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128-Kbyte Addressing with the M68HC11

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Overview

The maximum direct addressing capability of the M68HC11 device is 64 Kbytes, but this can be insufficient for some applications.

This application note describes two methods of memory paging that allow the MCU to fully address a single 1 megabit EPROM (128 Kbytes) by manipulation of the address lines.

The two methods illustrate the concept of paging and the inherent compromises. The technique may be expanded to allow addressing of several EPROM, RAM, or EEPROM memories, or several smaller memories by using both address lines and chip enables.

Paging Scheme

The M68HC11 8-bit MCU is capable of addressing up to 64 Kbytes of contiguous address space. Addressing greater than 64 Kbytes requires that a section of the memory be replaced with another block of memory at the same address range. This technique of swapping memory is known as paging and is simply a method of overlaying blocks of data over each other such that only one of the blocks or pages is visible to the CPU at a given time.

In a system requiring more than 64 Kbytes of user code and tables, it is possible to use the port lines to extend the memory addressing range of the M68HC11 device. This has certain restrictions, but these can be minimized by careful consideration of the user code implementation.

There are two basic configurations:

- Method A uses only software plus a single port line to control the high address bit A16.
- Method B is a combination of a small amount of hardware and software controlling the top three address bits — A14, A15, and A16.

In the examples that follow, the MC68HC11G5 device is used to demonstrate the paging techniques, since this device has a non-multiplexed data and address bus. Any M68HC11 device may be used in a similar way.

Method A has the advantage of no additional hardware and very few limitations in the software. The user code main loop can be up to 64 Kbytes long and remain in the same page, but this is at the expense of longer interrupt latency. The vector table and a small amount of code must be present in both pages of memory to allow correct swapping of the pages.

Method B has the advantage of not affecting the interrupt latency and has just one copy of the vector table. The maximum length of the user code main loop in this example is 48 Kbytes with a further five paged areas of 16 Kbytes for subroutines and tables.

Method A — Software Technique

Address A16 of the EPROM is directly controlled by port D(5) of the M68HC11 as shown in **Figure 1**. This port is automatically configured to be in the input state following reset. It is vital that the state of the port line controlling address A16 is known following reset and so there is a 10-kΩ pullup resistor on this port line to force the A16 address bit to a logic high state following reset. This port bit is then made an output during the setup code execution, but care must be taken in ensuring that the data register is written to a logic 1 before the data direction register is written with a 1 to make the port line output a high state.

This port bit allows the M68HC11 to access the 128-Kbyte EPROM as two memories of 64 Kbytes each, which are paged by changing the state of the address A16 line on the EPROM. It is important to make sure that the port timing enables the port line to change state, at least the setup and hold time, before the address strobe (E clock rising edge on the MC68HC11G5), otherwise, there could be problems with address timing.

Figure 2 shows a schematic representation of the paging technique for this method where there are two separate 64-Kbyte pages of memory which may be addressed only individually.

This paging scheme means that code cannot directly jump from one 64-Kbyte page to another without running some common area of code during the page switch. This may be accomplished in two basic ways:

- The user code could build a routine in RAM, which is common to both pages, since it is internal and, therefore, unaffected by the port D(5) line.
- The user code could have the same location in both pages devoted to a page change routine.

The example software listing in **Appendix A — Software Paging Scheme** uses the latter approach.

Interrupt Routines

The change of page routine stores the current page before setting or clearing the port D(5) line and then has a jump command which must be at exactly the same address in both pages of memory. This is because the setting or clearing of the port D(5) line will immediately change the page of memory but the program counter will increment normally. Thus a change from page 0 to page 1 will result in the BSET PORTD command from page 0 followed by the JMP 0,X instruction from page 1 (the new page). To enable a jump to work, the X index register has been loaded with the address of the routine to be run in the new page. **Figure 3** shows the execution of code to perform a change of page from page 1 to page 0.

