AN1597

Longwave Radio Data Decoding using an HC11 and an MC3371

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INTRODUCTION

The BBC's Radio 4 198 kHz Longwave transmitter carries data as well as the audio signal. This has some similarities with the RDS data included in VHF radio signals in many European countries but has a much lower data rate and is used for a different purpose. There are 16 data block types. Type 0 is used for time and date (and filler data) while the other blocks are used commercially where each block is available to the company leasing it for use in a specific application. Typical uses are electricity tariff switching, foreign exchange rate board updating and lighting control. The whole of the UK is covered by a 500 kW transmitter at Droitwich in England with a little help from two 50 kW transmitters at Westerglen and Burghead in Scotland. All three transmitters use the same frequency. The specification of LF Radio Data is described in a BBC document[1].

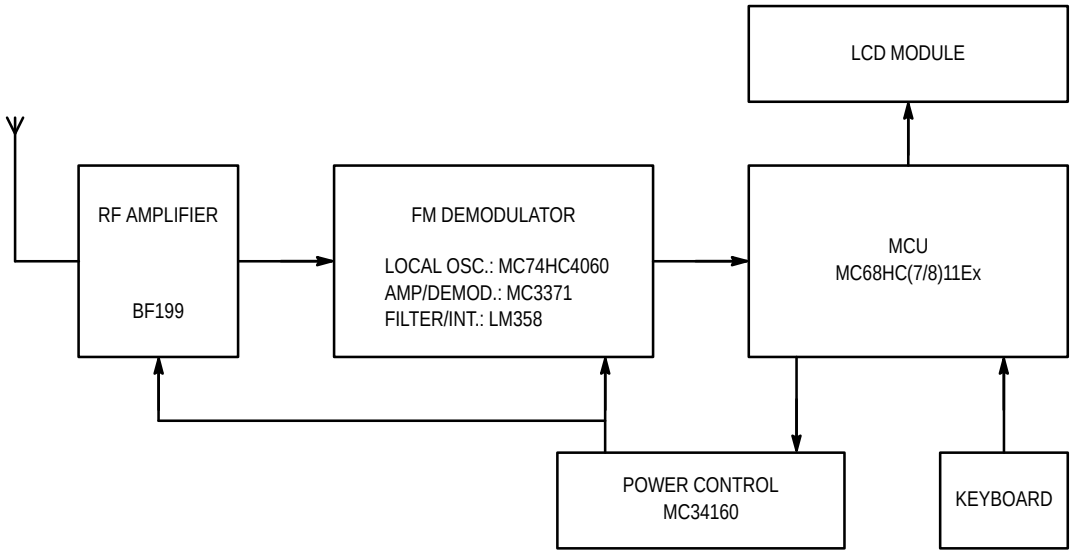

Figure 1. Block Diagram

Time data is transmitted every minute on the minute and provides a very accurate clock, traceable to national standards. Local time variation (e.g. BST) is also transmitted. In this application, time and date can be permanently displayed whilst all incoming data can be displayed in hexadecimal form. The microprocessor converts the transmitted date information (day–of–week, week number and year type) into day–of–month and month. The year is not transmitted and cannot be uniquely determined from the available data. The position in the 28–year leap–year/year–start–day cycle can, however, be worked out and this can be used to calculate a year in the range 1995 to 2022. It is not possible to distinguish between 1995 and 2023.

Figure 1 shows a block diagram of the application; the microprocessor used for decoding is the MC68HC(7)11 while an MC3371 is used for the radio receiver. Unlike RDS, where demodulation chips are available, the capability of retrieving the data bits has to be included in the hardware design. The MC3371 is a superheterodyne receiver which includes a mixer, limiting IF amplifier and FM demodulator primarily intended for dual conversion VHF communication equipment. The radio data modulation is FM so the MC3371 is suitable although it works at an unusually low RF frequency. The RF frequency of 198 kHz is converted to the standard 455 kHz IF and operational amplifiers are used to amplify, filter, integrate and limit the signal into a form which can be used by the microprocessor. The decoder is controlled by 4 keys and a 16–character dot–matrix LCD module is used to display data, time, etc.

This application incorporates an alarm clock similar to that described in AN460[2] which, if permanently powered, can be used to switch on the radio supplying the data at the required alarm time. This control could be to the power supply of the radio, or to the audio stage only. If an audio mute is used, radio data time information can be updated even when the radio is "off". Alternatively the decoder can be used simply to display time and date with its power being supplied from the radio and manually switched on and off.

LW Radio data

The transmitted data is conveyed using linear phase–modulation of the carrier by a shaped and bi–phase encoded waveform. This is applied to the main carrier as there is insufficient space in the low bandwidth AM signal ($\pm$4.5 kHz) for a subcarrier. In order not to interfere with the normal modulation, the data rate is a very low 25 Hz. Bi–phase coding and a small deviation ($\pm$22.5 degrees) are used so that the transmission's use as a frequency standard is retained. The data stream is partitioned into 50–bit blocks but, like RDS data, there are no gaps between blocks. Additional character redundancy checkword (CRC) bits are used to enable synchronisation. The bit rate of 25 Hz and the block length of 50 bits mean that a block takes 2 seconds, hence 30 blocks are transmitted every minute.

Each 50–bit block contains a single bit prefix (always a 1), a 4–bit application code (block number), 32 bits of data and 13 extra CRC bits which are used for synchronisation and error detection/correction. The particular code used is the 49, 13 shortened–cyclic code (G(x) = 36365 octal) described by Kasami[3] but modified by the addition of the fixed prefix to address the cyclic code's poor block–synchronisation capability. The CRC is the remainder calculated in the transmitter by dividing the 36 data bits (including the application code) with the generator polynomial. As this remainder is then used as the 13–bit check word, the 49 received bits should give a remainder of zero when divided by the generator polynomial. Synchronisation is thus carried out by looking for a zero 13–bit remainder. Multiplication of the 49–bit received data by the matrix shown in Table 2 is equivalent to this polynomial division and is the method used here. During synchronisation this calculation has to take place after each bit is received, using the last 50 (actually 49 as the first fixed bit is not used), until a valid (zero) remainder is found. Once this has been found, the check need only be done after another 50 bits have been received, as this is when the next valid block would be expected. If, at that point, a zero remainder is not found the bit–by–bit check is re–started. The CRC bits are capable of error correction but this application does not attempt correction, using them only for synchronisation and error detection. Use of the burst error correction capability can allow good data to be received in the presence of errors but also increases the undetected error rate as blocks with more errors than the code is capable of correcting (a single burst of up to 6 bits) may be deemed correctable and thus pass through undetected.

Blocks of type zero are used for transmitting the time and date information and also for filler codes. All other types (1 to 15) are user blocks whose data is meaningless in this context but can be displayed in hexadecimal form as it comes in. The first of the 32 data bits in a type 0 block determines if it is a time–code block (first bit a zero) or simply a filler (first bit a one). Time–code blocks are transmitted immediately prior to the minute epoch so that the exact time is indicated although only hours and minutes are included in the data. The structure of the time–code block is shown in Table 1.

Table 1. Structure of Clock–time Blocks

BIT	FUNCTION	
1	Prefix (1)	Used only for synchronisation and error detection
2–5	Block type no.	0000
6	Time/filler flag	0
7–8	Leap year cycle	00: this year leap 01: last year leap 10: leap year 2 (or more) years away 11: next year leap
9–11	Year start day	Day–of–week on 1st January (1:Monday, 0 not used)
12–17	Week number	Week number (1–53, 0 & 54–63 not used)
18–20	Day of week	Current day–of–week (1: Monday, 0 not used)
21–25	Hours	0–23 UTC (24–31 not used)
26–31	Minutes	0–59 UTC (60–63 not used)
32–37	Local offset	Local deviation from UTC in 2's complement form in increments of 30 minutes (BST = CET = 000010)
38–50	CRC	Used only for synchronisation and error detection

Table 2. 13 x 49 Decoding Matrix

HEX	BINARY	OCTAL
17 3B	1 0111 0011 1011	13473
15 E7	1 0101 1110 0111	12747
14 89	1 0100 1000 1001	12211
14 3E	1 0100 0011 1110	12076
0A 1F	0 1010 0001 1111	05037
1B 75	1 1011 0111 0101	15565
13 C0	1 0011 1100 0000	11700
09 E0	0 1001 1110 0000	04740
04 F0	0 0100 1111 0000	02360
02 78	0 0010 0111 1000	01170
01 3C	0 0001 0011 1100	00474
00 9E	0 0000 1001 1110	00236
00 4F	0 0000 0100 1111	00117
1E 5D	1 1110 0101 1101	17135
11 54	1 0001 0101 0100	10524
08 AA	0 1000 1010 1010	04252
04 55	0 0100 0101 0101	02125
1C 50	1 1100 0101 0000	16120
0E 28	0 1110 0010 1000	07050
07 14	0 0111 0001 0100	03424
03 8A	0 0011 1000 1010	01612
01 C5	0 0001 1100 0101	00705
1E 98	1 1110 1001 1000	17230
0F 4C	0 1111 0100 1100	07514
07 A6	0 0111 1010 0110	03646
03 D3	0 0011 1101 0011	01723
1F 93	1 1111 1001 0011	17623
11 B3	1 0001 1011 0011	10663
16 A3	1 0110 1010 0011	13243
15 2B	1 0101 0010 1011	12453
14 EF	1 0100 1110 1111	12357
14 0D	1 0100 0000 1101	12015
14 7C	1 0100 0111 1100	12174
0A 3E	0 1010 0011 1110	05076
05 1F	0 0101 0001 1111	02437
1C F5	1 1100 1111 0101	16365
10 00	1 0000 0000 0000	10000
08 00	0 1000 0000 0000	04000
04 00	0 0100 0000 0000	02000
02 00	0 0010 0000 0000	01000
01 00	0 0001 0000 0000	00400
00 80	0 0000 1000 0000	00200
00 40	0 0000 0100 0000	00100
00 20	0 0000 0010 0000	00040
00 10	0 0000 0001 0000	00020
00 08	0 0000 0000 1000	00010
00 04	0 0000 0000 0100	00004
00 02	0 0000 0000 0010	00002
00 01	0 0000 0000 0001	00001

Circuit

Figure 1 shows a block diagram of the application, the microprocessor used is the MC68HC811E2 (a 711E9 or E20 could also be used) while an MC3371 is used for the radio receiver. The MC3371 is a superheterodyne receiver including mixer, limiting IF amplifier and FM demodulator. The RF frequency of 198 kHz is converted to the standard 455 kHz IF. This would require a crystal of 653 kHz which is not a standard frequency and would be difficult and expensive to obtain. To avoid this, higher standard crystal frequencies were investigated to find one suitable for dividing down to approximately the correct frequency. Two suitable crystals were found: 10.5 MHz intended for 14 MHz to 3.5 MHz amateur band conversion (divide by 16 to give 656.25 kHz) and 20.945 MHz for 21.4 MHz to 455 kHz conversion (divide by 32 to give 654.53 kHz). An MC74HC4060 is employed as an oscillator and divider to provide this clock to the MC3371's mixer.

The complete circuit diagram of the analogue board is shown in Figure 2. The RF signal is derived from a ferrite rod whose coil can be either a standard LW winding or can be flat–wound with thin insulated wire. On a standard 0.25 inch ferrite rod using 36swg wire this winding is about 3.75 inches long (190 turns). The easiest way to get the winding to the correct inductance is to wind it on a paper former so that it can be slid along the rod. If a 4.25 inch winding (210 turns) is made and the 330pf capacitor and trimmer connected, resonance will be found by sliding the winding partially off the end of the rod. Resonance can be observed on an oscilloscope but is most easily found by holding the rod close to a radio (preferably with a signal strength meter) tuned to 198 kHz. The radio's signal will be noticeably affected as resonance is achieved. The winding can then be adjusted by slowly sliding it fully onto the rod, maintaining resonance by removing turns. If this is done with the trimmer in the mid position, the aerial can be completed, and finally adjusted using the trimmer, without any specialized equipment. The output winding consists of a further 20 turns at the earthed end of the main coil. An aerial made this way worked satisfactorily but the prototype performed better (less sensitive to orientation) using a Litz–wound rod taken from an old radio. The signal is amplified by a BF199 with a tuned load employing a Toko CAN1A350EK LW RF coil and 220 pF. The coil should be tuned for maximum output. Additional selectivity is incorporated by the inclusion of a 198 kHz crystal (available from AEL Crystals[7]. The application works without this crystal but with a much reduced sensitivity and tolerance to interference.

This signal goes into the mixer of the MC3371. As this application operates at a single frequency, it is not really necessary to use a superheterodyne arrangement but it allows the use of an off–the–shelf high–Q 455 kHz demodulator coil (Toko RHCS45328AC2) rather than using a separate coil and capacitor at 198 kHz. With this latter arrangement it would be very difficult to achieve as high a Q (180). The local oscillator is provided from an MC74HC4060 as described above and the intermediate frequency filtered by a Murata CFU455D2 ceramic filter. This filter's bandwidth (20 kHz) is far wider than necessary in this application but its selectivity is not required and this width allows the use of the imprecise local oscillator frequency. The demodulator coil's high Q necessitates careful adjustment. The Q is kept as high as possible (by omitting a damping resistor) as the output signal, which is small (about 9 mV peak–to–peak) due to the

low deviation employed, is proportional to this Q. The voltage on the collector of the BC377 can be used to make this adjustment. It will jump from about 1.4 volts to close to 5 volts as the correct IF is passed. The coil should be adjusted for a collector voltage of 2.5 volts. The DC working voltage of the first two op–amps is derived from this voltage so that any drifting is cancelled out.

