
MKE20       LDAA        #$20                  MAKE SPACE
            BRA         CNTS
MKE2E       LDAA        #$2E                  MAKE .
            BRA         CNTS
MKE5A       LDAA        #$5A                  MAKE Z
            BRA         CNTS
MKE7A       LDAA        #$7A                  MAKE z
            BRA         CNTS
MKE39       LDAA        #$39                  MAKE A
CNTS        STAA        0,X
            LDAA        #80

OUTCH       STAA        DIST
            BSET        STAT4,$01             SET DISPLAY TRANSIENT FLAG
            BCLR        STAT4,$08             NOT ALARM DISPLAY MODE
            RTS
```

```
            ********************************
            *                              *
            *      Program number decrement. *
            *                              *
            ********************************

CONTD       BSET        PORTA,Y,$10         MUTE
            LDAA        LED                 PROG. No. DECREMENT
            BRSET       STAT2,$80,RETUNE    IF SWITCHED TO TA DON'T DECREMENT
PNM1        DECA                            DECREMENT PROGRAM NUMBER
            BPL         SK2P                TOO FAR ?
            LDAA        #9
SK2P        STAA        LED                 SAVE NEW PROGRAM NUMBER
RETUNE      PSHA
            LDAB        #120                CHANGE PROGRAM NUMBER IN NVM
            JSR         WRITE1
            PULA
            BRCLR       STAT4,$80,RETUNE2   TA SWITCHED ?
            BCLR        STAT4,$80           YES, MANUAL RETURN FROM TA
            LDAA        #9
            STAA        REARET
            RTS

RETUNE2     JSR         DOIT                NEW PROGRAM
            JSR         P5170
            LDX         #64                 WAIT 100ms
            JSR         SKDB
            BCLR        PORTA,Y,$10         DEMUTE
            BCLR        STAT2,$02           KILL ANY PENDING RDS GROUP
            BCLR        STAT3,$01           AND INHIBIT FM PS-NAME CLEARING
            BCLR        STAT,$10            RE-ENABLE RDS DATA CLEARING
            RTS

FOK         LDAB        #10
            MUL
            ADDB        #$5C
            STAB        SMEM
            ADCA        #$26
            STAA        SMEM+1
            JMP         NEW

            ********************************
            *                              *
            * Tune to TA (using EEPROM data)*
            *                              *
            ********************************

TASW        CLRB
TPIC        ADDB        #10
            JSR         READ1               FIND PI
            INCB
            CMPA        PION                MSB OK ?
            BNE         TNP
            DECB
            JSR         READ1
            CMPA        PION+1              LSB OK ?
            BNE         TNP
            SUBB        #12                 YES, FOUND IT
            JSR         READ1
            PSHA
            ANDA        #$80                NVM INHIBIT FLAG SET ?
            BEQ         TASOK
            LDAA        #8                  NVM INHIBIT MESSAGE
            BRA         ABTA
TASOK       PULA
            STAA        SMEM+1
            JSR         NEWSUB2
            JMP         NEW

TNP         CMPB        #252                TRY NEXT RECORD
            BLO         TPIC
            PSHA
            LDAA        #7
ABTA        STAA        REARET
            PULA
```

```
            BCLR        STAT4,$80             PI MATCH NOT FOUND, FORGET IT
            RTS

            *******************************
            *                             *
            *     Program store/recall.   *
            *                             *
            *******************************

DOIT        BRSET       STAT2,$80,TASW
            LDAB        #12
            MUL
            BRSET       STAT5,$40,STORE
            JMP         RECALL

            *******************************
            *                             *
            * NVW write, sub-address in X.*
            *                             *
            *******************************

STORE       BCLR        SMEM+1,$80
            BRCLR       STAT5,$20,SKTA        TA NVM INHIBIT FLAG SET ?
            BSET        SMEM+1,$80
SKTA        LDAA        SMEM+1                BINARY FREQUENCY MSB
            JSR         WRITE1
            LDAA        SMEM                  BINARY FREQUENCY LSB
            JSR         WRITE1
            LDAA        PSN
            CMPA        #$A0                  PS NAME OK ?
            BEQ         PSNOK
            CMPA        #$FF                  PERHAPS, TRY FF
            BNE         PSOK
PSNOK       LDAA        #$FF
            JSR         WRITE1
            LDAA        DISP+10
            JSR         WRITE1
            LDAA        DISP+11
            JSR         WRITE1
            LDAA        DISP+12
            JSR         WRITE1
            LDAA        DISP+13
            JSR         WRITE1
            LDAA        DISP+14
            JSR         WRITE1
            LDAA        DISP+15
            JSR         WRITE1
            LDAA        #$20
            JSR         WRITE1
            LDAA        #$00                  DUMMY PI CODE
            JSR         WRITE1
            LDAA        #$00
            BRA         FINST