Returning from the interrupt routine requires the return-from-interrupt (RTI) command to be replaced with an RTI routine that checks the RAM location containing the memory page number prior to the interrupt routine execution. The routine then either performs an RTI command immediately, if it is to remain in the same page, or otherwise changes the state of the port D(5) line and then performs an RTI command in the correct page. Note that as with the JMP 0,X command, the RTI must be at the same address in both pages. It is important that the I bit in the condition code register (CCR) (interrupt inhibit) is set during this time for the example code to run correctly. Otherwise, the return page may be altered. This limitation can be overcome by using the stack to maintain a copy of the last page prior to the current interrupt.

The latency for an interrupt routine in a different page from the currently running user code is increased by 21 cycles on entering the interrupt routine and 18 cycles on leaving the interrupt routine. Any interrupt code that could not tolerate any such latency could be repeated in both pages of memory.

Other Routines

Jumping from one page to another may be done at any time by using the same change of page routine, but there is no need to store the current page in RAM, and so these two lines of code become redundant. In the example, the change page routine could be started at the BCLR or BSET command and save four cycles. This would, therefore, reduce the page change delay to 17 cycles. Note that it is not possible to perform a JSR command to move into the other page with the method shown in the example, since the RTS would not return to the original page. However, a modification to the return-from-interrupt routine would allow an equivalent function for a return from subroutine. In this case, the stack should be used to maintain the correct return page or the I bit in the CCR should be set to prevent interrupts.

Important Conditions

The state of the port line controlling address A16 after reset is very important. In the example, port D(5) is used which is an input after reset and has a pullup resistor to force a logic high on A16. If an output-only port line was used, then it could be reset such that A16 is a logic 0 (no pullup resistor required), which has an important consequence. The initialization routine which sets up the ports must be in the default page dictated by the state of address A16 following reset; otherwise, the user code may not be able to correctly configure the ports and hence be unable to manipulate address A16. Similarly, a bidirectional port line could have a pull-down resistor to determine the address A16 line after reset with the same implications.

The assembler generates two blocks of code with identical address ranges used by the user code. This could not be programmed directly into an EPROM since the second page would simply attempt to overwrite the first page. The code must, therefore, be split into two blocks and programmed into the correct half of the EPROM. Some linkers may be capable of performing this function automatically. **Figure 2** illustrates the expansion of the pages into the 128-Kbyte EPROM memory.

The RAM and registers, and internal EEPROM if available and enabled, will all appear in the memory map in preference to external memory, so care must be taken to avoid these addresses or move the RAM or registers away to different addresses by writing to the INIT register.