The only other adjustment which may be required is to the amplifier gain but the two prototypes tested worked well with the values shown. To increase the gain the value of the 3.3 kohm resistor should be reduced. With a 3.3 kohm resistor the overall gain, including that of the BC377 and the first, low pass filter op–amp., is 110 giving a peak–to–peak signal of about 1 volt at the output of the first op–amp. The peak–to–peak signal at the output of the second integrating op–amp is also nearly a volt but the DC level at this point is not well defined so AC coupling is used to pass the signal to the comparator. The op–amp within the MC3371 is suitable for use with this type of coupling and is used to provide the comparator.

Figure 3 shows the circuit diagram of the digital board. A parallel high–contrast LCD module (based on an HD44780 driver with an HD44100 expansion chip) was used but a lower–contrast module using only an HD44780 could be used if the additional code shown as comments in the listing is included. The only connection between the two boards is the four–wire connector shown in both diagrams. With the arrangement shown, this interface provides the 5 volt supply to the analogue board. Two signals are returned; the demodulated radio data signal and the signal level (RSSI). The data signal goes directly into the IRQ on the HC11. As edge timing is used to decode the data, a timer input capture would be more appropriate but IRQ works as well in this application where the required accuracy is measured in milliseconds. The IRQ was used simply because debug hardware (an HC11K4 with PCbug11) was available and it used the K4's port A for the LCD. Conditional assembly (Introl) was used to differentiate between the K4 and the intended target MCU, an 811E2. The link shown on the MODB pin is to allow the use of the bootstrap mode to program the 811E2 (or 711E9/20). If using bootstrap mode, remember to use a baud rate appropriate to the crystal being used. If the crystal is in a socket it may be simpler to change to an 8 MHz crystal and use the standard PCbug11 baud rate of 9600 baud.

The MC34160 is used as a 5 volt regulator to supply the analogue board. The regulator is switched off when the software is in standby mode. This arrangement requires a second regulator for the MCU and display. If the standby mode is not required then a single, simple regulator is all that would be required. The 10 k and 3.3 k resistors divide the battery voltage by four before it is read by the HC11's A/D converter. As the RSSI level is always in the range 0–5 v it goes directly into an A/D input.

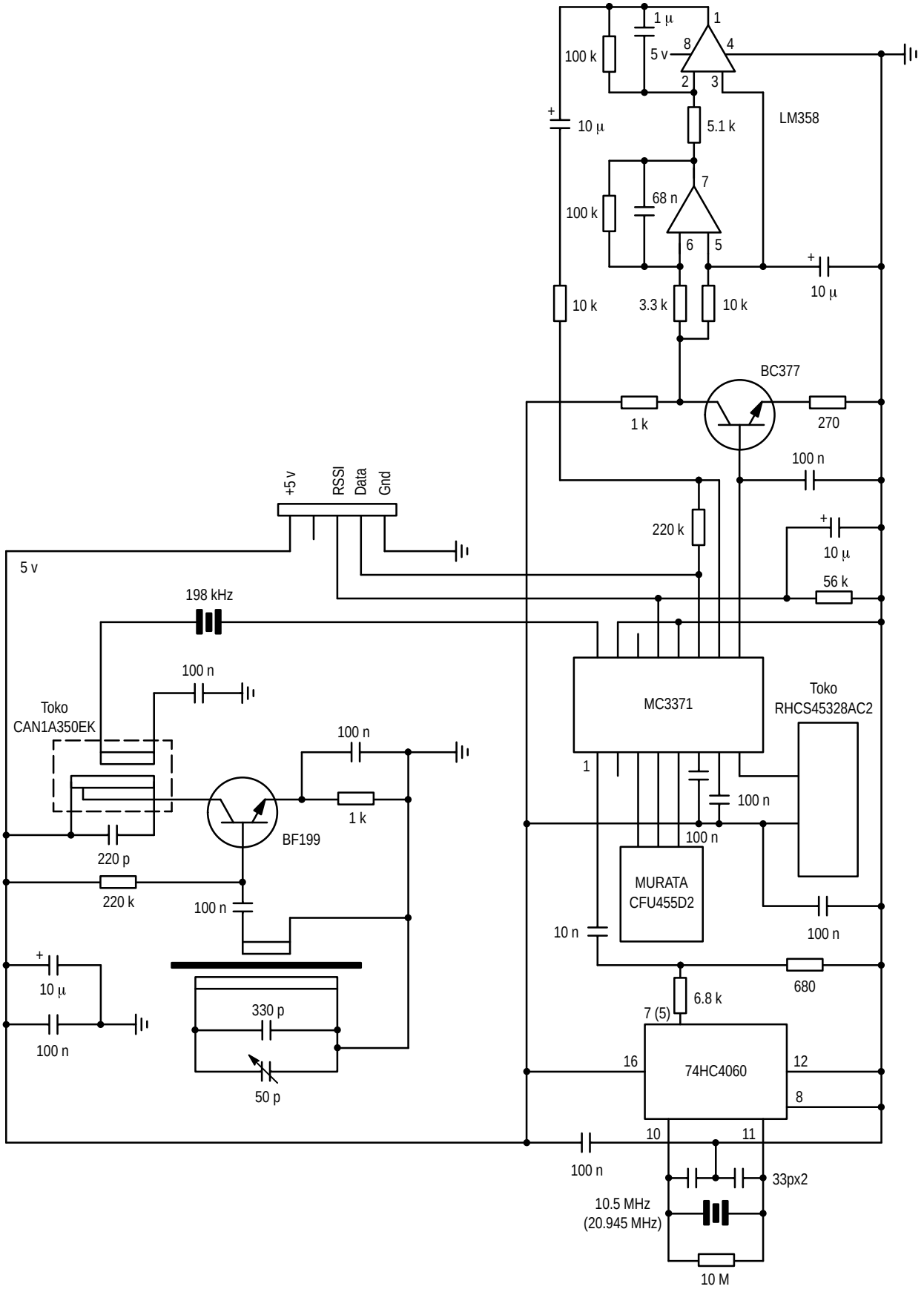

Figure 2. Analogue Board

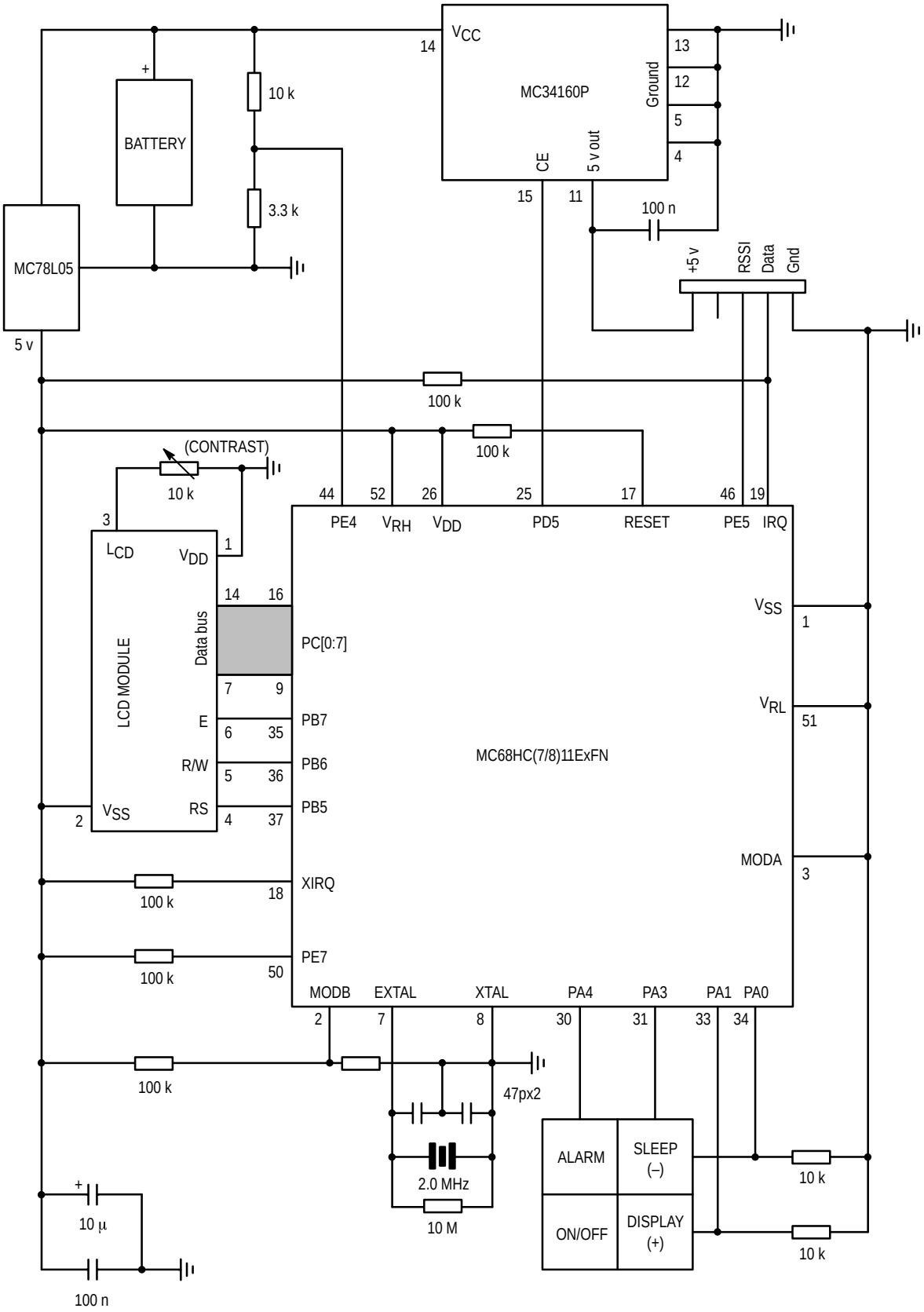

Figure 3. Digital Board

Principle of operation

Table 3 shows the various functions available in each mode via the 4–key keyboard. The operation of the keys and modes is derived from the RDS application described in AN460[2].

Table 3. Key Functions

		KEY			
		ON/OFF	**SLEEP**	**ALARM**	**DISPLAY**
M	STANDBY (OFF)	NORMAL MODE (ON)	SLEEP MODE (ON)	ALARM MODE	DATA DISPLAY
O	NORMAL (ON)	STANDBY MODE (OFF)	SLEEP MODE (ON)	ALARM MODE	DATA DISPLAY
D	ALARM (OFF)	STANDBY MODE (OFF)	SLEEP MODE (ON)	ALARM ON MODE	DATA DISPLAY
E	ALARM (ON)	ALARM SET–UP MODE	SLEEP MODE (ON)	ALARM OFF MODE	DATA DISPLAY
	ALARM SET–UP	TOGGLE HR/MIN	DEC HR/MIN	ALARM OFF MODE	INC HR/MIN

The On/Off key uses the subroutine ONOFF to toggle between ON and standby. The port pin PD5 is used to control the power to the analogue section and can also switch a radio or other external hardware. In the standby mode, time is displayed with the date (if the alarm is disabled) or the alarm time (if enabled). In the ON mode the time is displayed with the current hexadecimal data. Table 4 shows these display formats.

The Alarm key calls the subroutine ALARM which displays the current alarm status. A second press changes the alarm armed status. When armed, the alarm time is displayed. In this mode the On/Off key can be used to select either hours or minutes (indicated by flashing) and the Sleep and Display keys used to increment and decrement the settings. The alarm display has one of the two alarm formats shown in Table 4 according to whether or not the alarm is armed. As all the keys have a special function in the alarm mode the only way to exit this mode (if the alarm is armed) is to wait for a timeout. If no keys are pressed, the mode returns to normal in 10 seconds.

The alarm time can be entered as described above. If the alarm is enabled (alarm time displayed on first press of the ALARM key, and permanently displayed in standby mode) then at the alarm time the auxiliary control line (PD5) will go low activating the sleep timer for an hour. This takes place whether the decoder was previously on, off or running the sleep timer and has the effect of switching the auxiliary line high again an hour after the alarm time, regardless of its condition prior to the alarm.

The Sleep key controls the sleep timer. If the decoder is in the standby mode the first press of SLEEP switches it on and initializes the sleep time to 60 minutes. When the sleep timer is running this is indicated by a decimal point in the second character of the display modules (normal mode display). Subsequent presses of SLEEP decrement the time remaining by 5 minutes. When the sleep time has elapsed the decoder returns to standby. In the alarm set–up mode this key decrements the alarm time.

The Display key selects the alternative displays of transmitted data, year and week information and battery and tuning voltages. In the alarm set–up mode this key increments the alarm time. The “normal’’ display comprises the block number (“t” if it is a time code block), the data in hexadecimal (split into two groups of four digits if there is room) and the time. The standby display replaces the block data with the date as the intention is that in this mode the analogue circuitry is switched off. The three alternative displays are available whether or not in standby mode. The first is similar to the normal display except that the time is replaced by the confidence (incremented up to F when a good block is received and decremented when a block fails the CRC check) and time seconds. The second alternative display shows the year type (leap–year cycle/year start day), the actual year (assumed to be in the range 1995–2022) and the week number. The year is the “week–number’’ year. This year does not usually change at the transition between 31st December and 1st January (it did, however, do this at the 95/96 transition). It advances to the next year when the week number goes from 52 or 53 back to 1. While the local time offset adjusts the time and, if necessary, the date, it does not adjust the year. The method of adjusting the date can also use non–standard week numbers during the time when the local offset causes a change from 31st Dec to 1st Jan (or vice versa). During this time (it will not happen as long as the current practice of using GMT in the winter in the UK continues) a week number of 54 or 0 is possible. The third display shows the battery voltage (19.9 v max) and the RSSI level (4.98 v max.).