PSOK        JRS         WRITE1
            LDAA        PSN+1
            JSR         WRITE1
            LDAA        PSN+2
            JSR         WRITE1
            LDAA        PSN+3
            JSR         WRITE1
            LDAA        PSN+4
            JSR         WRITE1
            LDAA        PSN+5
            JSR         WRITE1
            LDAA        PSN+6
            JSR         WRITE1
            LDAA        PSN+7
            JSR         WRITE1
            LDAA        PI                    PI CODE
            JSR         WRITE1
            LDAA        PI+1
FINST       JSR         WRITE1
            BCLR        STAT5,$40             CLEAR STORE MODE
            RTS
```

```
            ********************************
            *                              *
            *   NVW read, sub-address in X.  *
            *                              *
            ********************************

RECALL      BSR         NEWSUB
            JMP         NEW

NEWSUB      JSR         READ1
            STAA        SMEM+1
            BCLR        STAT5,$20
            BRCLR       SMEM+1,$80,NEWSUB2
            BSET        STAT5,$20
NEWSUB2     JSR         READ1
            CMPA        #$FF
            BNE         NOTFF2
            LDAA        #$26                $04
            STAA        SMEM+1
            LDAA        #$5C                $2E
NOTFF2      STAA        SMEM
            JSR         READ1
            STAA        PSN
            JSR         READ1
            STAA        PSN+1
            JSR         READ1
            STAA        PSN+2
            JSR         READ1
            STAA        PSN+3
            JSR         READ1
            STAA        PSN+4
            JSR         READ1
            STAA        PSN+5
            JSR         READ1
            STAA        PSN+6
            JSR         READ1
            STAA        PSN+7
            RTS

            ********************************
            *                              *
            *   NVW read & write one byte. *
            *                              *
            ********************************

READ1       JSR         GETAD
            LDAA        0,X
            INCB
            RTS

WRITE1      LDY         #$1000
            BSET        PPROG,Y,$16         SET EELAT, ERASE & BYTE ERASE BITS
            BSR         WBYTE               ERASE BYTE
            JSR         DBOUNC              WAIT 15 ms
            BSET        PPROG,Y,$02         SET EELAT TO WRITE BYTE
            DECB

WBYTE       JSR         GETAD
            STAA        0,X                 LATCH DATA
            BSET        PPROG,Y,$01         SET EEPGM BIT TO START PROGRAMMING
            JSR         DBOUNC              WAIT 15 ms
            CLR         PPROG,Y             STOP
            INCB
            RTS

GETAD       PSHA
            PSHB
            JSR         BAND                GET BAND
            LDX         #$B618              EEPROM START ADDRESS
            TBA
            CMPA        #1                  FM ?
            BLS         FMB
            LDAB        #122                NO, AM
            ABX
            CMPA        #2                  MW ?
            BEQ         FMB
```

```
            ABX                                 NO, SW
            BRCLR       PORTE,Y,$40,SWB2        SECOND BANK ?
            ABX                                 YES
SWB2
*           BRCLR       PORTE,Y,$80,FMB         SECOND PAIR OF BANKS ?
*           ABX                                 YES
*           ABX
FMB         PULB
            PULA
            ABX
            RTS

            *********************************
            *                               *
            *          RDS displays.        *
            *                               *
            *********************************

RTDSP       BRSET       PORTD,Y,$20,SRT         STANDBY ?
            BRSET       STAT5,$02,NOTRT         ALREADY RDS DISPLAY ?
            BRCLR       STAT2,$04,NORT          ALREADY RT DISPLAY ?

NOTRT       BSET        STAT5,$02               SET RDS DISPLAY FLAG
            LDAA        RTDIS                   YES, MOVE ON
            INCA
            CMPA        #26
            BEQ         NORT
            STAA        RTDIS
            LDAA        #100
            STAA        DIST
            BSET        STAT4,$01               RE-START TRANSIENT TIMEOUT
            RTS

NORT        JSR         CLTR
            BSET        STAT2,$04               SET RT DISPLAY FLAG
            LDAA        #9
            STAA        DISP1
            LDAA        #1
            STAA        DISP2
            RTS

            ************************************
            *                                  *
            * Increment and decrement routines. *
            *                                  *
            ************************************

UP          BSR         LDXR
IF          INC         SMEM                    NO, INCREMENT LSB
            BNE         TT1                     DID IT WRAP ROUND
            INC         SMEM+1                  YES, INCREMENT MSB
TT1         DECB
            BNE         IF                      ALL DONE ?
            BRA         NEWJ

DOWN        BSR         LDXR
DF          TST         SMEM                    NO, IS LSB ZERO ?
            BNE         TT2                     IF NOT LEAVE MSD
            DEC         SMEM+1                  DECREMENT MSB
TT2         DEC         SMEM                    DECREMENT LSB
            DECB
            BNE         DF                      ALL DONE ?
NEWJ        JSR         NEW
            JSR         P5170
            BCLR        PORTA,Y,$10             DEMUTE
            RTS

LDXR        BRCLR       STAT6,$08,LDXR2         AM ?
            BSET        STAT2,$40               YES, CLEAR PS NAME
            BRA         NFMB
LDXR2       BSET        STAT3,$01               NO, FM, ENABLE PS NAME CLEARING
NFMB        JSR         BAND                    GET BAND
            TBA
            LDAB        #1                      SINGLE STEP (1,5,10 kHz FOR MW,SW,FM)
            BRCLR       STAT,$02,SRT            LARGE STEPS SELECTED ?
            CMPA        #3                      YES, BAND 3 (SW) ?
```