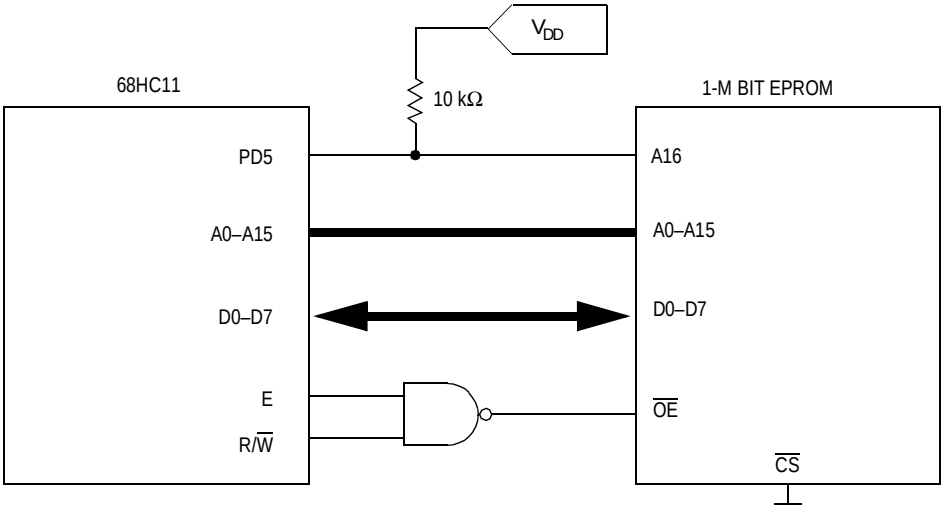

Figure 1. Software Paging Schematic Diagram

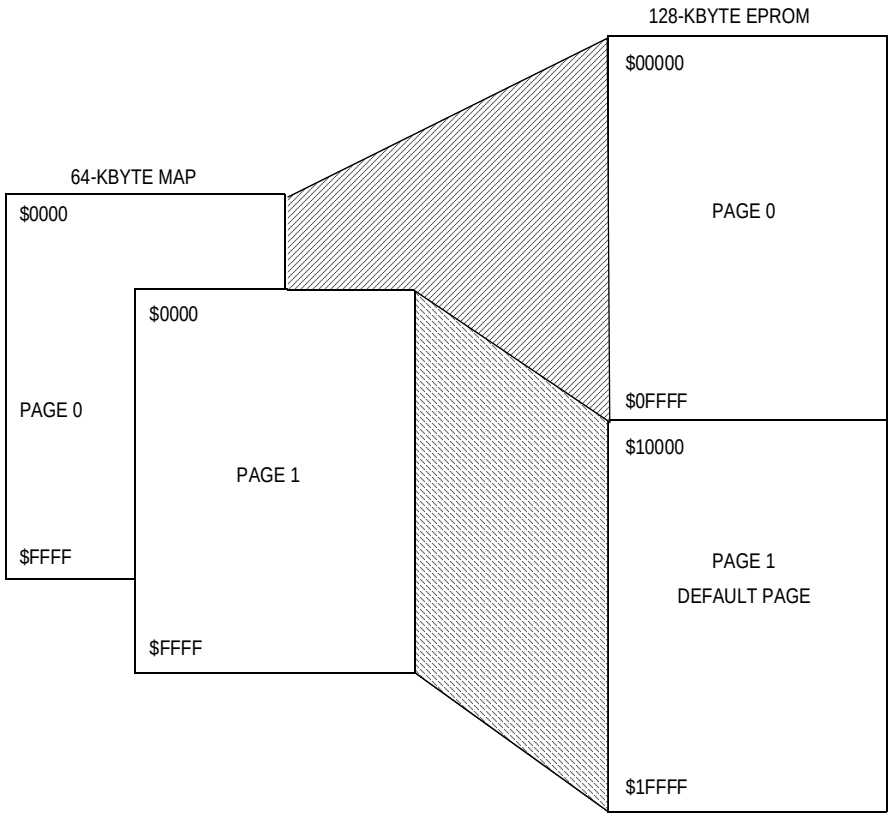

Figure 2. Software Paging Representation

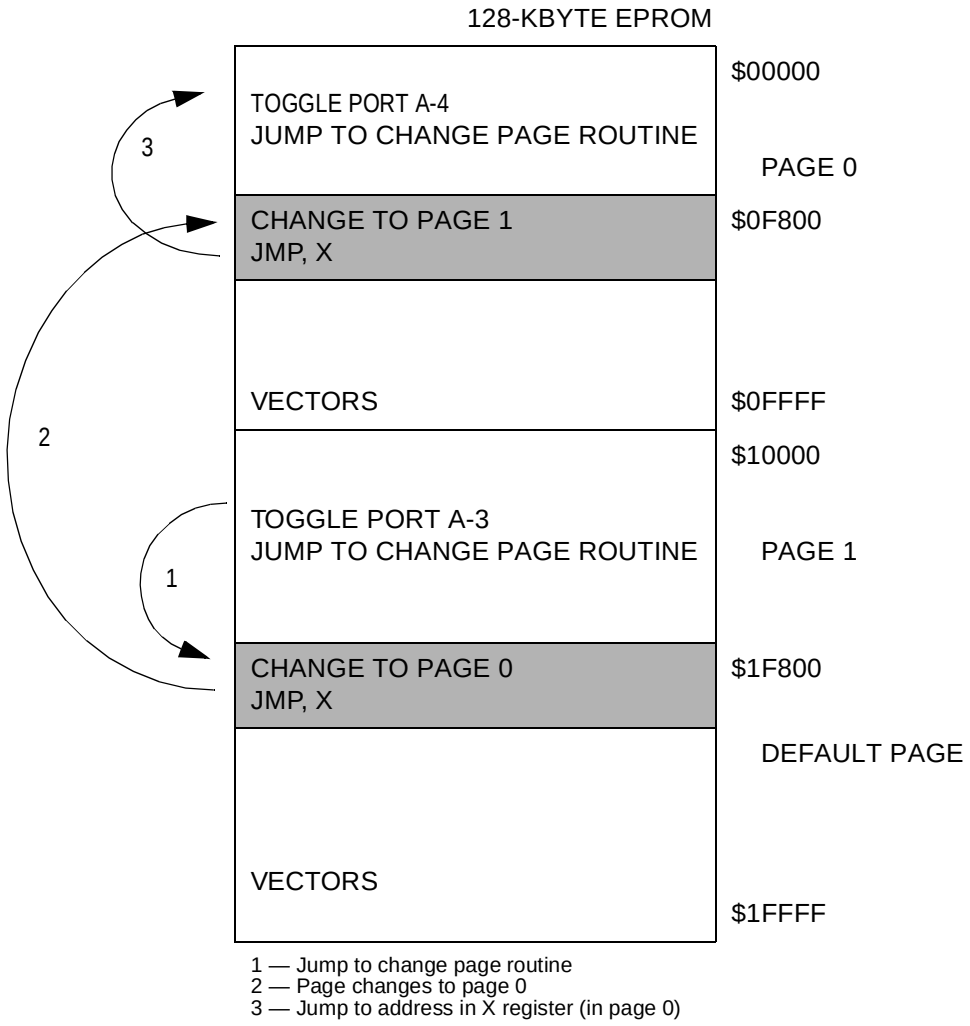

Figure 3. Flow of Program Changing from Page 1 to Page 0

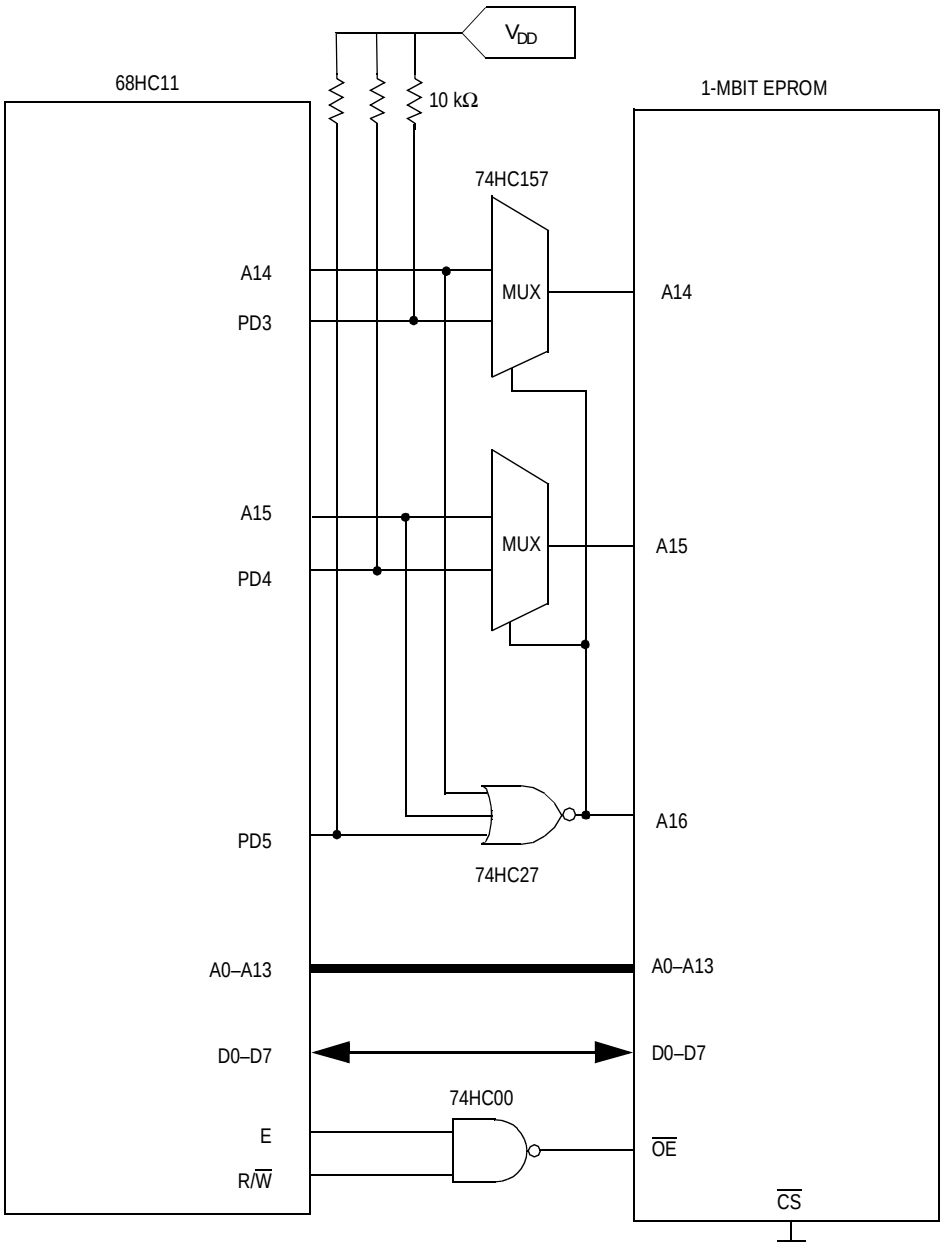

Figure 4. Hardware and Software Paging Schematic Diagram

Method B — Combined Hardware and Software Technique

The basic approach to this method is the same as in **Method A — Software Technique** except that hardware replaces some of the software. A port line together with M68HC11 addresses A14 and A15 are NORed to control the address A16 line of the EPROM. This signal is also used to select between the port line and address line for A15 and A15 (see **Figure 4**). The hardware between the port lines controlling the A14 and A15 addresses enables 64 Kbytes of user code to be addressed at all times with 48 Kbytes common to all the pages and then selecting one of five 16-Kbyte pages of EPROM memory.

In the example, port D(3) and address A14 are connected to the input of a 2-channel multiplexer such that port D(5), address A14, and address A14 control which of these two signals reaches the A14 pin of the EPROM. If addresses A14 or A15 are logic 1, the NOR gate outputs a logic 0 