Table 4. Display Formats

DISPLAY MODE		FORMAT
Normal (On):		t 7D6537C2 20:31
	no radio data	– 0000 0000 0:00
Standby (Off):	Alarm Off	Tue 30 May 20:31
	no time–code block	--- 0 --- 0:00
	Alarm armed	0659 ALARM 20:31
Alarm:	Alarm off	Alarm – Off
	armed/set up	Alarm – 6:59
Sleep:		Sleep 60 min.
Alternative displays:	1	t 7D65 37C2 F 00
	2	Y:3/7 (1995) W:22
	3	B: 9.00 T: 3.45

Software

The complete software is listed. The reset routine (START) sets up the registers and I/O ports. External interrupts are enabled on negative edges so that the signal from the demodulator can interrupt the microprocessor on each falling edge. The RTI timer is enabled to cause an interrupt every 133 ms to run the real–time clock. Correct operation of this clock in the absence of continuous data requires that a 2.0 MHz crystal be used (a trimmer on pin 7 could be added to adjust for accurate timekeeping). The main free–running timer's pre–scaler is set up to divide by 1. The reset routine also enables interrupts, clears the RAM, initializes the LCD module and sets the mode to "ON'' with alternative display 1. When a valid time–code block is received the mode switches to standby.

The idle loop (IDLE) uses the main free–running timer to loop at 64 Hz. It regularly reads the keyboard for a keypress, updates the display module, compares the current time with the alarm time and performs other time–dependent functions related to the display module and the sleep and alarm functions. To ensure that a radio is switched on prior to a time signal, the alarm operates two seconds before the set time. This is why the displayed time is incremented by a minute before the comparison is made. The capability of stopping keyboard scanning using PE7 is included in case it causes interference on a connected (or nearby) radio.

The keyboard software (KBD) scans the 4–key matrix for a keypress every 16 ms. If the same key is pressed on 3 successive scans it executes the appropriate key function by calling the relevant subroutine (ALARM, ONOFF, SLEEP or DCK). Table 3 shows the various functions available in each mode.

The timer interrupt routine (TINTB) decrements the sleep timer and updates the RAM locations used to store hours, minutes, seconds and eighths–of–seconds so that the time and date remain valid in the absence of regular time information. As the 2.0 MHz crystal used does not give exact eighths of a second ticks, the software compensates by counting 458 "eighths'' of seconds in all but every ninth minute and 456 in the ninth minute. The day–of–week (and if necessary week number and year–type numbers) are also updated in case the clock is required to keep track of the date as well as the time in the absence of radio data. This is not the easiest way to organize a calendar but is necessary as this is the form in which the time–code block provides the information. There are 53 weeks if the year–start–day was a Thursday or, in the case of a leap year, a Wednesday. The year–start–day is incremented twice at the end of a leap year to allow for the extra day and wraps back from 7 to 1. The year type simply increments and wraps from 3 back to 0. The sequence repeats every 28 years until the year 2100. (2100 is not a leap year).

Hardware interrupts are vectored to jump to SDATA when a negative edge is received from the demodulator. This edge causes an interrupt and the data is calculated from the time interval from the previous edge. The bi–phase coded data bit (or bits) also depend(s) on the value of the previous bit (see Table 5). The bit(s) is/are shifted into a 7–byte RAM register (DAT through DAT+6) and the matrix multiplication performed. The state of flag STAT2,$01 determines if the multiplication is to take place after every bit or only after all 50 bits have arrived. The multiplication is performed using EOR instructions for every bit. As the bottom of the matrix (see Table 2) is a unity matrix, the first 13 bits are transferred directly into the accumulators. The matrix multiplication is done in the loop MULT which reduces the code required but increases the execution time of the algorithm. The table B5–B1 represents the decoding matrix (Table 2). In this case the execution time penalty is not a problem as the bit rate is very low. The same procedure was carried out using in–line code in the RDS application[2] as the bit rate was too high for a loop to be workable. Because the interpretation of an edge depends on the previous bit, an error or a wrong guess at the start can cause all subsequent edges to be misunderstood. The illegal entry in the table is thus used to invert the current (perhaps the first guessed) previous bit, preventing decoding from getting stuck in this mode.

Table 5. Bi–phase Decoding

PREVIOUS BIT	1 BIT TIME	1.5 BIT TIME	2 BIT TIME
0	0	1	ILLEGAL
1	1	00	01

When a valid remainder is found, CONF is incremented and the 36 data bits saved in BLOCK (4 bytes). The confidence level CONF is used to decide when to switch to checking the CRC only every 50 bits. This is done once CONF has reached $F (15). If a valid block has been received the data can be processed. A time block is used to initialize or update time, local time difference and date information but any other block

is meaningless in this application and so is displayed in its raw hexadecimal form. The broadcast time is Universal Co–ordinated Time (UTC — effectively the same as GMT). Time differences from UTC, including summer (daylight saving) time, are sent as a 2's complement offset of up to ±12 hours in half–hour increments. The time block is checked before it is used although most errors should have been detected by the CRC check. If the minutes are over 59, the hours over 23, the day–of–week a zero etc., then the block is not used. The first successful receipt of a time–code block after power–up or a reset switches the mode to standby, switching off the analogue section. The time data is transferred to other RAM locations for local offset adjustment and display. After this adjustment is made the date (month and day–of–month) are calculated by first working out a day–of–year number and then converting to the usual month format using tables (a separate table is used for leap years).

The software drives a parallel LCD module (based on an HD44780 driver with an HD44100 expander). The display routine (MOD) is executed in the idle loop if the STAT2 flag is set. It is set every 266 ms by RTI timer interrupts. The LCD module is updated with new data only if there has been a change since the last time the routine was executed. This reduces the likelihood of unnecessary I/O activity interfering with a radio. Before anything is written to the module the subroutine WAIT is used; this ensures that the controller in the module is not busy. This is indicated by a low on bit 7 of the LCD's bus. The listing is shown for use with a divide by 8 multiplexing LCD module. If a divide by 16 module (HD44780 only) is to be used, the subroutine LCD16 should be enabled.

The different display formats are selected by checking the various flags and the relevant routine executed. As the locations in RAM used for hours and minutes contain binary numbers they are converted to ASCII BCD using the subroutine CBCD before being written to the display buffer. If this subroutine is entered at the label SPLIT then the data is simply split into nibbles and converted to ASCII. This is used for the display of the raw hexadecimal data. If the alarm is not armed, the standby display converts the day–of–week and day–of–month numbers into three–character strings using the tables at the end of the listing. MNAME has an additional month at each end to facilitate a correct display when the local time offset causes a transition to the next (or previous) year. The year and week display routine (ALTD2) calculates a year in the range 1995 to 2022 from the year type (leap year) and year start day information. This is done using the table YRTAB which constitutes the offsets from the start of the 28–year cycle (arbitrarily taken to be 1995) according to the values of year type (down the table) and year start–day (across the table).

REFERENCES

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2. Application note AN460, An RDS Decoder using the MC68HC05E0.
3. Optimum Shortened Cyclic Codes for Burst–Error Correction, Tadao Kasami, IEEE Transaction on information theory, April 1963, pp 105–109.
4. M68HC11 Reference Manual (M68HC11RM/AD rev. 3).
5. M68HC11 E Series Technical Data.
6. Data sheets for the MC3371 and MC34160.
7. AEL Crystals, Module D, Genner Rd., Crawley, RH10 2GA, 01293 524245

Appendix

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3                           ****************************************************
4                           *           MC68HC11K4/E2 Longwave RD Clock.       *
5                           *                                                  *
6                           *                                                  *
7                           *         P. Topping            21st August '95    *
8                           *                                                  *
9                           ****************************************************
10
11 00000002                       HC11    EQU     2               2 FOR E2, 4 FOR K4
12
13 00000000                       PORTA   EQU     $00     PORT A ADDRESS
14 00000004                       PORTB   EQU     $04       "  B    "
16 00000003                       PORTC   EQU     $03       "  C    "
20 00000008                       PORTD   EQU     $08       "  D    "
21 0000000a                       PORTE   EQU     $0A       "  E    "
28
29 00000007                       PORTCD  EQU     $07    PORT C DATA DIRECTION REG.
30 00000009                       PORTDD  EQU     $09      "   D   "       "     "
37
38 0000000e                       TCNT    EQU     $0E
39 00000024                       TMSK2   EQU     $24
40 00000026                       PACTL   EQU     $26
42 00000028                       SPCR    EQU     $28
46 00000030                       ADCTL   EQU     $30
47 00000031                       ADR1    EQU     $31
48 00000032                       ADR2    EQU     $32
49 00000034                       ADR4    EQU     $34
50 00000039                       OPTION  EQU     $39
51 0000003d                       INIT    EQU     $3D
52
53 00001000                       RBO     EQU     $1000       REGISTER BLOCK OFFSET
54
55                          ****************************************************
56                          *                                                  *
57                          *            RAM allocation – status flags.        *
58                          *                                                  *
59                          ****************************************************
60
61                                *       ORG     $0000
62                                        SECTION.S  .RAM1,COMM
63
64 00000000                       STAT1   RMB      1        0: VALID CRC
65                                *                         3: UPDATE DISPLAY
66                                *                         6: DATE VALID
67                                *                         7: LWRD DATA BIT
68
69 00000001                       STAT2   RMB      1        0: DISPLAY TRANSIENT
70                                *                         1: SLEEP TIMER RUNNING
71                                *                         2: SLEEP DISPLAY
72                                *                         3: ALARM DISPLAY
73                                *                         4: ALARM ARMED
74                                *                         5: ALARM SET-UP
75                                *                         6: ALARM HOURS (SET-UP)
76                                *                         7: ALTERNATIVE DISPLAY


78                          ****************************************************
79                          *                                                  *
80                          *            RAM allocation.                       *
81                          *                                                  *
82                          ****************************************************
83
84 00000002                       DOY     RMB     2          DAY OF YEAR
85 00000004                       MNTH    RMB     1          MONTH
86 00000005                       DOM     RMB     2          DAY OF MONTH
87 00000007                       DOW     RMB     2          DAY OF WEEK
88 00000009                       WEEK    RMB     1          WEEK NUMBER
89 0000000a                       SDAY    RMB     2          YEAR START DAY
90 0000000c                       TYPE    RMB     1          YEAR TYPE (LEAP)
91 0000000d                       OFSET   RMB     1          LOCAL OFFET
92 0000000e                       DAT     RMB     7          SERIAL DATA BUFFER
93 00000015                       BLOCK   RMB     4          BLOCK DATA
94 00000019                       BIT     RMB     1          BIT LEVEL
95 0000001a                       CONF    RMB     1          CRC CONFIDENCE
96 0000001b                       QSEC    RMB     1          QUARTER SECONDS
97 0000001c                       TH8     RMB     1          EIGHTHS OF SECONDS
98 0000001d                       M9      RMB     1          9 MINUTE COUNTER
99 0000001e                       CODE    RMB     1          BLOCK CODE
100 0000001f                      MIN     RMB     1          MINUTES
101 00000020                      OUR     RMB     1          HOURS
102 00000021                      DMIN    RMB     1          DISPLAYED MINUTES
103 00000022                      DOUR    RMB     1          DISPLAYED HOURS
104 00000023                      DDOW    RMB     2          DISPLAYED DAY OF WEEK
105 00000025                      DWEEK   RMB     1          DISPLAYED WEEK NUMBER
106 00000026                      TMIN    RMB     1          TEMPORARY MINUTES
107 00000027                      TOUR    RMB     1          TEMPORARY HOURS
108 00000028                      TDOW    RMB     1          TEMPORARY DAY OF WEEK
109 00000029                      TWEEK   RMB     1          TEMPORARY WEEK NUMBER
110 0000002a                      SUP     RMB     1          VDD (A/D RESULT)
111 0000002b                      RSSI    RMB     1       SIGNAL LEVEL (A/D RESULT)
112 0000002c                      RSS4    RMB     1          AVERAGED SIGNAL LEVEL
113 0000002d                      DISP    RMB     16         LCD MODULE BUFFER
114 0000003d                      DSPOLD  RMB     16      LCD MODULE PREVIOUS DATA
115 0000004d                      W1      RMB     2       \
116 0000004f                      W2      RMB     2       >  USED IN INTERRUPT
117 00000051                      W3      RMB     2       /
118 00000053                      TEMP    RMB     3
```