```
            BEQ         SRT
            LDAB        #5                  NO, x5 STEP (50 kHz FOR FM)
            CMPA        #2                  MW ?
            BNE         SRT
            LDAB        #9                  YES, 9kHz
            BRCLR       STAT6,$40,SRT       OR SHOULD IT BE 10kHz
            INCB                            YES
SRT         RTS

            *******************************
            *                             *
            *              TA test.       *
            *                             *
            *******************************

TEST        BRSET       PORTD,Y,$20,AOB     STANDBY ?
            LDD         #$C5B1              CLYDE 1
            STD         PION
            BRSET       STAT4,$04,NABT      TA SWITCHING ENABLED ?
            LDAA        #1                  NO, SET RETURN REASON
            STAA        REARET
AOB         RTS
NABT        BSET        STAT4,$80           YES, DO IT
            RTS

            *******************************
            *                             *
            *           Store key.        *
            *                             *
            *******************************
SAVE        BRCLR       STAT4,$08,NAME      ALARM DISPAY ?
            BRCLR       STAT4,$10,NTB2      YES, ALARM ARMED ?
            BRSET       STAT4,$20,AISM      YES, ALREADY SET-UP MODE ?
            BSET        STAT4,$60           NO, ENTER SET-UP MODE, HOURS
A5SD        LDAA        #80
            BRA         SDT
AISM        BRSET       STAT4,$40,MSM       YES, SET-UP HOURS ?
            BCLR        STAT4,$20           NO, CANCEL SET-UP
            BRA         A5SD
MSM         BCLR        STAT4,$40           YES, MAKE IT MINUTES
            BRA         A5SD

NAME        BRSET       PORTD,Y,$20,NTB2    STANDBY ?
            BRSET       STAT,$01,NFM        NO, FREQUENCY MODE ?
            BRSET       STAT5,$40,ASM       YES, STORE MODE ?
            BSET        STAT5,$40           NO, ENTER STORE MODE
            RTS

ASM         LDAA        LED
            JMP         DOIT                SAVE

NFM         LDAA        PSNP                NOT FREQUENCY MODE
            BNE         SKPCLR              SET
            JSR         CLTR                UP
SKPCLR      INC         PSNP                PS-NAME CHANGE MODE
            LDAA        PSNP
            CMPA        #8
            BLS         NTB3
            CLR         PSNP
NTB3        LDAA        #80
SDT         STAA        DIST
            BSET        STAT4,$01           SET DISPLAY TRANSIENT FLAG
NTB2        RTS

            ****************************************
            *                                      *
            * PROG, the displayed number is added to  *
            * the IF offset, converted to binary and  *
            * stored in SMEM & SMEM+1.             *
            *                                      *
            * NEW takes binary working frequency   *
            * in SMEM & SMEM+1 converts it to BCD and *
            * subtracts the IF offset.             *
            *                                      *
            ****************************************
```

```
PROG    BRSET   STAT,$01,NEW    STATION MODE ?
        JSR     IFO             P < IF OFFSET
        JSR     ADB             Q < FREQ + IF

        JSR     BAND
        BNE     ONE             BAND 3 (SW) ?
        JSR     ADD             YES, DIVIDE BY 5, Q < 2 X (FREQ + IF)
        LDX     #5
LPP     LDAA    RQ-1,X          MOVE ALL DIGITS
        STAA    RQ,X            IN Q DOWN ONE
        DEX                     PLACE TO DEVIDE
        BNE     LPP             BY 10 (Q < Q/5)

ONE     JSR     BCON            CONVERT Q TO BINARY

NEW     JSR     DCON            CONVERT TO BCD IN Q

        JSR     BAND
        BNE     STIF            BAND 3 (SW) ?
        STX     NUM1            YES
        LDX     #RP
        JSR     ADD             P < 2Q
        LDX     #RP
        STX     NUM1
        LDX     #RQ
        JSR     ADD             Q < 3Q
        LDX     #RQ
        JSR     ADD             Q < 5Q


STIF    JSR     IFO             P < IF OFFSET
        BSET    STAT,$04
        JMP     SUB             Q < (RATIO X STEP) -IF

        ****************************************
        *                                      *
        * The IF offset is selected according to  *
        * the required band and placed in "RP."   *
        *                                      *
        ****************************************

IPO     BSR     BAND            FIND BAND
        BRSET   PORTA,Y,$04,NOTN NEGATIVE FM IF ?
        CMPB    #1              YES
        BHI     NOTN            BUT IS IT FM ?
        LDAB    #4              YES, FIFTH IS FROM TABLE
NOTN    LDAA    #6
        MUL                     TIMES 6
        LDX     #1FS
        ABX
        LDY     #RP
LP6     LDAA    0,X             TRANSFER
        STAA    0,Y             INTO RP
        INX
        INY
        CPY     #RP+6
        BLO     LP6             DONE ?
        LDY     #$1000          RE-INITIALISE Y
        LDX     #RP             SET-UP POINTERS
        STX     NUM2
        LDX     #RQ
        STX     NUM1
        RTS