state, ensuring the A16 pin of the EPROM is a logic 0. In this case, address A14 controls the A14 pin of the EPROM and similarly A15 and port D(4) are selected such that address A15 controls the A15 pin of the EPROM. Thus the main 48-Kbyte portion of the EPROM memory may be addressed at all times at addresses $4000 up to $FFFF. With port D(5) and address A14 and A15 all at logic 0 (address range $0000 to $3FFF), the port lines port D(3) and port D(4) are selected in place of address lines A14 and A15. Page 0 is always selected whenever port D(5) is a logic 1. This makes it possible to have one of the five pages of 16 Kbytes paged into the 64-K addressing range of the HC11 while always maintaining the main 48 Kbytes of user code in the memory map.

There are few restrictions on the user code since the hardware provides the switching logic. Code can be made to run from one paged area to another by jumping to an intermediate routine in the main page. Port D is configured to be in the input state following reset which results in the main page plus page 0 of the paged memory in the 64-Kbyte address map since the port D lines each have a pullup resistor to maintain a logic high state after reset. A simple change memory map routine can then bring in the desired page at any time. **Appendix B — Hardware and Software Paging Scheme** shows the assembly code for a program that toggles different port pins in each of the five pages controlled from a

main routine in the main page. **Figure 5** shows the five overlaid pages expanded to a 128-K map with the flow of the program demonstrating a change from page 0 to page 1 by running the change page subroutine shown in bold type.

Implementation in C Language

The demonstration code was originally written in assembly language, but it may also be implemented in C, as shown in **Appendix C — C Language Routines for Method B**. The change of page routines were written in C with the first part an example of using in-line code and the second part calling a function. The short example shows the assembly code on the left, generated by the C code on the right. This is very similar to the assembly code example in **Appendix B — Hardware and Software Paging Scheme**, and so it is possible to extend the memory addressing beyond 64-Kbytes with the C language just as with assembly language.

Interrupt Conditions

The interrupt routines have normal latency when they reside in the main 48-Kbytes page since this is always visible to the CPU. The 25-cycle delay for changing pages may cause problems for interrupt routines in a paged area of memory.