```
119 00000056                  DIST    RMB     1       TRANSIENT DISPLAY TIMEOUT COUNTER
120 00000057                  SLEPT   RMB     1       SLEEP TIMER MINUTES COUNTER
121 00000058                  AMIN    RMB     1       ALARM MINUTES
122 00000059                  AOUR    RMB     1       ALARM HOURS
123 0000005a                  KEY     RMB     1       CODE OF PRESSED KEY
124 0000005b                  KOUNT   RMB     1       KEYBOARD COUNTER
125 0000005c                  ADIS    RMB     1       ALTERNATIVE DISPLAY TYPE
127                           SECTION .ROM1
128                   *       ORG     $4000
129
130                     ************************************************************
131                     *                                                          *
132                     *       Reset & initialisation.                            *
133                     *                                                          *
134                     ************************************************************
135
137 00000000  8e00ff    START  LDS     #$00FF          INITIALISE STACK POINTER
143 00000003  8640             LDAA    #$40            ENABLE REAL TIME INTERRUPTS
144 00000005  b71024           STAA    TMSK2+RBO
145 00000008  86b0             LDAA    #$B0            IRQ EDGE SENSETIVE, A/D ON
146 0000000a  b71039           STAA    OPTION+RBO
147 0000000d  860b             LDAA    #$0B            133072 us WITH A 2.0 MHz XTAL
148 0000000f  b71026           STAA    PACTL+RBO
149 00000012  8634             LDAA    #$34            ENABLE CONTINUOUS A/D
150 00000014  b71030           STAA    ADCTL+RBO
155 00000017  18ce1000         LDY     #$1000
156
157 0000001b  cc003c           LDD     #$003C          0,1: SCI (PCBUG11), 2–4: not used
158 0000001e  18ed08           STD     PORTD,Y         5: CONTROL OUTPUT
159                   *               PORTE           4: BATTERY (A/D), 5: TUNING (A/D)
160                   *               PORTE           7: KEYBOARD INHIBIT,
                                                      0,1,2,3,6: not used
162 00000003            LCDB   EQU     PORTC
163 00000007            LCDBDD EQU     PORTCD
164 00000021  86ff             LDAA    #$FF
165 00000023  18a707           STAA    LCDBDD,Y
166 00000004            LCDC   EQU     PORTB
167 00000026  186f04           CLR     LCDC,Y          LCD CONTROL BITS: 5(RS), 6(R/W),7(E)
168 00000000            KEYP   EQU     PORTA           0,1: KEY INS, 3,4: KEY OUTS
169 00000008            R1     EQU     $08             ROW 1 – BIT 3
170 00000010            R2     EQU     $10             ROW 2 – BIT 4
171 00000003            KINS   EQU     $03
187
188 00000029 >bd0000           JSR     CLOCK3          INITIALISE LCD
189 0000002c  c605             LDAB    #5
190 0000002e >bd0000    CLAG   JSR     CLRAM           CLEAR RAM
191 00000031  5a               DECB                    5 TIMES TO PROVIDE A 5mS DELAY
192 00000032  26fa             BNE     CLAG            FOR LCD INITIALISATION
193 00000034 >bd0000           JSR     CLOCK3          INITIALISE LCD
194 00000037 >bd0000           JSR     CLRAM           1mS DELAY FOR LCD
195 0000003a >bd0000           JSR     NEXTD           START WITH CONFIDENCE
                                                       DISPLAY
196 0000003d >bd0000           JSR     CLOCK3          INITIALISE LCD
197 00000040 >bd0000           JSR     WAIT
198 00000043  860c             LDAA    #$0C            SWITCH DISPLAY ON
199 00000045 >bd0000           JSR     CLOCK           LATCH IT
200 00000048  0e               CLI                     ENABLE IRQ

202                     ************************************************************
203                     *                                                          *
204                     *       Idle loop.                                         *
205                     *                                                          *
206                     ************************************************************
207
208 00000049  181f0e1f02       IDLE    BRCLR   TCNT,Y,$1F,NO2D    64 Hz
209 0000004e  20f9                     BRA     IDLE
210
211 00000050 >13000107         NO2D    BRCLR   STAT2,$01,NOPS     DISPLAY TRANSIENT?
212 00000054 >9600                     LDAA    DIST
213 00000056  2603                     BNE     NOPS               YES, TIMED OUT?
214 00000058 >bd0000                   JSR     CLTR
215
216 0000005b >13000806         NOPS    BRCLR   STAT1,$08,SCA       DISPLAY UPDATE REQUIRED?
217 0000005f >bd0000                   JSR     MOD                YES, DO IT (4 Hz)
218 00000062 >150008                   BCLR    STAT1,$08          AND CLEAR FLAG
219
220 00000065 >13001023         SCAN    BRCLR   STAT2,$10,CHSLP    ALARM ARMED?
221 00000069 >dc00                     LDD     DMIN               YES, COMPARE TIME
                                                                  WITH ALARM TIME
222 0000006b  4c                       INCA                       ADD A MINUTE
223 0000006c  813c                     CMPA    #60                NEXT HOUR?
224 0000006e  2607                     BNE     ITOK
225 00000070  4f                       CLRA                       YES, CLEAR MINUTES
226 00000071  5c                       INCB                       AND INCREMENT HOURS
227 00000072  c118                     CMPB    #24                NEXT DAY?
228 00000074  2601                     BNE     ITOK
229 00000076  5f                       CLRB                       YES, CLEAR HOURS
230 00000077 >1a9300           ITOK    CPD     AMIN               ALARM TIME
231 0000007a  2610                     BNE     CHSLP              SAME?
232 0000007c >9600                     LDAA    QSEC               WAKE–UP TWO SECONDS
                                                                  EARLY
233 0000007e  81da                     CMPA    #218
234 00000080  260a             BNE     CHSLP                      TO PREVENT SWITCH–OFF
                                                                  LOCKOUT
235 00000082  181d0820                 BCLR    PORTD,Y,$20        YES, SWITCH ON
236 00000086 >bd0000                   JSR     INSLP              START SLEEP TIMER
237 00000089 >7c0000                   INC     SLEPT              61 TO COMPENSATE FOR
                                                                  IMMEDIATE DECREMENT
238 0000008c >1300020b         CHSLP   BRCLR   STAT2,$02,FLN      SLEEP TIMER RUNNING?
```

```
239 00000090 >9600                  LDAA    SLEPT             YES
240 00000092  2607                  BNE     FLN               TIME TO FINISH?
241 00000094 >150002                BCLR    STAT2,$02         YES, CLEAR FLAG
242 00000097  181c0820              BSET    PORTD,Y,$20       AND SWITCH OFF
243 0000009b  181f348002    FLN     BRCLR   ADR4,Y,$80,SKBD   KEYBOARD ENABLED?
244 000000a0  8d02                  BSR     KBD               YES, READ KEYBOARD
245 000000a2  20a5          SKBD    BRA     IDLE


247                     ************************************************************
248                     *                                                          *
249                     *       Keyboard routine.                                  *
250                     *                                                          *
251                     ************************************************************
252
253 000000a4  181c0008      KBD     BSET    KEYP,Y,R1         ROW 1
254 000000a8  181d0010              BCLR    KEYP,Y,R2
255 000000ac  18a600                LDAA    KEYP,Y            READ KEYBOARD
256 000000af  8503                  BITA    #KINS             ANY INPUT LINE HIGH?
257 000000b1  2613                  BNE     L1
258 000000b3  181c0010              BSET    KEYP,Y,R2         ROW 2
259 000000b7  181d0008              BCLR    KEYP,Y,R1
260 000000bb  18a600                LDAA    KEYP,Y            READ KEYBOARD
261 000000be  8503                  BITA    #KINS             ANY INPUT LINE HIGH?
262 000000c0  2604                  BNE     L1
263 000000c2 >7f0000                CLR     KEY               NO KEY PRESSED
264 000000c5  39            DNT     RTS
265
266 000000c6  841b          L1      ANDA    #$1B
267 000000c8 >9100                  CMPA    KEY               SAME AS LAST TIME?
268 000000ca  2705                  BEQ     EXIT
269 000000cc >9700                  STAA    KEY               NO, SAVE THIS KEY
270 000000ce >7f0000                CLR     KOUNT
271 000000d1 >7c0000        EXIT    INC     KOUNT             YES, THE SAME
272 000000d4 >9600                  LDAA    KOUNT
273 000000d6  8103                  CMPA    #3                3 THE SAME?
274 000000d8  26eb                  BNE     DNT               IF 3 THEN PERFORM KEY
                                                              FUNCTION
275
276 000000da >9600          GOON    LDAA    KEY
277 000000dc  8009                  SUBA    #$09              SLEEP ($09)?
278 000000de  277c                  BEQ     SLEEP
279 000000e0  4a                    DECA                      NO, DISPLAY CONTROL($0A)?
280 000000e1  2765                  BEQ     DCK
281 000000e3  8007                  SUBA    #$7               NO, ALARM ($11)?
282 000000e5  273f                  BEQ     ALARM
283 000000e7  4a                    DECA                      NO, ON/OFF ($12)?
284 000000e8  26db                  BNE     DNT               IF NOT DO NOTHING


286                     ************************************************************
287                     *                                                          *
288                     *       On/off key.                                        *
289                     *                                                          *
290                     ************************************************************
291
292 000000ea >1300081d      ONOFF   BRCLR   STAT2,$08,NOTALR  ALARM DISPLAY?
293 000000ee >13001019              BRCLR   STAT2,$10,NOTALR  YES, ALARM ARMED?
294 000000f2 >12002007              BRSET   STAT2,$20,AISM    YES, ALREADY SET-UP
                                                              MODE?
295 000000f6 >140060                BSET    STAT2,$60         NO, ENTER SET-UP
                                                              MODE WITH HOURS
296 000000f9  8628          A5SD    LDAA    #40               10 SECOND TIMEOUT
297 000000fb  2045                  BRA     TRAN
298
299 000000fd >12004005      AISM    BRSET   STAT2,$40,MSM     SET-UP HOURS?
300 00000101 >150020                BCLR    STAT2,$20         NO, CANCELL SET-UP
301 00000104  20f3                  BRA     A5SD
302 00000106 >150040        MSM     BCLR    STAT2,$40         YES, MAKE IT MINUTES
303 00000109  20ee                  BRA     A5SD
304
305 0000010b  8d12          NOTALR  BSR     CLTR
306 0000010d >150002                BCLR    STAT2,$02         CANCELL SLEEP TIMER
307 00000110  181f082005            BRCLR   PORTD,Y,$20,ALRON ON?
308 00000115  181d0820      SODM    BCLR    PORTD,Y,$20       NO, SWITCH ON
309 00000119  39                    RTS
310 0000011a  181c0820      ALRON   BSET    PORTD,Y,$20       YES, SWITCH OFF
311 0000011e  39                    RTS
312
313 0000011f >1500ad        CLTR    BCLR    STAT2,$AD         CLEAR DISPLAY FLAGS
                                                              (TRANSIENT, ALARM,
                                                              ALT. DISPLAY, SLEEP)
314 00000122 >7f0000                CLR     ADIS
315 00000125  39                    RTS
316
317                     ************************************************************
318                     *                                                          *
319                     *       Alarm key.                                         *
320                     *                                                          *
321                     ************************************************************
322
323 00000126 >1300080e      ALARM   BRCLR   STAT2,$08,ADON    ALARM DISPLAY?
324 0000012a >13001005              BRCLR   STAT2,$10,ALOF    YES, ALARM ON?
325 0000012e >150010                BCLR    STAT2,$10         YES, SWITCH OFF
326 00000131  200a                  BRA     UDCNT
327 00000133 >140010        ALOF    BSET    STAT2,$10         NO, SWITCH ON
328 00000136  2005                  BRA     UDCNT
329 00000138  8de5          ADON    BSR     CLTR              NO,START ALARM DISPLAY
```

```
330 0000013a >140008                BSET    STAT2,$08       ALARM DISPLAY FLAG
331 0000013d >150020         UDCNT  BCLR    STAT2,$20       CANCEL SET-UP
332 00000140  860c           T25    LDAA    #12             3 SECONDS TIMEOUT
333 00000142 >9700           TRAN   STAA    DIST
334 00000144 >140001         BSET   STAT2,$01               SET DISPLAY TRANSIENT
                                                            FLAG
335 00000147  39                    RTS


337                     ************************************************************
338                     *                                                          *
339                     *       Alternative displays key.                          *
340                     *                                                          *
341                     ************************************************************
342
343 00000148 >12002036       DCK    BRSET   STAT2,$20,PINC  ALARM SET-UP?
344
345 0000014c >140080         NEXTD  BSET    STAT2,$80       NO, SET ALTERNATIVE
                                                            DISPLAY FLAG AND
346 0000014f >15002d                BCLR    STAT2,$2D       CLEAR OTHER DISPLAY
                                                            FLAGS
347 00000152 >7c0000                INC     ADIS            INCREMENT DISPLAY TYPE
348 00000155 >9600                  LDAA    ADIS
349 00000157  8104                  CMPA    #04             TOO FAR?
350 00000159  27c4                  BEQ     CLTR            IF SO BACK TO ZERO
351 0000015b  39                    RTS
352
353                     ************************************************************
354                     *                                                          *
355                     *       Sleep key.                                         *
356                     *                                                          *
357                     ************************************************************
358
359 0000015c >1200203f       SLEEP  BRSET   STAT2,$20,PDEC  ALARM SET-UP?
360
361 00000160 >12000412              BRSET   STAT2,$04,DECS  NO, ALREADY SLEEP DISPLAY?
362 00000164 >12000207              BRSET   STAT2,$02,STR2  NO, SLEEP TIMER ALREADY
                                                            RUNNING?
363 00000168  863c           INSLP  LDAA    #60             NO, INITIALISE SLEEP TIMER
364 0000016a >9700                  STAA    SLEPT
365 0000016c >140002                BSET    STAT2,$02       START SLEEP TIMER
366 0000016f  8dae           STR2   BSR     CLTR            YES, CLEAR DISPLAY
                                                            TRANSIENTS
367 00000171 >140004                BSET    STAT2,$04       SLEEP DISPLAY
368 00000174  2008                  BRA     SLPTOK          NO DECREMENT IF FIRST TIME
369 00000176 >9600           DECS   LDAA    SLEPT           DECREMENT SLEEP TIMER
370 00000178  8005                  SUBA    #5
371 0000017a >9700                  STAA    SLEPT
372 0000017c  2bea                  BMI     INSLP           IF UNDERFLOW, WRAP
                                                            ROUND TO 60
373 0000017e  8dc0           SLPTOK BSR     T25
374 00000180  2093                  BRA     SODM