IFS     FCB     0,0,1,0,7,0      10.70 MHz FM OSC HIGH
        FCB     0,0,1,0,7,0      10.70 MHz FM OSC HIGH
        FCB     0,0,0,4,5,5        455 kHz SW/MW
        FCB     0,1,0,7,0,0      10.70 MHz SW (EXT/5 FOR 5157)
        FCB     9,9,8,9,3,0     -10.70 MHz FM OSC LOW

BAND    LDAB    PORTA,Y         GET BAND
        ANDB    #$03
        LDX     #RQ
        STX     NUM2
        CMPB    #3              BAND 3 (SW, /5) ?
        RTS
```

```
            ******************************
            *                            *
            *  Mode change & clear routines.*
            *                            *
            ******************************

MODE        BRSET       PORTD,Y,$20,CLP     STANDBY ?
            JSR         CLTR
            JSR         PROG                SEND DISPLAYED FREQUENCY
SKIP        BRCLR       STAT,$01,SK         FREQUENCY MODE ?
            BCLR        STAT,$01            NO, SET TO FREQUENCY MODE
            RTS

SK          BCLR        STAT5,$40           FREQ. MODE, CLEAR STORE MODE
            BRCLR       STAT5,$10,NNTR      NEW FREQUENCY ENTERED ?
            BSET        PORTA,Y,$10         YES, MUTE
            JSR         DBNC                WAIT 15ms
            JSR         P5170
            LDX         #64
            JSR         SKDB                WAIT 100ms
            BCLR        PORTA,Y,$10         DE-MUTE
            BCLR        STAT2,$02           AND KILL ANY PENDING RDS GROUP
SKSM        BCLR        STAT5,$10           CLEAR RETUNE FLAG
            RTS
NNTR        BSET        STAT,$01            NO, RETURN TO STATION MODE
            BCLR        STAT5,$40           CANCEL STORE MODE
            RTS

CLEAR       BRSET       PORTD,Y,$20,CLP     STANDBY ?
            BRSET       STAT,$01,SM         NO, STATION MODE ?
            BSET        STAT5,$10           FREQUENCY CHANGED
CLAL        BSR         CLQ                 NO, CLEAR Q
SM          LDAA        PSNP
            BEQ         SPCC
            JSR         PSC
SPCC        JSR         CLTR                CLEAR DISPLAY TRANSIENTS
            BRSET       STAT,$02,KHZ
            BSET        STAT,$02            9 (MW), 50 (FM) kHz STEPS
            RTS
KHZ         BCLR        STAT,$02            1 (MW), 10 (FM) kHz STEPS
CLP         RTS

CLQ         LDX         #RQ                 CLEAR RQ
CLRAS       LDAA        #06                 CLEAR 6 BYTES
            STAA        COUNT               STARTING AT X
CR          CLR         0,X
            INX
            DEC         COUNT
            BNE         CR                  DONE ?
            RTS

CLTR        BCLR        STAT4,$01           CLEAR DISPLAY TRANSIENT FLAG
CLTR2       BCLR        STAT2,$04           CANCEL RT DISPLAY
            CLR         RTDIS
            BCLR        STAT4,$28           NOT ALARM (DISPLAY OR SET-UP)
            BCLR        STAT5,$06           NOT RT OR SLEEP DISPLAY
            CLR         PSNP                NOT PS-EDIT
            RTS

            ******************************************
            *                                        *
            * BCD to binary conversion. No, in "RQ" is *
            * converted to binary in SMEM & SMEM+1.    *
            *                                        *
            ******************************************

BCON        CLR         SMEM                CLEAR WORKING
            CLR         SMEM+1              FREQUENCY LOCATIONS
            LDX         #0
L2          LDAA        SMEM                LS BYTE
            LSLA                            2xLSB
            STAA        W1                  SAVE 2xLSB
            ROL         SMEM+1              2xMS BYTE
            LDAA        SMEM+1
            STAA        W2                  SAVE 2xMSB
```

```
            LDAA        W1                  2xLSB
            LSLA                            4xLSB
            ROL         SMEM+1              4xMSB
            LSLA                            8xLSB
            ROL         SMEM+1              8xMSB
            ADDA        W1                  10xLSB
            STAA        SMEM
            LDAA        SMEM+1
            ADCA        W2
            STAA        SMEM+1
            ADCA        W2                  10xMSB
            STAA        SMEM+1
            INX                             FETCH
            LDAA        RQ,X                NEXT
            ADDA        SMEM                DIGIT
            STAA        SMEM                AND
            LDAA        #0                  (CLRA CLEARS THE C BIT)
            ADCA        SMEM+1              ADD IT TO WORKING
            STAA        SMEM+1              FREQUENCY
            CPX         #5                  DONE ?
            BNE         L2
            RTS

            *******************************
            *                             *
            *       Clear NVM - not used.    *
            *                             *
            *******************************