Important Conditions

There are few special conditions for this method. The vectors must point to the main page of memory where the page changing routine must also reside. Routines in a paged area can only move to another page via the main 48-Kbyte page unless the technique in method A is utilized (for example, page change routine duplicated at identical addresses in both pages).

As with method A, the RAM and registers and internal EEPROM, if available and enabled, will all appear in the memory map in preference to external memory, so care must be taken to avoid these addresses or move the RAM or registers away to different addresses.

The assembler generates five blocks of code with identical address ranges used by the user code plus the main 48-Kbyte section. This could not be programmed directly into an EPROM since the second and subsequent pages would simply attempt to overwrite the first page. The code must, therefore, be split into blocks and programmed into the correct part of the EPROM. Some linkers may be capable of performing this function automatically.

Figure 6 illustrates the expansion of the pages into a single 128-Kbyte EPROM memory.

Customization

Clearly, the size of the paged areas may be made to suit the application with, for example, a 32-Kbyte main page and three 32 Kbytes of paged memory simply by not implementing control over the A14 address of the EPROM and not including port D(3) control. Similarly, by adding another port line to control address A13, the main program can be 56 Kbytes with nine pages of eight Kbytes each.

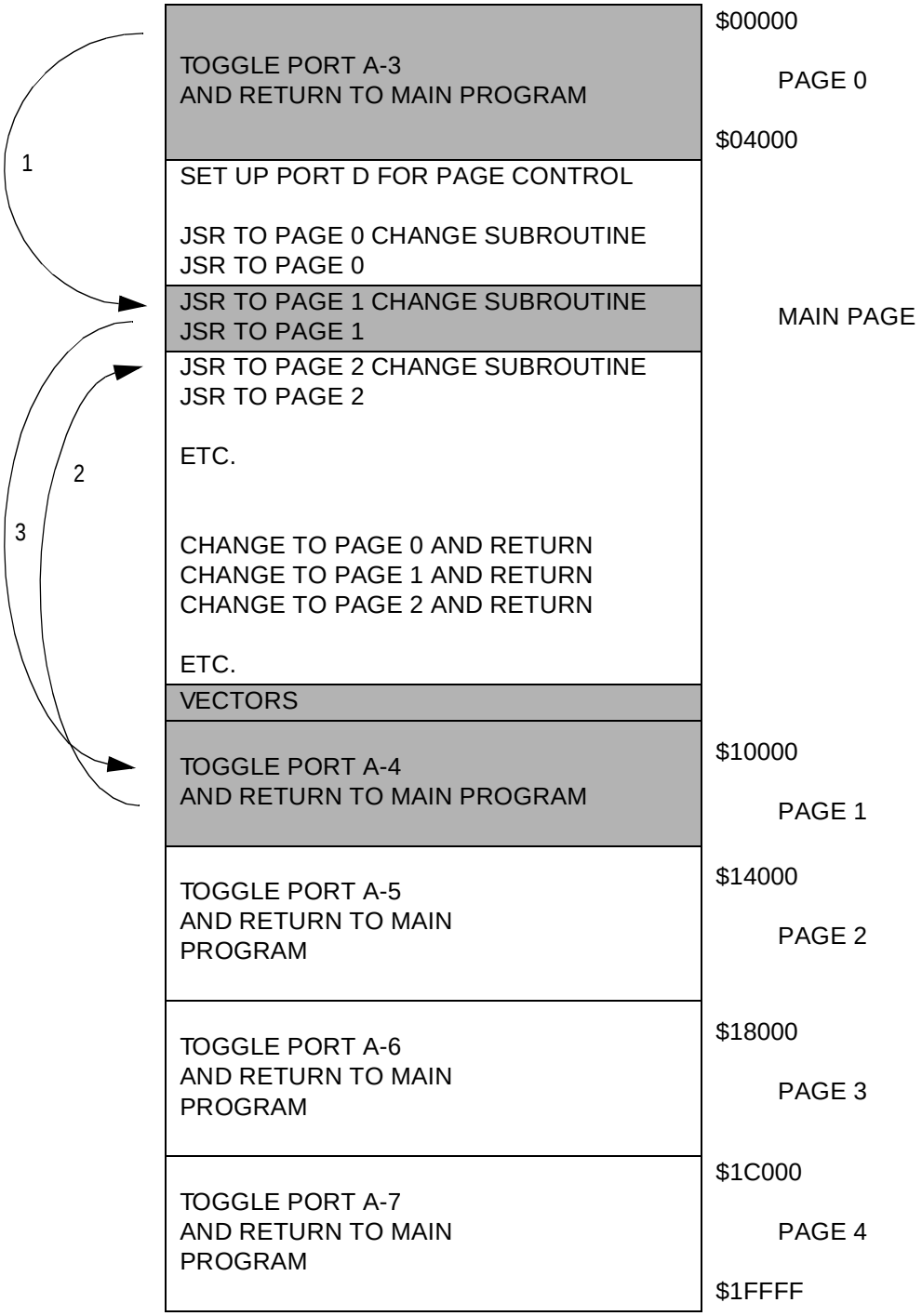

Figure 5. Illustration of Changing from Page 0 to Page 1

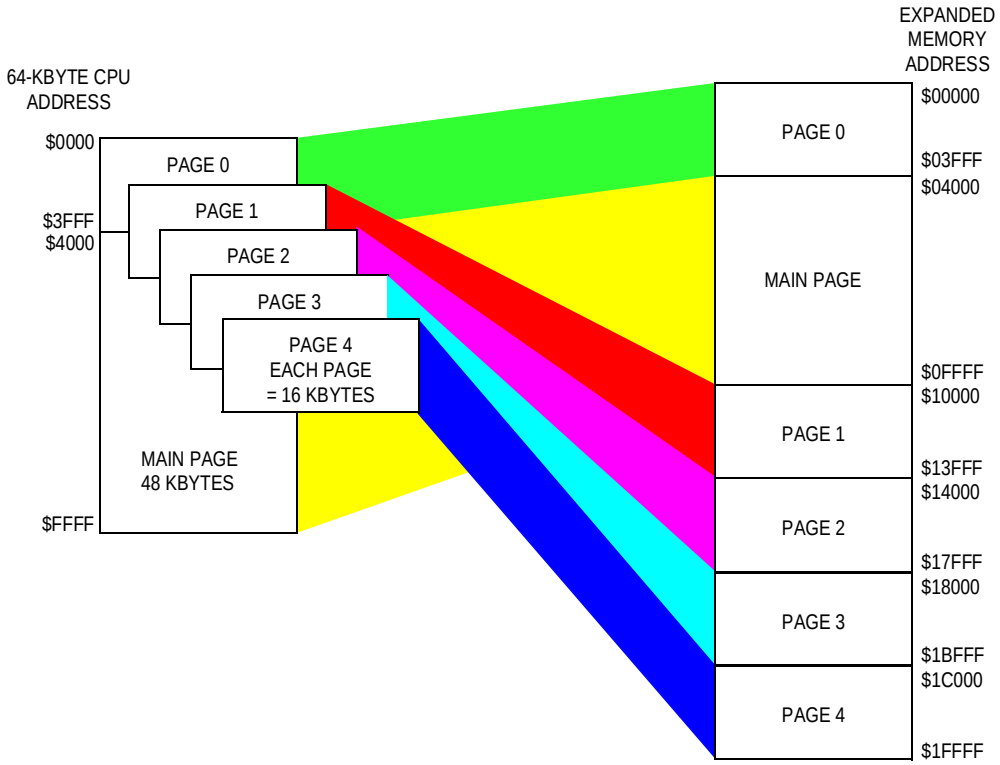

Figure 6. Hardware and Software Paging Representation