376                     ************************************************************
377                     *                                                          *
378                     *       Increment alarm time.                              *
379                     *                                                          *
380                     ************************************************************
381
382 00000182 >1200400c       PINC   BRSET   STAT2,$40,IHR   SET-UP HOURS?
383 00000186 >9600                  LDAA    AMIN
384 00000188  4c                    INCA
385 00000189  813b                  CMPA    #59
386 0000018b  2f01                  BLE     MINOK
387 0000018d  4f                    CLRA
388 0000018e >9700           MINOK  STAA    AMIN
389 00000190  200a                  BRA     T5S             10 SECOND TIMEOUT
390
391 00000192 >9600           IHR    LDAA    AOUR
392 00000194  4c                    INCA
393 00000195  8117                  CMPA    #23
394 00000197  2f01                  BLE     OUROK
395 00000199  4f                    CLRA
396 0000019a >9700           OUROK  STAA    AOUR
397 0000019c >7e0000         T5S    JMP     A5SD            10 SECOND TIMEOUT
398


399                     ************************************************************
400                     *                                                          *
401                     *      Decrement alarm time.                               *
402                     *                                                          *
403                     ************************************************************
404
405 0000019f >1200400b       PDEC   BRSET   STAT2,$40,IHRD  SET-UP HOURS?
406 000001a3 >7a0000                DEC     AMIN
407 000001a6  2af4                  BPL     T5S
408 000001a8  863b                  LDAA    #59
409 000001aa >9700                  STAA    AMIN
410 000001ac  20ee                  BRA     T5S
411
412 000001ae >7a0000         IHRD   DEC     AOUR
413 000001b1  2ae9                  BPL     T5S
414 000001b3  8617                  LDAA    #23
415 000001b5 >9700                  STAA    AOUR
416 000001b7  20e3                  BRA     T5S
```

```
                    ************************************************************
                    *                                                          *
                    *       Timer interrupt routine.                           *
                    *                                                          *
                    ************************************************************

000001b9  18ce1000        TINTB   LDY     #$1000
000001bd  181d25bf                BCLR    $25,Y,$BF  CLEAR RTI INTERRUPT FLAG
000001c1 >7c0000                  INC     TH8        EIGTHS OF SECONDS
000001c4 >9600                    LDAA    TH8
000001c6  8102                    CMPA    #2         QUARTER SECOND?
000001c8  2701                    BEQ     QUART
000001ca  3b              ENDINT  RTI

000001cb >7f0000          QUART   CLR     TH8
000001ce >7a0000                  DEC     DIST       DECREMENT TRANSIENT DISPLAY TIMER
000001d1 >140008                  BSET    STAT1,$08  UPDATE DISPLAY

                    ************************************************************
                    *                                                          *
                    *       Update clock.                                      *
                    *                                                          *
                    ************************************************************

000001d4 >7c0000                  INC     QSEC       UPDATE "QUARTER" SECONDS
000001d7 >d600                    LDAB    QSEC
000001d9 >9600                    LDAA    M9         9 MINUTE COUNTER
000001db  2604                    BNE     NOT7       TIME TO COMPENSATE FOR
                                                     2.000 MHz CRYSTAL?
000001dd  c1e4                    CMPB    #228       YES, 228 QUARTER SECONDS A MINUTE
000001df  2002                    BRA     CAON
000001e1   c1e5           NOT7    CMPB    #229       NO, 229 (DIVIDE RATIO=2x228.888)
000001e3  26e5            CAON    BNE     ENDINT     IE 457.778, 457.778x131.072=
                                                     60.00185 sec/min)
000001e5 >7f0000                  CLR     QSEC       IF 228 OR 229 THEN CLEAR SECONDS
000001e8 >7c0000                  INC     MIN        AND UPDATE MINUTES
000001eb >7a0000                  DEC     SLEPT      AND SLEEP TIMER
000001ee >9600                    LDAA    M9         AND 9 MINUTE COUNTER
000001f0  4c                      INCA
000001f1  8109                    CMPA    #9
000001f3  2601                    BNE     M9OK       TENTH MINUTE FINISHED?
000001f5  4f                      CLRA               YES, START AGAIN
000001f6 >9700            M9OK    STAA    M9

000001f8 >9600            NOT10   LDAA    MIN
000001fa  813c                    CMPA    #60
000001fc  2657                    BNE     NOTC       PAST 59?
000001fe >7f0000                  CLR     MIN        YES, CLEAR
00000201 >7c0000                  INC     OUR        UPDATE HOURS
00000204 >9600                    LDAA    OUR
00000206  8118                    CMPA    #24
00000208  264b                    BNE     NOTC       PAST 23?
0000020a >7f0000                  CLR     OUR        YES CLEAR

                    ************************************************************
                    *                                                          *
                    *       Update date.                                       *
                    *                                                          *
                    ************************************************************

0000020d >7c0001          TEST1   INC     DOW+1       NEXT DAY
00000210 >9601                    LDAA    DOW+1
00000212  8107                    CMPA    #7          PAST SUNDAY?
00000214  233f                    BLS     NOTC
00000216  c601                    LDAB    #1          YES, BACK TO MONDAY
00000218 >d701                    STAB    DOW+1
0000021a >7c0000          TEST2   INC     WEEK        INCREMENT WEEK NUMBER
0000021d >9600                    LDAA    WEEK

0000021f >d601                    LDAB    SDAY+1
00000221  c104                    CMPB    #4          1st JANUARY WAS A
                                                      THURSDAY?
00000223  2709                    BEQ     W53         IF SO, 53 WEEKS
00000225  c103                    CMPB    #3          WEDNESDAY?
00000227  2609                    BNE     W52         NEITHER WED NOR THU SO
                                                      52 WEEKS
00000229 >7d0000              TST     TYPE    WED., BUT IS IT LEAP?
0000022c  2604                BNE     W52     IF NOT THEN ONLY 52
0000022e  8135          W53   CMPA    #53     (THU.) OR (WED. & LEAP) SO
                                              53 WEEKS
00000230  2002                BRA     TWN
00000232  8134          W52   CMPA    #52     ELSE, 52 WEEKS
00000234  231f          TWN   BLS     NOTC    TOO BIG?
00000236  c601                LDAB    #1      YES, BACK TO 1

00000238 >d700                STAB    WEEK
0000023a >7c0001              INC     SDAY+1
0000023d >9600                LDAA    TYPE    IF LEAP THEN START DAY
                                              INCREASES BY 2
0000023f  2603                BNE     CSD
00000241 >7c0001              INC     SDAY+1  SO INCREMENT AGAIN
00000244 >dc00          CSD   LDD     SDAY
00000246  c107                CMPB    #7      UPDATED START DAY TO BIG?
00000248  2304                BLS     NOV2
0000024a  c007                SUBB    #7      YES, CORRECT
0000024c >dd00                STD     SDAY
0000024e >9600          NOV2  LDAA    TYPE        YEAR TYPE
00000250  4c                  INCA
00000251  8403                ANDA    #$03        IF 4, BACK TO 0
```

```
511 00000253 >9700                      STAA    TYPE
512
513 00000255 >bd0000              NOTC  JSR     CDATE
514 00000258  3b                        RTI


516                           ****************************************************
517                           *                                                  *
518                           *       LW RD input interrupt (IRQ).               *
519                           *       Get bits from this edge.                   *
520                           *                                                  *
521                           ****************************************************
522
523 00000259  f51c1f053e0a      B5      FCB           $F5,$1C,$1F,$05,$3E,$0A
524 0000025f  7c140d14ef142b15  B4      FCB           $7C,$14,$0D,$14,$EF,$14,$2B,$15,$A3,
                                                      $16,$B3,$11,$93,$1F,$D3,$03
525 0000026f  a6074c0f981ec501  B3      FCB           $A6,$07,$4C,$0F,$98,$1E,$C5,$01,$8A,
                                                      $03,$14,$07,$28,$0E,$50,$1C
526 0000027f  5504aa0854115d1e  B2      FCB           $55,$04,$AA,$08,$54,$11,$5D,$1E,$4F,
                                                      $00,$9E,$00,$3C,$01,$78,$02
527 0000028f  f004e009c013751b  B1      FCB           $F0,$04,$E0,$09,$C0,$13,$75,$1B,$1F,
                                                                  $0A,$3E,$14,$89,$14,$E7,$15
529 00000014                QBP     EQU     20        MSB COUNTS FOR 10 ms
                                                      (BIT PERIOD/4)
531 0000029f  fc100e        SDATA   LDD     TCNT+RBO  READ TIMER
532 000002a2 >dd00                  STD     W1        SAVE IT
533 000002a4 >9300                  SUBD    W2        SUBTRACT PREVIOUS
534 000002a6 >dd00                  STD     W3        AND SAVE DELTA
535 000002a8  8128                  CMPA    #2*QBP    OVER 20 ms?
536 000002aa  250c                  BLO     LT20
537 000002ac >dc00                  LDD     W1        YES, UPDATE PREVIOUS WITH
                                                      CURRENT TIME
538 000002ae >dd00                  STD     W2
539 000002b0 >dc00                  LDD     W3        RELOAD DELTA
540 000002b2  8164                  CMPA    #5*QBP    2 HALF BITS?
541 000002b4  2403                  BHS     NT2HB
542 000002b6  8d50          INBIT   BSR     BITIN     YES, REPEAT LAST BIT
543 000002b8  3b            LT20    RTI
545 000002b9  818c          NT2HB   CMPA    #7*QBP    3 HALF BITS?
546 000002bb  240e                  BHS     NOT3HB
547 000002bd >12008003              BRSET   STAT1,$80,WAS1   YES, LAST BIT A 1?
548 000002c1  8d42                  IN1     BSR     BITIN1   NO, MAKE THIS ONE A 1
549 000002c3  3b                    RTI
551 000002c4 >150080        WAS1    BCLR    STAT1,$80         YES, ENTER TWO 0s
552 000002c7  8d3f                  BSR     BITIN
553 000002c9  20eb                  BRA     INBIT
555 000002cb  81c8          NOT3HB  CMPA    #10*QBP    4 HALF BITS?
556 000002cd  240b                  BHS     ILL        NO, TOO BIG
557 000002cf >13008007              BRCLR   STAT1,$80,ILL    YES, BUT WAS LAST BIT A 0?

558 000002d3 >150080                BCLR    STAT1,$80         NO, ENTER A 0 AND A 1
559 000002d6  8d30                  BSR     BITIN
560 000002d8  20e7                  BRA     IN1
562 000002da >13008005      ILL     BRCLR   STAT1,$80,B0      ILLEGAL, TRY INVERTING
                                                              CURRENT BIT
563 000002de >150080                BCLR    STAT1,$80
564 000002e1  2003                  BRA     FINV
565 000002e3 >140080        B0      BSET    STAT1,$80
566 000002e6 >150001        FINV    BCLR    STAT1,$01  AND FORCE RE-SYNC
567 000002e9  3b                    RTI


569                             ****************************************************
570                             *                                                  *
571                             *       Shift in bit and calculate CRC.            *
572                             *                                                  *
573                             ****************************************************
574
575 000002ea >9700                  MULT    STAA    TEMP
576 000002ec  8608                          LDAA    #8
577 000002ee >9701                          STAA    TEMP+1
578 000002f0 >9602                          LDAA    TEMP+2
579
580 000002f2 >760000              CRCLOP  ROR     TEMP
581 000002f5  2404                        BCC     SKEOR
582 000002f7  a800                        EORA    0,X
583 000002f9  e801                        EORB    1,X
584 000002fb  08                  SKEOR   INX
585 000002fc  08                          INX
586 000002fd >7a0001                      DEC     TEMP+1
587 00000300  26f0                        BNE     CRCLOP
588
589 00000302 >9702                        STAA    TEMP+2
590 00000304  39                  NTT     RTS
591
592 00000305 >140080              BITIN1  BSET    STAT1,$80       FORCE TO 1
593 00000308 >9600                BITIN   LDAA    STAT1
594 0000030a  49                          ROLA                    PUT STAT1 $80 BIT INTO
                                                                  C BIT
595 0000030b >790006              DHIGH   ROL     DAT+6           MOVE ALL (50) BITS UP
596 0000030e >bd0000                      JSR     SHFT
597 00000311 >13000109                    BRCLR   STAT1,$01,TRY2  BIT BY BIT CHECK?
598 00000315 >7a0000                      DEC     BIT             NO, WAIT FOR BIT 50
599 00000318  26ea                        BNE     NTT             THIS TIME?
600 0000031a  8632                TRY1    LDAA    #50             YES, RELOAD BIT COUNTER
601 0000031c >9700                        STAA    BIT
602 0000031e >1300022f            TRY2    BRCLR   DAT,$02,NOTV    PRE-BIT SHOULD BE A 1
603 00000322 >9606                        LDAA    DAT+6           LSB
604 00000324 >d605                        LDAB    DAT+5           MSB (5 BITS)
```