CLRNVW      CLR         COUNT
CLOP        LDAA        #$FF
            LDAB        COUNT
            JSR         WRITE1
            INC         COUNT
            BNE         CLOP
            CLRA
            LDAB        #120                CLEAR MAX. PROG. No.
            JMP         WRITE1

            *****************************************
            *                                       *
            * Addition and subtraction of BCD numbers. *
            *                                       *
            *****************************************

SUB         STX         W5                  ANSWER POINTER
COM2        LDX         NUM2                9S COMPLIMENT
COMP        LDAB        #$06                SECOND NUMBER
LOOP3       LDAA        #$09
            SUBA        5,X                 SUBTRACT FROM 9
            STAA        5,X                 AND PUT IT BACK
            DEX
            DECB
            BNE         LOOP3
            CLR         CARRY               SET CARRY TO ONE
            INC         CARRY               BEFORE ADDING
            BRA         AD                  ADD FIRST NUMBER

ADD         CLR         CARRY
            STX         W5                  ANSWER POINTER
AD          LDAB        #$06
            LDX         NUM1                1st No. POINTER
            STX         W3
            LDX         NUM2                2nd No. POINTER
            STX         W4
LOOP        LDX         W3
            LDAA        5,X
            DEX
            STX         W3
            LDX         W4
            ADDA        5,X                 ADD
            DEX
            STX         W4
            ADDA        CARRY               SET ON ADDITION OVERFLOW
            CLR         CARRY               OR POS. RESULT SUBTRACTION
            BSR         ADJ                 DECIMAL ADJUST
```

```
            LDX         W5
            STAA        5,X                 SAVE ANSWER
            DEX
            STX         W5
            DECB
            BNE         LOOP                DONE ?
            RTS

AJ          SUBA        #10                 YES, SUBTRACT 10
            INC         CARRY               AND RECORD CARRY
ADJ         CMPA        #10
            BHS         AJ                  10 OR MORE ?
            RTS                             NO

            ****************************************
            *                                      *
            *  Current binary divide ratio in SMEM & *
            * SMEM+1 is converted to decimal in RQ.  *
            *                                      *
            ****************************************

DCON        LDAA        SMEM+1              TRANSFER CURRENT
            STAA        W2                  FREQUENCY DIVIDE
            LDAA        SMEM                RATIO INTO
            STAA        W1                  WORKING AREA
DCON2       LDX         #RR                 CLEAR
            STX         NUM1
            JSR         CLRAS               RR
            INC         RR+5                RR <- 1
            JSR         CLQ                 CLEAR RQ
            LDAA        #14                 14 BITS TO CONVERT
            STAA        W6
LOOP2       LSR         W2                  MOVE OUT
            ROR         W1                  FIRST (LS) BIT
            BCC         NXT                 ZERO
            LDX         #RQ                 ONE, ADD
            STX         NUM2                CURRENT VALUE
            BSR         ADD                 OF RR
NXT         LDX         #RR                 ADD RR
            STX         NUM2                TO
            BSR         ADD                 ITSELF
            DEC         W6                  ALL
            BNE         LOOP2               DONE ?
            RTS

            *******************************
            *                             *
            *        Delay (X x 1.5mS).   *
            *                             *
            *******************************

DBNC        LDX         #100                150mS
            BRA         SKDB
DBOUNC      LDX         #10                 APPROX 15mS WITH A 8.388 MHz XTAL
SKDB        STX         W6                  X x 1.5mS
DLP         LDX         #$FF                PAUSE
DLOOP       BRN         "                   256X12
            BRN         "                   CYCLES
            DEX
            BNE         DLOOP
            DEC         W6+1
            BNE         DLP
ABO         RTS

            ****************************************
            *                                      *
            *  Serial output routine to the MC145170. *
            *                                      *
            ****************************************

P5170       BCLR        PORTB,Y,$01         CLOCK LOW
            BCLR        PORTB,Y,$10         LE LOW
            LDAA        #0                  CLEAR
            BSR         SQU8I               CONTROL REGISTER
            BSET        PORTB,Y,$10         LATCH IT
```

```
            BCLR        PORTB,Y,$10         LE LOW
            LDAA        SMEM+1
            ANDA        #$7F
            BSR         SQU8I               SEND MSBYTE
            LDAA        SMEM                AND LSBYTE OF
            BSR         SQU8I               NEW FREQUENCY
            BSET        PORTB,Y,$10         LATCH IT

            BCLR        PORTB,Y,$10         LE LOW
            LDAA        #$03                SEND
            BSR         SQU7I               REFERENCE
            LDAA        #$20                DIVIDE RATIO
            BSR         SQU8I               800 = 8MHz/10kHz
            BSET        PORTB,Y,$10         LATCH IT

            ****************************************
            *                                      *
            *  Serial output routine to the MC145157. *
            *                                      *
            ****************************************
P5157
            LDAA        SMEM                TRANSFER SMEM AND
            LSLA                            MEM+1 TO TEMPORARY
            STAA        W4                  LOCATIONS AND MOVE
            LDAA        SMEM+1              UP ONE BIT TO INCLUDE
            ROLA                            THE 5157 CONTROL BIT.
            BSR         SQU7                SEND MSBYTE (7 BITS)
            LDAA        W4                  AND LSBYTE OF
            BSR         SQU8                NEW FREQUENCY
            BSET        PORTB,Y,$08         LATCH
            BCLR        PORTB,Y,$08         IT
            LDAA        #$4E                SEND 15 BIT (14+1)
            BSR         SQU7                REFERENCE
            LDAA        #$21                DIVIDE RATIO
            BSR         SQU8
            BSET        PORTB,Y,$08         LATCH IT
            BCLR        PORTB,Y,$08         ALL LOW (5157/70 SWITCHED OFF)
            RTS

            ************************************
            *                                  *
            *  Subroutines for the MC145157/170. *
            *                                  *
            ************************************

SQU8I       LDAB        #8                  SEND 8 BITS
            BRA         S1I
SQU7I       LSLA                            MOVE OUT MS BIT
            LDAB        #7                  AND SEND OTHER 7
S1I         LSLA                            MOVE I BIT INTO "C"
            BCC         S2I                 ZERO ?
            BSET        PORTB,Y,$02         NO
S21         BSET        PORTB,Y,$01         CLOCK
            BCLR        PORTB,Y,$01         IT
            BCLR        PORTB,Y,$02
            DECB
            BNE         S1I                 ANY MORE ?
            RTS

SQU8        LDAB        #8                  SEND 8 BITS
            BRA         S1
SQU7        LSLA                            MOVE OUT MS BIT
            LDAB        #7                  AND SEND OTHER 7
S1          LSLA                            MOVE 1 BIT INTO "C"
            BCC         S2                  ZERO ?
            BSET        PORTB,Y,$02         NO
S2          BCLR        PORTB,Y,$01         CLOCK
            BSET        PORTB,Y,$01         IT
            BCLR        PORTB,Y,$02
            DECB
            BNE         S1                  ANY MORE ?
            RTS
```

```
            ******************************
            *                            *
            *    Toggle 9/10 kHz  step (MW). *
            *                            *
            ******************************

T910        BRSET       STAT6,$40,CBH
            BSET        STAT6,$40
            RTS
CBH         BCLR        STAT6,$40
            RTS

            ********************************************************************************
                                                                                          *
            *       LINK batch files (RLE.BAT & RDE.LD) and PCBUG11 Vectors.              *
            *                                                                             *
            *       ILD11 RADE.O FNCE.O RDSE.O -MKUF E32.MAP -G RDE -O RDE.OUT            *
            *       IHEX RDE.OUT -O RDE.0                                                 *
            *       TYPE E32.MAP                                                          *
            *                                                                             *
            *       section .RAM1 BSS origin 0x0000                                       *
            *       section .RAM2 BSS origin 0x0100                                       *
            *       section .RAM3 BSS origin 0x0200          E32                          *
            *       section .ROM1 origin 0xD000             $9000                         *
            *       section .ROM2 origin 0xE000             $9c00                         *
            *       section .ROM3 origin 0xF000             $A000                         *
            *       section .VECT origin 0xBFC1               -                           *
            *       section .VECT2 origin 0xFFD6            ($FFD6)                       *
            *                                                                             *
            ********************************************************************************

*           SECTION       .VECT

*           JMP         START               SCI
*           JMP         START               SPI
*           JMP         START               PULSE ACCUMULATOR EDGE
*           JMP         START                 "      "        OVER
*           JMP         START               TIMER OVER
*           JMP         START               "     IC4/OC5
*           JMP         START               "     OC4
*           JMP         START               "     OC3
*           JMP         START               "     OC2
*           JMP         START               "     OC1
*           JMP         START               "     IC3
*           JMP         START               "     IC2
*           JMP         START               "     IC1
*           JMP         TINTB               RTI
*           JMP         SDATA               IRQ
*           JMP         SHAFTX              NOT USED, XIRQ USED BY PCbug11
*           JMP         START               SWI
*           JMP         START               ILLEGAL OP CODE
*           JMP         START               COP
*           JMP         START               CLOCK MONITOR
*           JMP         START               RESET

            ******************************
*           *                            *
*           *       MC68HC11E32 Vectors.   *
*           *                            *
            ******************************

            SECTION     .VECT2
*           ORG         $FFD6

            FDB         START               SCI
            FDB         START               SPI
            FDB         START               PULSE ACCUMULATOR EDGE
            FDB         START                  "      "       OVER
            FDB         START               TIMER OVER
            FDB         START               "     IC4/OC5
            FDB         START               "     OC4
            FDB         START               "     OC3
            FDB         START               "     OC2
            FDB         START               "     OC1
            FDB         START               "     IC3
            FDB         START               "     IC2
```

```
                FDB         START                   "     IC1
                FDB         TINTB                   RTI
                FDB         SDATA                   IRQ
                FDB         SHAFTX                  XIRQ
                FDB         START                   SWI
                FDB         START                   ILLEGAL OP CODE
                FDB         START                   COP
                FDB         START                   CLOCK MONITOR
                FDB         START                   RESET

                END

                          Section synopsis
                174)        .RAM1
                256)        .RAM2
                109)        .RAM3
                2889)       .ROM1
                42)         .VECT2
```