```
605 00000326  c41f                    ANDB    #$1F
606 00000328 >9702                    STAA    TEMP+2
607 0000032a >9605                    LDAA    DAT+5
608 0000032c  84e0                    ANDA    #$E0
609 0000032e >cefff6                  LDX     #B5-10          OFFSET FOR MISSING
                                                              MATRIX ENTRIES
610 00000331  8db7                    BSR     MULT
611 00000333 >9604                    LDAA    DAT+4
612 00000335  8db3                    BSR     MULT
613 00000337 >9603                    LDAA    DAT+3
614 00000339  8daf                    BSR     MULT
615 0000033b >9602                    LDAA    DAT+2
616 0000033d  8dab                    BSR     MULT
617 0000033f >9601                    LDAA    DAT+1
618 00000341  8da7                    BSR     MULT
619 00000343 >13000104                BRCLR   DAT+0,$01,FIN
620 00000347  883b                    EORA    #$3B
621 00000349  c817                    EORB    #$17

623                          *******************************************************
624                          *                                                     *
625                          *       CRC check and confidence handling.            *
626                          *                                                     *
627                          *******************************************************
628
629 0000034b  1a830000           FIN     CPD     #$0000
630 0000034f  2719                       BEQ     VALID
631
632 00000351 >9600               NOTV    LDAA    CONF
633 00000353  810f                       CMPA    #$0F            CONFIDENCE 15?
634 00000355  270f                       BEQ     DECC
635 00000357 >150001                     BCLR    STAT1,$01       NO, BIT BY BIT CRC CHECK
636 0000035a  4d                         TSTA
637 0000035b  270c                       BEQ     NNOW            CONFIDENCE ZERO?
638 0000035d >7a0000                     DEC     BIT
639 00000360  2607                       BNE     NNOW            USE BIT COUNTER TO SLOW
                                                                 CONFIDENCE
640 00000362  860f                       LDAA    #15             DROP DURING BIT BY BIT
                                                                 ATTEMPT TO
641 00000364 >9700                       STAA    BIT             RE-SYNCRONISE
642 00000366 >7a0000             DECC    DEC     CONF
643 00000369  39                 NNOW    RTS
644
645 0000036a >140001             VALID   BSET    STAT1,$01
646 0000036d >9600                       LDAA    CONF
647 0000036f  810e                       CMPA    #14
648 00000371  2203                       BHI     NMR
649 00000373  4c                         INCA
650 00000374 >9700                       STAA    CONF
651 00000376  8632               NMR     LDAA    #50
652 00000378 >9700                       STAA    BIT
653 0000037a  8d19                       BSR     SHFT
654 0000037c  8d17                       BSR     SHFT
655 0000037e  8d15                       BSR     SHFT
656 00000380 >dc01                       LDD     DAT+1
657 00000382 >dd00                       STD     BLOCK
658 00000384 >dc03                       LDD     DAT+3
659 00000386 >dd02                       STD     BLOCK+2
660 00000388 >9600                       LDAA    DAT
661 0000038a  840f                       ANDA    #$0F
662 0000038c >9700                       STAA    CODE
663 0000038e  2604                       BNE     NBLK0           BLOCK 0?
664 00000390 >13008014           BLK0    BRCLR   BLOCK,$80,TIME  BLOCK 0, TIME?
665 00000394  39                 NBLK0   RTS
666
667 00000395 >790005             SHFT    ROL     DAT+5
668 00000398 >790004                     ROL     DAT+4
669 0000039b >790003                     ROL     DAT+3
670 0000039e >790002                     ROL     DAT+2
671 000003a1 >790001                     ROL     DAT+1
672 000003a4 >790000                     ROL     DAT
673 000003a7  39                 ABO     RTS


675                          *******************************************************
676                          *                                                     *
677                          *       Process time block.                           *
678                          *                                                     *
679                          *******************************************************

681 000003a8 >dc02               TIME    LDD     BLOCK+2
682 000003aa  05                         LSLD
683 000003ab  05                         LSLD
684 000003ac  843f                       ANDA    #$3F
685 000003ae  813b                       CMPA    #59
686 000003b0  22f5                       BHI     ABO             OVER 59?
687 000003b2 >9700                       STAA    TMIN            NO, MINUTES OK
688 000003b4 >dc01                       LDD     BLOCK+1
689 000003b6  04                         LSRD
690 000003b7  54                         LSRB
691 000003b8  54                         LSRB
692 000003b9  54                         LSRB
693 000003ba  c117                       CMPB    #23
694 000003bc  22e9                       BHI     ABO             OVER 23?
695 000003be >d700                       STAB    TOUR            NO, HOURS OK
696 000003c0 >9601                       LDAA    BLOCK+1
697 000003c2  46                         RORA
698 000003c3  8407                       ANDA    #$07
699 000003c5  27e0                       BEQ     ABO             ZERO?
```

```
000003c7 >9700                  STAA    TDOW            NO, DAY-OF-WEEK OK
000003c9 >dc00                  LDD     BLOCK
000003cb  04                    LSRD
000003cc  04                    LSRD
000003cd  54                    LSRB
000003ce  54                    LSRB
000003cf  27d6                  BEQ     ABO             ZERO?
000003d1  c135                  CMPB    #53             NO, OVER 53?
000003d3  22d2                  BHI     ABO             NO, WEEK NUMBER OK
000003d5 >d700                  STAB    TWEEK
000003d7  8407                  ANDA    #$07
000003d9  27cc                  BEQ     ABO             YEAR START DAY ZERO?
000003db >9701          TYPOK   STAA    SDAY+1          NO, OK
000003dd >d600                  LDAB    BLOCK
000003df  4f                    CLRA
000003e0  05                    LSLD
000003e1  05                    LSLD
000003e2  05                    LSLD
000003e3 >9700                  STAA    TYPE            YEAR TYPE (LEAP)
000003e5 >9603                  LDAA    BLOCK+3
000003e7  843f                  ANDA    #$3F
000003e9 >9700                  STAA    OFSET           LOCAL TIM OFFSET
000003eb >7f0000                CLR     QSEC
000003ee >7f0000                CLR     TH8
000003f1 >dc00                  LDD     TDOW            UPDATE DOW & WEEK
000003f3 >dd01                  STD     DOW+1
000003f5 >dc00                  LDD     TMIN            UPDATE MINUTE & HOUR
000003f7 >dd00                  STD     MIN
000003f9 >12004006              BRSET   STAT1,$40,CDATE DATE ALREADY VALID?
000003fd >bd0000                JSR     NOTALR          NO, FIRST TIME, STANDBY
00000400 >140040                BSET    STAT1,$40       AND SET FLAG

                        *******************************************************
                        *                                                     *
                        *       Calculate offset.                             *
                        *                                                     *
                        *******************************************************

00000403 >dc00                CDATE   LDD     MIN             XFER MINUTES AND HOURS
00000405 >dd00                        STD     DMIN
00000407 >9600                        LDAA    WEEK            XFER WEEK NUMBER
00000409 >dd00                        STD     DWEEK
0000040b >dc00                        LDD     DOW             XFER DAY-OF-WEEK
0000040d >dd00                        STD     DDOW

                        *******************************************************
                        *                                                     *
                        *       Local time difference adjustment (neg.).      *
                        *                                                     *
                        *******************************************************

0000040f >d600                LOCAL   LDAB    OFSET           CHECK FOR OFFSET
00000411 >1300202d                    BRCLR   OFSET,$20,POS   POSITIVE?
00000415  54                  NEG     LSRB                    NO, NEGATIVE HOURS
                                                              IN B
00000416  caf0                        ORAB    #$F0            MS BITS TO 1s
00000418  8d16                        BSR     HALF            HALF HOUR ADJUSTMENT
0000041a >db00                        ADDB    DOUR            HOUR OFFSET, MINUS
                                                              UTC HOURS
0000041c  250e                        BCS     ZOM             OVERFLOW?
0000041e  cb18                        ADDB    #24           NO, ADD 24 HOURS
00000420 >9601                        LDAA    DDOW+1
00000422  4a                          DECA                  AND GO BACK A DAY
00000423  2605                        BNE     DOWOK         WAS MONDAY?
00000425 >7a0000                      DEC     DWEEK         YES, LAST WEEK
00000428  8607                        LDAA    #7            SUNDAY
0000042a >9701                DOWOK   STAA    DDOW+1
0000042c  c41f                ZOM     ANDB    #$1F
0000042e  202b                        BRA     TFIN

00000430  240f                HALF    BCC     NOTH          1/2 HOUR?
00000432 >9600                        LDAA    DMIN          YES
00000434  8b1e                        ADDA    #30           ADD 30 MINUTES
00000436  813b                        CMPA    #59
00000438  2305                        BLS     MT60          OVERFLOW?
0000043a  803c                        SUBA    #60           YES, SUBTRACT 60 MINUTES
0000043c >7c0000                      INC     DOUR          AND ADD 1 HOUR
0000043f >9700                MT60    STAA    DMIN
00000441  39                  NOTH    RTS

                        *******************************************************
                        *                                                     *
                        *       Local time difference adjustment (pos).       *
                        *                                                     *
                        *******************************************************

00000442  54                  POS     LSRB                  HOURS IN B
00000443  8deb                       BSR     HALF          HALF HOUR ADJUSTMENT
00000445 >db00                        ADDB    DOUR          HOUR OFFSET, ADD UTC HOURS
00000447  c117                        CMPB    #23
00000449  2310                        BLS     TFIN          OVERFLOW?
0000044b  c018                        SUBB    #24           YES, SUBTRACT 24 HOURS
0000044d >9601                        LDAA    DDOW+1
0000044f  4c                          INCA                  AND INCREMENT DAY-OF-WEEK
00000450  8107                        CMPA    #7
00000452  2f05                        BLE     DOWOKI        WAS SUNDAY?
00000454 >7c0000                      INC     DWEEK         YES, NEXT WEEK
```

```
795 00000457  8601                      LDAA    #1              MONDAY
796 00000459 >9701              DOWOKI  STAA    DDOW+1
797
798 0000045b >d700              TFIN    STAB    DOUR
799
800                          ********************************************************
801                          *                                                      *
802                          *       Calculate date (month & day-of-month).         *
803                          *                                                      *
804                          ********************************************************
805
806 0000045d >9600                DATE    LDAA    DWEEK           WEEK NUMBER ADJUSTED FOR
                                                                  LOCAL OFFSET
807 0000045f >d601                        LDAB    SDAY+1          CAN BE 0 OR 54 (53 IN A
                                                                  52 WEEK YEAR)
808 00000461  c105                        CMPB    #5              IF 1st JAN/31st DEC
                                                                  RANSITION CAUSED
809 00000463  2501                        BLO     WNOK            BY OFFSET
810 00000465  4c                          INCA                    ADJUST WEEK FOR
                                                                  YEAR-START-DAY-OF-WEEK
811 00000466  c607                WNOK    LDAB    #7              AND MULTIPLY BY 7 TO GET
                                                                  DAY-OF-YEAR
812 00000468  3d                          MUL
813 00000469 >d300                        ADDD    DDOW            ADD CURRENT DAY-OF-WEEK
814 0000046b  c30037                      ADDD    #55             START AT 1st NOV
                                                                  (PREVIOUS YEAR)
815 0000046e >9300                        SUBD    SDAY            SUBTRACT YEAR START
                                                                  DAY-OF-WEEK
816 00000470 >dd00                        STD     DOY             SAVE DAY-OF-YEAR
                                                                  (DEBUG)
817 00000472 >1300401c                    BRCLR   STAT1,$40,DNV   DATE VALID?
818 00000476 >7f0000                      CLR     MNTH            MONTH=0: NOVEMBER
                                                                  (PREVIOUS YEAR)
819 00000479 >ce0000                      LDX     #MTAB
820 0000047c >7d0000                      TST     TYPE
821 0000047f  2603                        BNE     MLOP            LEAP YEAR?
822 00000481 >ce0018                      LDX     #MTAB+24        YES, USE SECOND TABLE
823 00000484 >7c0000              MLOP    INC     MNTH
824 00000487  a300                        SUBD    0,X
825 00000489  08                          INX
826 0000048a  08                          INX
827 0000048b  1aa300                      CPD     0,X
828 0000048e  22f4                        BHI     MLOP
829 00000490 >dd00                        STD     DOM
830 00000492  39                  DNV     RTS
831
832 00000493  001e001f            MTAB    FDB     30,31
                                                  NOVEMBER, DECEMBER
833 00000497  001f001c001f001e            FDB     31,28,31,30,31,30,31,31,30,31,30,31
                                                   JANUARY-DECEMBER
834 000004af  001f001d001f001e            FDB     31,29,31,30,31,30,31,31,30,31,30,31
                                                  JANUARY-DECEMBER (LEAP)
835 000004c7  001f                        FDB     31
                                                  JANUARY