```
                  Symbol table
.RAM1      1 00000000 | CONTD        4 000005df | INSLP      4 000003fe | NNTR     4 00000968 | RECALL      4 00000702
.RAM2      2 00000000 | CONTI        4 00000529 | IOK        4 0000053c | NO2D     4 000000c6 | RETUNE      4 000005f0
.RAM3      3 00000000 | COUNT        1 0000009a | IOOK       4 0000022e | NOPS     4 000000d1 | RETUNE2     4 00000603
.ROM1      4 00000000 | CPSL         4 000003cc | IRQ        4 00000006 | NORT     4 000007c0 | RJ          4 0000030a
.VECT2     5 00000000 | CR           4 0000099a | ITMP1      1 00000069 | NOTCH    4 000002bc | RKEY        4 000002ea
A5SD       4 00000847 | CTAB         4 00000325 | KBD        4 0000026f | NOTFF2   4 00000723 | RP          1 0000007c
A7         4 00000524 | DAT          1 0000004b | KCLC       4 000002f3 | NOTN     4 000008e0 | RPT         4 00000309
ABO        4 00000aa7 | DBNC         4 00000a8e | KEY        1 00000096 | NOTRT    4 000007ac | RQ          1 00000076
ABO3       4 00000470 | DBOUNC       4 00000a93 | KEY1       4 00000279 | NOTSNZ   4 000000e0 | RR          1 00000082
ABOA       4 000003a3 | DCON         4 00000a58 | KEYP       4 000002f5 | NRDSP    4 0000019b | RT          3 00000028
ABTA       4 0000065c | DCON2    E   4 00000a60 | KEYP2      4 000002f7 | NRML     4 000002c0 | RTDIS       1 000000a3
AD         4 00000a24 | DECS         4 0000040d | KHZ        4 0000098f | NS1      4 000003ea | RTDSP       4 0000079f
ADD        4 00000a1f | DEL500       4 00000471 | KOUNT      1 00000097 | NSRO     4 00000194 | S1          4 00000b26
ADJ        4 00000a53 | DF           4 000007e0 | L1         4 00000298 | NT1      4 00000165 | S1I         4 00000b08
ADON       4 00000393 | DI           1 000000a4 | L2         4 000009bf | NT2      4 0000017b | S2          4 00000b2d
AGS        4 0000044e | DIG2         1 00000098 | L5         4 000001b8 | NT2J     4 000000e4 | S2I         4 00000b0f
AISM       4 0000084b | DIGIT        4 00000426 | L6         4 000001d6 | NTB2     4 00000889 | SAVE        4 00000838
AJ         4 00000a4e | DISP         3 00000000 | LAST       4 0000037d | NTB3     4 00000882 | SCHAN       1 000000a5
ALARM      4 00000381 | DISP1        1 00000074 | LDRX       4 000007f9 | NUM1     1 0000009b | SCNT        1 000000ad
ALOF       4 0000038e | DISP2        1 00000075 | LDXR2      4 00000802 | NUM2     1 0000009d | SDATA   I   0 00000000
ALRON      4 000003be | DISPP        3 00000010 | LED        1 0000009f | NWA      4 000000f1 | SDT         4 00000884
ALSU1      4 000004a5 | DIST         1 00000047 | LEV        1 00000067 | NWWS     4 00000173 | SEC         1 0000006f
ALSU2      4 00000569 | DLOOP        4 00000a9b | LOOP       4 00000a2e | NXT      4 00000a81 | SEM         4 00000257
AMIN       1 00000072 | DLP          4 00000a98 | LOOP2      4 00000a72 | OK6      4 0000020b | SHAFT   E   4 0000024d
ANTI       4 00000191 | DMD          4 00000594 | LOOP3      4 00000a0d | ONAG     4 00000101 | SHAFTX      4 0000025e
AOB        4 00000833 | DMI          4 000004d2 | LP6        4 000008eb | ONE      4 000008a6 | SHIFT       4 0000044a
AOUR       1 00000073 | DNT          4 000002f4 | LPP        4 0000089f | ONOFF    4 000003a4 | SK          4 00000946
ARI        4 00000220 | DNT2         4 000002ed | M8         4 00000079 | OUR      1 00000071 | SK2P        4 000005ee
ASM        4 0000086a | DOIT         4 00000663 | MAK20      4 000004fe | OUTCH    4 000005d6 | SKDB        4 00000a96
BAND       4 00000926 | DOM          1 00000044 | MAK2E      4 00000502 | P        1 00000015 | SKIP        4 0000093e
BCON       4 000009b6 | DOW          1 00000046 | MAK30      4 00000506 | P5157    4 00000ada | SKP         4 0000045c
BCTO       1 000000ac | DOWN         4 000007de | MAK41      4 0000050a | P5170    4 00000aa8 | SKPCLR      4 00000876
BD3        4 000001ec | DR1          4 00000466 | MAK61      4 0000050e | PDEC     4 00000555 | SKSM        4 00000964
BIT        1 00000068 | E6L          4 000001fa | MIN        1 00000070 | PDEC2    4 00000541 | SKTA        4 0000067b
BMJD       1 00000000 | EON          2 00000000 | MJD        1 00000030 | PI       1 00000061 | SLEEP       4 000003f6
BTO        4 00000201 | EXIT         4 000002ab | MJDAT   I  0 00000000 | PIN      1 00000065 | SLEP        4 00000400
CARRY      1 00000099 | FINST        4 000006fb | MKE20      4 000005c0 | PINC     4 00000491 | SLEPT       1 00000048
CBCD   I   0 00000000 | FLN          4 00000122 | MKE2E      4 000005c4 | PINC2    4 0000047d | SLPTOK      4 00000415
CBH        4 00000b45 | FMB          4 0000079b | MKE39      4 000005d0 | PINOK1   4 00000161 | SM          4 0000097d
CE6        4 000001ec | FOK          4 00000061 | MKE5A      4 000005c8 | PION     1 00000063 | SMEM        1 000000a0
CG6        4 000001c8 | FULON        4 0000010f | MKE7A      4 000005cc | PJ       4 0000031d | SODM        4 000003b2
CHE        4 000001e6 | GETAD        4 00000780 | MNTH       1 00000042 | PNM1     4 000005e9 | SOK         4 00000148
CLAL       4 0000097b | GON2         4 000002c8 | MOD    I   0 00000000 | PROC     0 00000000 | SPCC        4 00000984
CLEAR      4 0000096f | GOON         4 000002e4 | MODE       4 00000933 | PROG     4 0000088a | SQU7        4 00000b23
CLOCK  I   0 00000000 | GOON2        4 000002d0 | MSH        4 00000238 | PSC      4 000003c7 | SQU7I       4 00000b05
CLOOP      4 0000005a | GOON3        4 000002de | MSM        4 00000854 | PSN      3 00000020 | SQU8        4 00000b1f
CLOP       4 000009f5 | GROUP        1 00000057 | MZ         4 00000577 | PSN0     4 000004d7 | SQU8I       4 00000b01
CLP        4 00000992 | H2L          4 00000032 | NABT       4 00000834 | PSN1     4 00000599 | SRT         4 00000820
CLQ        4 00000993 | HIGH         4 000003e9 | NACS       4 000004d3 | PSNOK    4 00000690 | START       4 00000009
CLRAS      4 00000996 | HTOH         4 000004c4 | NACS2      4 00000595 | PSNP     1 0000004a | STAT        1 000000a6
CLREON I   0 00000000 | HZ           4 00000586 | NAME       4 00000859 | PSOK     4 000006c7 | STAT2       1 000000a7
CLRNVM     4 000009f2 | IDLE         4 000000ac | NDU        4 000000db | PTY      1 0000005f | STAT3       1 000000a8
```

```
CLTR    E   4 000009a3 | IDLJ          4 0000023c | NEW     E   4 000008a9 | PTYCMP    1 00000060 | STAT4        1 000000a9
CLTR2       4 000009a6 | IF            4 000007d1 | NEWJ        4 000007ee | Q         1 00000003 | STAT5        1 000000aa
CNTB        4 00000510 | IFO           4 000008d3 | NEWSUB     4 00000707 | R         1 00000027 | STAT6        1 000000ab
CNTS        4 000005d2 | IFS           4 00000908 | NEWSUB2    4 00000716 | RCLP      4 0000023f | STIF         4 000008ca
COM2        4 00000a09 | IHR           4 000004b9 | NFM        4 0000086f | RDSTO     1 00000049 | STORE        4 00000671
COMP        4 00000a0b | IHRD          4 0000057d | NFMB       4 00000805 | READ1     4 00000756 | STR          4 00000405
CONF        1 0000006c | INITD     I   0 00000000 | NNT2       4 000000e7 | REARET    1 000000a2 | STRST        4 00000000

SUB         4 00000a07 | TATP          4 0000022a | TMPGRP     1 0000004f | TPOF      4 000003f2 | W4           1 0000008e
SWB2        4 0000079b | TBH           4 000000be | TMQ        1 0000000c | TPOK      4 00000155 | W5           1 00000090
SYN         1 0000006a | TEM           4 0000025a | TMRB       4 00000003 | TT1       4 000007d9 | W6           1 00000092
T5S         4 000004c7 | TEST          4 00000821 | TNP        4 00000655 | TT2       4 000007e8 | W7           1 00000094
T5SD        4 00000589 | TFCC      I   0 00000000 | TOG57      4 00000517 | UDCNT     4 00000399 | WAIT     I   0 00000000
T910        4 00000b3d | TH32          1 0000006d | TOG57J     4 00000495 | UP        4 000007cf | WBYTE        4 0000076f
TAEH        4 000003e6 | TH8           1 0000006e | TOOH       4 000004b4 | W1        1 00000088 | WRITE1       4 0000075d
TASOK       4 0000064c | TINTB     I   0 00000000 | TPEN       4 000003d5 | W2        1 0000008a | XEM          4 00000268
TASW        4 0000062b | TMP           1 0000001e | TPIC       4 0000062c | W3        1 0000008c | YEM          4 0000026b
TATP        4 0000022a
```

Application Note

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