837                          ********************************************************
838                          *                                                      *
839                          *       Display type selection.                        *
840                          *                                                      *
841                          ********************************************************
842
843 000004c9 >12000422       MOD     BRSET   STAT2,$04,SLPD    SLEEP DISPLAY?
844 000004cd >12000831                BRSET   STAT2,$08,ALRMJ   NO, ALARM DISPLAY?
845
846 000004d1 >1300801f       ALT1    BRCLR   STAT2,$80,NRMD    NO,ALTERNATIVE DISPLAYS?
847 000004d5 >9600                   LDAA    ADIS
848 000004d7  4a                     DECA
849 000004d8  2605                   BNE     ALT2
850 000004da >bd0000                 JSR     ALTD1             DATA & TIME DISPLAY
851 000004dd  2026                   BRA     ROW1
852 000004df  4a             ALT2    DECA
853 000004e0  2605                   BNE     ALT3
854 000004e2 >bd0000                 JSR     ALTD2             YEAR & WEEK DISPLAY
855 000004e5  201e                   BRA     ROW1
856 000004e7  4a             ALT3    DECA
857 000004e8  2605                   BNE     SLPD
858 000004ea >bd0000                 JSR     ALTD3             VDD & TUNING DISPLAY
859 000004ed  2016                   BRA     ROW1
860
861 000004ef >bd0000         SLPD    JSR     SLEEPD            SLEEP TIMER DISPLAY?
862 000004f2  2011                   BRA     ROW1
863 000004f4  181e082004     NRMD    BRSET   PORTD,Y,$20,STND  STANDBY?
864 000004f9  8d3a                   BSR     NORMD             "NORMAL" DISPLAY
865 000004fb  2008                   BRA     ROW1
866 000004fd >bd0000         STND    JSR     STBYD             STANDBY DISPLAY
867 00000500  2003                   BRA     ROW1
868 00000502 >bd0000         ALRMJ   JSR     ALRMD             ALARM DISPLAY
869
870 00000505 >ce0000         ROW1    LDX     #DISP
871 00000508  a600           CMPLP   LDAA    0,X
872 0000050a  a110                   CMPA    16,X              HAS CHARACTER CHANGED?
873 0000050c  2607                   BNE     DIFF
874 0000050e  08                     INX
875 0000050f >8c0010                 CPX     #DISP+16
876 00000512  26f4                   BNE     CMPLP
877 00000514  39                     RTS
878
```

```
879 00000515 >bd0000         DIFF    JSR     WAIT
880 00000518  8680                   LDAA    #$80              ADDRESS DISPLAY RAM
881 0000051a >bd0000                 JSR     CLOCK             LATCH IT
882 0000051d >ce0000                 LDX     #DISP
883 00000520 >bd0000         LCD     JSR     WAIT
885 00000523  181c0420               BSET    LCDC,Y,$20        WRITE DATA
889 00000527  a600                   LDAA    0,X               GET A BYTE
890 00000529  a710                   STAA    16,X
891 0000052b >bd0000                 JSR     CLOCK             SEND IT TO MODULE
892 0000052e  08                     INX
893 0000052f >8c0010                 CPX     #DISP+16          DONE?
894 00000532  26ec                   BNE     LCD
895 00000534  39                     RTS                       REMOVE FOR /16 DISPLAY

897                          ********************************************************
898                          *                                                      *
899                          *       Additional code for /16 LCD modules.           *
900                          *       (also change CLOCK3 to LDAA   #$38)            *
901                          *                                                      *
902                          ********************************************************
903
904                             *LCD16  JSR     WAIT
905                             *       LDAA    #$A8              ADDRESS 40
906                             *       JSR     CLOCK             SEND IT TO MODULE
907                             *       LDX     #DISP
908                             *LCD6   JSR     WAIT
909                             *       IF      HC11==2           E2
910                             *       BSET    LCDC,Y,$20        WRITE DATA
911                             *       ELSE                      K4
912                             *       BSET    LCDC,Y,$04        WRITE DATA
913                             *       ENDIF
914                             *       LDAA    8,X               GET A BYTE
915                             *       JSR     CLOCK             SEND IT TO MODULE
916                             *       INX
917                             *       CPX     #DISP+8           DONE?
918                             *       BNE     LCD6
919                             *       RTS
920
921                          ********************************************************
922                          *                                                      *
923                          *       Normal and Standby (alarm armed) displays.     *
924                          *                                                      *
925                          ********************************************************
926
927 00000535  8d17             NORMD   BSR     STIME
928 00000537 >7e0000                 JMP     DSUB1
929
930 0000053a >cefffd         ALRMA   LDX     #ALARMS-3
931 0000053d >bd0000                 JSR     XFER16
932 00000540 >9600                   LDAA    AOUR              GET ALARM HOURS
933 00000542 >bd0000                 JSR     CBCD
934 00000545 >dd00                       STD     DISP
935 00000547 >9600                       LDAA    AMIN
936 00000549 >bd0000                     JSR     CBCD
937 0000054c >dd02                       STD     DISP+2
938
939 0000054e >9600               STIME   LDAA    DOUR              GET TIME
940 00000550  8d0e                       BSR     SUBSP
941 00000552 >dd0b                       STD     DISP+11
942 00000554 >9600                       LDAA    DMIN
943 00000556 >bd0000                     JSR     CBCD
944 00000559 >dd0e                       STD     DISP+14
945 0000055b  863a                       LDAA    #$3A              0.5 Hz FLASHING COLON
946 0000055d >970d               DTF     STAA    DISP+13
947 0000055f  39                         RTS
948
949 00000560 >bd0000             SUBSP   JSR     CBCD
950 00000563  8130                       CMPA    #$30              LEADING ZERO?
951 00000565  2602                       BNE     TMZ
952 00000567  8620                       LDAA    #$20              YES, MAKE IT A SPACE
953 00000569  39                 TMZ     RTS


955                           ********************************************************
956                           *                                                      *
957                           *       Standby display (alarm not armed).             *
958                           *                                                      *
959                           ********************************************************
960
961 0000056a  8de2                   STBYD   BSR     STIME
962 0000056c >120010ca                       BRSET   STAT2,$10,ALRMA   ALARM ARMED?
963 00000570 >d601                           LDAB    DDOW+1            NO, GET DAY OF WEEK
964 00000572 >cefffd                         LDX     #DNAME-3
965 00000575  8d22                           BSR     T3X               AND CONVERT TO STRING
966 00000577 >dd00                           STD     DISP
967 00000579  a602                           LDAA    2,X
968 0000057b >9702                           STAA    DISP+2
969
970 0000057d  8620                   NDISP   LDAA    #$20
971 0000057f >9703                           STAA    DISP+3
972 00000581 >9706                           STAA    DISP+6
973 00000583 >970a                           STAA    DISP+10
974 00000585 >9601                           LDAA    DOM+1             DAY OF MONTH
975 00000587  8dd7                           BSR     SUBSP
976 00000589 >dd04                   DTNZ    STD     DISP+4
977 0000058b >d600                           LDAB    MNTH              MONTH
978 0000058d >cefffd                         LDX     #MNAME-3
979 00000590  8d07                           BSR     T3X               CONVERT TO STRING
980 00000592 >dd07                           STD     DISP+7
```

```
981 00000594  a602                    LDAA    2,X
982 00000596 >9709                    STAA    DISP+9
983 00000598  39                      RTS
984
985 00000599  8603              T3X   LDAA    #3
986 0000059b  3d                      MUL
987 0000059c  3a                      ABX
988 0000059d  ec00                    LDD     0,X
989 0000059f  39                      RTS

991                          ********************************************************
992                          *                                                      *
993                          *       LW data, confidence & seconds display.         *
994                          *                                                      *
995                          ********************************************************
996
997 000005a0  8620              ALTD1 LDAA    #$20
998 000005a2 >970b                    STAA    DISP+11
999 000005a4 >970d                    STAA    DISP+13
1000 000005a6 >9600                   LDAA    CONF
1001 000005a8 >bd0000                 JSR     SPLIT
1002 000005ab >d70c                   STAB    DISP+12
1003 000005ad >9600                   LDAA    QSEC            QSEC X 256 IN D
1004 000005af  5f                     CLRB
1005 000005b0  ce03d2                 LDX     #978            SCALE FOR QSEC = 229
1006 000005b3  02                     IDIV                    TO BE JUST BELOW 60
1007 000005b4  8f                     XGDX
1008 000005b5  17                     TBA
1009 000005b6 >bd0000                 JSR     CBCD
1010 000005b9 >dd0e                   STD     DISP+14
1011
1012 000005bb  cc2d20           DSUB1 LDD     #$2D20
1013 000005be >d706                   STAB    DISP+6
1014 000005c0 >d70a                   STAB    DISP+10
1015 000005c2 >13000202               BRCLR   STAT2,$02,STNR  SLEEP TIMER RUNNING?
1016 000005c6  c62e                     LDAB    #$2E            YES,"." IN 2nd CHARACTER
1017 000005c8 >dd00             STNR  STD     DISP
1018 000005ca >13000111               BRCLR   STAT1,$01,SYNNV
1019 000005ce >9600                   LDAA    CODE
1020 000005d0  2608                   BNE     NOTT0           BLOCK 0?
1021 000005d2 >12008004               BRSET   BLOCK,$80,NOTT0 YES, TIME?
1022 000005d6  c674                   LDAB    #'t             YES
1023 000005d8  2003                   BRA     SKSP
1024 000005da >bd0000           NOTT0 JSR     SPLIT
1025 000005dd >d700             SKSP  STAB    DISP
1026 000005df >9600             SYNNV LDAA    BLOCK
1027 000005e1 >bd0000                 JSR     SPLIT
1028 000005e4 >dd02                   STD     DISP+2
1029 000005e6 >9601                   LDAA    BLOCK+1
1030 000005e8 >bd0000                 JSR     SPLIT
1031 000005eb >dd04                   STD     DISP+4
1032 000005ed >9602                   LDAA    BLOCK+2
1033
1034 000005ef >d60b                   LDAB    DISP+11     t 7D65 37C2 1:23
1035 000005f1  c120                   CMPB    #$20        ^
1036 000005f3  260d                   BNE     MOVEIT      SPACE?
1037 000005f5 >bd0000                 JSR     SPLIT       DIVIDE HEX DATA
1038 000005f8 >dd07                   STD     DISP+7      INTO TWO BLOCKS
1039 000005fa >9603                   LDAA    BLOCK+3     OF FOUR IF THE
1040 000005fc >bd0000                 JSR     SPLIT       12th CHARACTER
1041 000005ff >dd09                   STD     DISP+9      IS A SPACE
1042 00000601  39                     RTS
1043
1044 00000602 >bd0000           MOVEIT JSR    SPLIT
1045 00000605 >dd06                   STD     DISP+6
1046 00000607 >9603                   LDAA    BLOCK+3
1047 00000609 >bd0000                 JSR     SPLIT
1048 0000060c >dd08                   STD     DISP+8
1049 0000060e  39                     RTS
1050
1051                         ********************************************************
1052                         *                                                      *
1053                         *        LW data year & week display.                  *
1054                         *                                                      *
1055                         ********************************************************
1056
1057 0000060f >ce0000           ALTD2 LDX     #ALT2ST
1058 00000612 >bd0000                 JSR     XFER16
1059 00000615 >9600                   LDAA    TYPE        LEAP YEAR (CYCLE) TYPE
1060 00000617  8b30                   ADDA    #$30
1061 00000619 >9702                   STAA    DISP+2
1062 0000061b >9601                   LDAA    SDAY+1      YEAR START DAY
1063 0000061d  8b30                   ADDA    #$30
1064 0000061f >9704                   STAA    DISP+4
1065 00000621 >9601                   LDAA    SDAY+1      IF 0 (NO TIME/DATE RECEIVED)
1066 00000623  2720                   BEQ     ILLSD       THEN DON'T CALCULATE YEAR
1067
1068 00000625 >d600                   LDAB    TYPE
1069 00000627  8607                   LDAA    #7          CALCULATE OFFSET TABLE OFFSET
1070 00000629  3d                     MUL
1071 0000062a >db01                   ADDB    SDAY+1
1072 0000062c  5a                     DECB
1073 0000062d >ce0000                 LDX     #YRTAB
1074 00000630  3a                     ABX
1075 00000631  e600                   LDAB    0,X         GET OFFSET FROM TABLE
1076 00000633  8613                   LDAA    #19         START AT 1995
1077 00000635  37                     PSHB
1078 00000636  c104                   CMPB    #4
1079 00000638  2301                   BLS     NINT        199x?
```

```
1080 0000063a  4c                      INCA              NO, 20xx
1081 0000063b >bd0000           NINT   JSR     CBCD
1082 0000063e >dd06                    STD     DISP+6     19 OR 20 TO DISPLAY BUFFER
1083 00000640  32                      PULA
1084 00000641  8b5f                    ADDA    #95        YEAR TENS AND UNITS
1085 00000643  8d71                    BSR     CBCD8      CONVERT TO ASCII BCD AND PUT
                                                          INTO DISP+8 & +9
1087 00000645 >9600             ILLSD  LDAA    DWEEK      WEEK NUMBER
1088 00000647 >bd0000                  JSR     CBCD
1089 0000064a >dd0e                    STD     DISP+14
1090 0000064c  39                      RTS
1091
1092 0000064d  010d1909150511   YRTAB  FCB     1,13,25,9,21,5,17   TABLE CONTAINING
                                                                  OFFSET RELATIVE TO
1093 00000654  0612020e1a0a16          FCB     6,18,2,14,26,10,22  1995 ACCORDING TO
                                                                  LEAP YEAR (CYCLE)
1094 0000065b  170713030f1b0b          FCB     23,7,19,3,15,27,11  TYPE (0-3) DOWN TABLE
                                                                  AND YEAR START DAY
1095 00000662  0c180814041000          FCB     12,24,8,20,4,16,0   (1-7) ACROSS TABLE

1097                        ********************************************************
1098                        *                                                      *
1099                        *           Alarm display.                             *
1100                        *                                                      *
1101                        ********************************************************
1102
1103 00000669 >ce0000           ALRMD  LDX     #ALARMS
1104 0000066c  8d2b                    BSR     XFER16
1105 0000066e >13001026                BRCLR   STAT2,$10,ALOF2     ALARM ARMED?
1106 00000672  863a                    LDAA    #$3A                YES
1107 00000674 >970c                    STAA    DISP+12
1108 00000676 >9600                    LDAA    AOUR                GET ALARM HOURS
1109 00000678 >bd0000                  JSR     SUBSP
1110 0000067b >dd0a                    STD     DISP+10
1111 0000067d >9600                    LDAA    AMIN
1112 0000067f >bd0000                  JSR     CBCD
1113 00000682 >dd0d                    STD     DISP+13
1114 00000684 >13002010                BRCLR   STAT2,$20,ALOF2     SET-UP?
1115 00000688 >1300020c                BRCLR   QSEC,$02,ALOF2
1116 0000068c  8620                    LDAA    #$20
1117 0000068e  16                      TAB
1118 0000068f >12004003                BRSET   STAT2,$40,FH        HOURS?
1119 00000693 >dd0d                     STD     DISP+13     NO, FLASH MINUTES
1120 00000695  39                       RTS
1121
1122 00000696 >dd0a              FH     STD     DISP+10     YES, FLASH HOURS
1123 00000698  39                ALOF2  RTS
1124
1125 00000699  c610              XFER16 LDAB    #16
1126 0000069b >18ce0000                 LDY     #DISP
1127 0000069f  a600              XFER   LDAA    0,X
1128 000006a1  18a700                   STAA    0,Y
1129 000006a4  08                       INX
1130 000006a5  1808                     INY
1131 000006a7  5a                       DECB
1132 000006a8  26f5                     BNE     XFER
1133 000006aa  18ce1000                 LDY     #$1000      RESTORE FOR I/O
1134 000006ae  39                       RTS
1135

1136                        ********************************************************
1137                        *                                                      *
1138                        *       Sleep display.                                 *
1139                        *                                                      *
1140                        ********************************************************
1141
1142 000006af >ce0000            SLEEPD LDX     #SLPST
1143 000006b2  8de5                     BSR     XFER16
1144 000006b4 >9600                     LDAA    SLEPT
1145 000006b6  8d49              CBCD8  BSR     CBCD
1146 000006b8 >dd08                     STD     DISP+8
1147 000006ba  39                       RTS

1149                        ********************************************************
1150                        *                                                      *
1151                        *    Voltage display.                                  *
1152                        *                                                      *
1153                        ********************************************************
1154
1155 000006bb >ce0000            ALTD3  LDX     #ADST
1156 000006be  8dd9                     BSR     XFER16
1157
1158 000006c0  b61031            VDD    LDAA    ADR1+RBO    VDD/4 (PE4)
1159 000006c3  4c                       INCA
1160 000006c4  c6c8                     LDAB    #200        SCALE AND RETURN WITH UP
                                                            TO 99 (9.9v) IN ACCA
1161 000006c6  8d29                     BSR     CSUB        AND 10s OF VOLTS IN TEMP
1162 000006c8  8d37                     BSR     CBCD        RETURN WITH ASCII VOLTS
                                                            IN ACCA AND 10ths IN ACCB
1163 000006ca >9704                     STAA    DISP+4      VOLTS
1164 000006cc >d706                     STAB    DISP+6      10ths OF VOLTS
1165 000006ce >9600                     LDAA    TEMP        10s OF VOLTS
1166 000006d0  2602                     BNE     V10NZ       ZERO?
1167 000006d2  86f0                     LDAA    #$F0        YES, MAKE IT A SPACE
1168 000006d4  8b30              V10NZ  ADDA    #$30        CONVERT TO ASCII
1169 000006d6 >9703                     STAA    DISP+3      10s OF VOLTS
1170
1171 000006d8  b61032            TUNE   LDAA    ADR2+RBO    RSSI (PE5)
1172 000006db  4c                       INCA
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```
1173 000006dc  c6fa                    LDAB    #250        SCALE AND RETURN WITH UP
                                                           TO 99 (1.98v) IN ACCA
1174 000006de  8d11                    BSR     CSUB        AND UP TO 2 (4v) IN TEMP
                                                           (MAX: 249 OR 4.98V)
1175 000006e0 >780000                  LSL     TEMP       DOUBLE TEMP TO VOLTS (MAX 4)
1176 000006e3  48                      ASLA                DOUBLE ACCA TO 100ths OF
                                                           VOLTS (MAX 198)
1177 000006e4  8d0f                    BSR     TFMH        CHECK FOR CARRY TO TEMP
1178 000006e6  8d19                    BSR     CBCD        RETURN WITH ASCII 10ths IN
                                                           ACCA AND 100ths IN ACCB
1179 000006e8 >dd0e                    STD     DISP+14     AND PUT BOTH IN DISPLAY
                                                           BUFFER
1180 000006ea >9600                    LDAA    TEMP
1181 000006ec  8b30                    ADDA    #$30        CONVERT VOLTS TO ASCII
1182 000006ee >970c                    STAA    DISP+12     AND PUT IN DISPLAY BUFFER
1183 000006f0  39                      RTS
1184
1185 000006f1  3d                CSUB  MUL                 TIMES 200 (OR 250) AND
1186 000006f2 >7f0000                  CLR     TEMP        DIVIDE BY 256 (BY USING
1187 000006f5  8164              TFMH  CMPA    #100        ONLY ACCA AS RESULT)
1188 000006f7  2507                    BLO     NHUN        OVER 99?
1189 000006f9 >7c0000                  INC     TEMP        YES, OVERFLOW AND
1190 000006fc  8064                    SUBA    #100        GET ACCA BELOW 100 BEFORE
                                                           CONVERSION TO BCD
1191 000006fe  20f5                    BRA     TFMH        AND AGAIN
1192 00000700  39                      NHUN    RTS


1194                        ****************************************************
1195                        *                                                  *
1196                        *       ACCA Hex->BCD conversion                   *
1197                        *                                                  *
1198                        *                  &                               *
1199                        *                                                  *
1200                        *       Split nibbles into ACCA (MS) and           *
1201                        *       ACCB (LS) and convert to ASCII.            *
1202                        *                                                  *
1203                        ****************************************************
1204
1205 00000701  16                CBCD  TAB                 HEX IN A & B
1206 00000702  840f                    ANDA    #$0F        LSB IN A
1207 00000704  c4f0                    ANDB    #$F0        MSB (x16) IN B
1208 00000706  8b00                    ADDA    #0          CLEAR H AND C BITS
1209 00000708  19                      DAA                 DECIMAL ADJUST ACCA
                                                           (ADD 6 IF OVER 9)
1210 00000709  c010              MOREB SUBB    #$10        DECREMENT MSB
1211 0000070b  2505                    BCS     SPLIT       TOO FAR?
1212 0000070d  8b16                    ADDA    #$16        NO, ADD 16 (BCD) TO
1213 0000070f  19                      DAA                 ACCA, AND ADJUST
1214 00000710  20f7                    BRA     MOREB       TRY AGAIN
1215
1216                        ****************************************************
1217                        *                                                  *
1218                        *       Split ACCA nibbles into ACCA (MS) and      *
1219                        *       ACCB (LS) and convert both to ASCII.       *
1220                        *                                                  *
1221                        ****************************************************
1222
1223 00000712  16                SPLIT TAB                 MSD INTO A, LSD INTO B
1224 00000713  0d                      SEC
1225 00000714  46                      RORA                SHIFT MS NIBBLE DOWN
1226 00000715  0d                      SEC
1227 00000716  46                      RORA                SHIFT IN TWO 1s TO ADD $30
1228 00000717  44                      LSRA                TO CONVERT DECIMAL
                                                           NUMBERS TO ASCII
1229 00000718  44                      LSRA
1230 00000719  8139                    CMPA    #$39
1231 0000071b  2302                    BLS     XOK         OVER 9?
1232 0000071d  8b07                    ADDA    #7          YES, ADJUST FOR A-F
1233 0000071f  c40f              XOK   ANDB    #$0F
1234 00000721  cb30                    ADDB    #$30        CONVERT LS NIBBLE TO ASCII
1235 00000723  c139                    CMPB    #$39
1236 00000725  2302                    BLS     AOK
1237 00000727  cb07                    ADDB    #7          AND ADJUST FOR A-F
1238 00000729  39                AOK   RTS

1240                        ****************************************************
1241                        *                                                  *
1242                        *       Send and clock data to LCD module.         *
1243                        *                                                  *
1244                        *       Check to see if LCD module is busy.        *
1245                        *                                                  *
1246                        ****************************************************
1247
1249 0000072a  8630              CLOCK3 LDAA   #$30        $38 FOR /16 DISPLAYS
1250 0000072c  18a703            CLOCK  STAA   LCDB,Y
1251 0000072f  181c0480                 BSET   LCDC,Y,$80
1252 00000733  181d0480                 BCLR   LCDC,Y,$80  CLOCK IT
1253 00000737  39                       RTS
1254
1255 00000738  181d04a0          WAIT   BCLR   LCDC,Y,$A0  READ LCD BUSY FLAG
1256 0000073c  181c0440                 BSET   LCDC,Y,$40
1257 00000740  186f07                   CLR    LCDBDD,Y    INPUT ON LCD BUS
1258 00000743  181c0480          WLOOP  BSET   LCDC,Y,$80  CLOCK HIGH
1259 00000747  18a603                   LDAA   LCDB,Y      READ MODULE
1260 0000074a  181d0480                 BCLR   LCDC,Y,$80  CLOCK LOW
1261 0000074e  2bf3                     BMI    WLOOP       BUSY?
1262 00000750  186307                   COM    LCDBDD,Y    OUTPUT ON LCD BUS
1263 00000753  181d0440                 BCLR   LCDC,Y,$40
```

```
1264 00000757  39                          RTS
1265
1284                          ******************************************************
1285                          *                                                    *
1286                          *       Strings.                                     *
1287                          *                                                    *
1288                          ******************************************************
1289
1290 00000758  423a202d2d2e2d20    ADST    FCC                 'B: --.-  T: -.'
1291 00000766  2d2d2d              FCC                         '---'
1292 00000769  4d6f6e5475655765    DNAME   FCC                 'MonTueWedThuFriSatSun'
1293 0000077e  2d2d2d              FCC                         '---'
1294 00000781  4465634a616e4665    MNAME   FCC                 'DecJanFebMarAprMayJun
                                                               JulAugSepOctNovDecJan'
1295
1296 000007ab  593a202f20282d2d    ALT2ST  FCC                 'Y: / (----) W:'
1297 000007b9  2020416c61726d20    ALARMS  FCC                 '  Alarm -  Off  '
1298 000007c9  20536c6565702020    SLPST   FCC                 ' Sleep   0 min. '
1299

1300                        ******************************************************
1301                        *                                                    *
1302                        *       RAM clear.                                   *
1303                        *                                                    *
1304                        ******************************************************
1305
1306 000007d9 >ce0000            CLRAM    LDX     #STAT1        INITIALISE RAM
1307 000007dc  6f00              CLOOP2   CLR     0,X
1308 000007de  08                         INX                    1mS DELAY FOR LCD
1309 000007df >8c0001                     CPX     #ADIS+1
1310 000007e2  26f8                       BNE     CLOOP2
1311 000007e4  39                         RTS

1313
                            ******************************************************
1314                        *                                                    *
1315                        *       LINK batch files (LWRD.BAT & LWRD.LD)        *
                            *       and PCBUG11 Vectors.                         *
1316                        *                                                    *
1317                        *       ILD11 LWRD.O -MKUF LWRD.MAP -G LWRD -O LWRD.OUT *
1318                        *       IHEX LWRD.OUT -O LWRD.0                      *
1319                        *       TYPE LWRD.MAP                                *
1320                        *       SYMBOL LWRD OFF 0                            *
1321                        *                                                    *
1322                        *       section .RAM1 BSS origin 0x0000   11K4   811E2  *
1323                        *       section .ROM1 origin 0x4000      $4000   $F800  *
1324                        *       section .VECT origin 0xBFC1      $BFC1   -----  *
1325                        *       section .VECTOR origin 0xFFD6    $FFD6   $FFF0  *
1326                        *                                                    *
1327                              ******************************************************
1328
1358                        ******************************************************
1359                        *                                                    *
1360                        *       MC68HC811E2 Vectors.                         *
1361                        *                                                    *
1362                        ******************************************************
1363
1364                              SECTION .VECTOR
1365                        *     ORG     $FFF0
1366
1367 00000000 >0000               FDB     TINTB           RTI
1368 00000002 >0000               FDB     SDATA           IRQ
1369 00000004 >0000               FDB     START           XIRQ
1370 00000006 >0000               FDB     START           SWI
1371 00000008 >0000               FDB     START           ILLEGAL OP CODE
1372 0000000a >0000               FDB     START           COP
1373 0000000c >0000               FDB     START           CLOCK MONITOR
1374 0000000e >0000               FDB     START           RESET
1407                              END
```


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