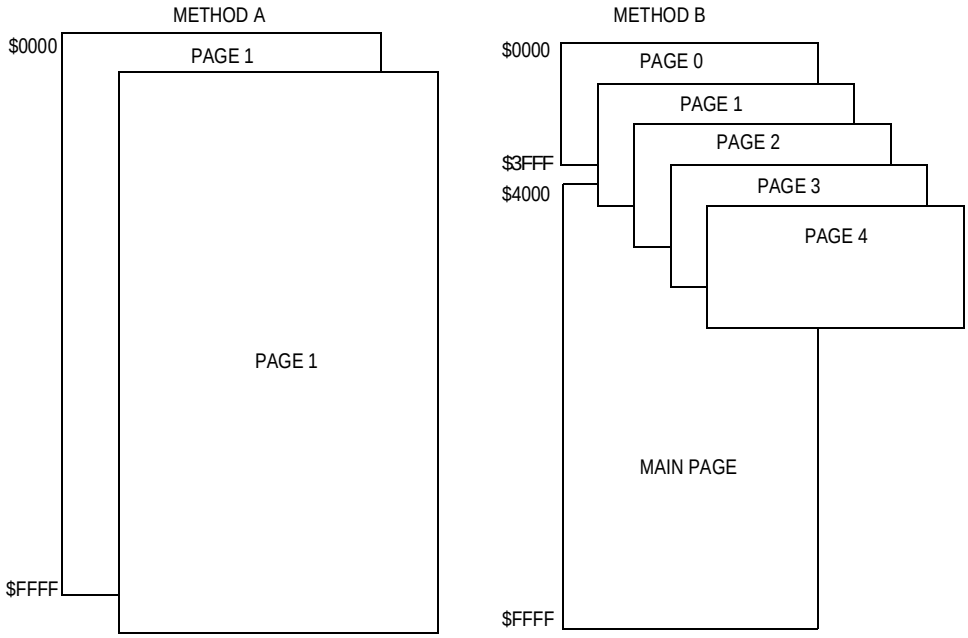

Figure 7. Comparison of Paging Schemes

In General

In both methods, the registers may be moved to more appropriate addresses. If the usage of RAM is not critical, the registers may be moved to address $0000 by writing $00 to the INIT register immediately after reset. For the MC68HC11G5, this means losing 128 bytes of RAM, but results in a clean memory map above $1FF. In the examples, the registers and RAM remain at the default addresses and so care must be taken not to have user code from address $0000 to $01FF and $1000 to $107F for the MC68HC11G5. Note that the MC68HC11E9 and MC68HC11A8 have slightly different RAM and register address ranges plus the internal EEPROM which should be disabled if not used.

Figure 7 demonstrates the differences between the paging techniques by showing the overlap of the pages. The number and size of the pages can easily be modified by small changes to the page change routines and hardware.

Beyond 128 Kbytes

Both techniques may be scaled up with several port lines controlling address lines beyond address A15 with the addition of further change page routines and enhancing the return-from-interrupt routine to allow a return to a specific page in method A or the addition of further multiplexing logic in method B.

In Conclusion

The two methods described in detail are the basis for many other ways of controlling paging on a single large EPROM memory device or several smaller EPROMs. It is a simple matter to scale up or modify the techniques to suit a particular application or EPROM.

The software approach is the cheapest and allows for a main program of up to the full size of the EPROM while the combined hardware and software approach has a maximum main program size of 48 Kbytes (in this example) and no additional interrupt latency.

Appendix A — Software Paging Scheme

```
                        **** EXTENDA.ASC ************************************************************************
                        *
                        * TESTS EXTENDED MEMORY CONTROL
                        *
                        * For a single 1M bit (128K byte) EPROM split into 2 x 64K byte pages
                        * A16 is connected to Port D(5) which then selects which half of
                        * the EPROM is being accessed. PD5 = 1 after reset since it is in
                        * the input state with a pull-up resistor to Vdd.
                        *
                        * This code is written for the 68HC11G5 MCU but can be easily modified
                        * to run on any 68HC11 device. The 68HC11G5 has a non-multiplexed
                        * address and data bus in expanded mode.
                        *
                        *
                        *
                        *****************************************************************************************
                        *
00000000                PORTA   EQU             $00
00000001                DDRA    EQU             $01
00000004                PORTB   EQU             $04
00000006                PORTC   EQU             $06
00000007                DDRC    EQU             $07
00000008                PORTD   EQU             $08
00000009                DDRD    EQU             $09
00000024                TMSK2   EQU             $24
00000025                TFLG2   EQU             $25
00000040                RTII    EQU             $40
00000040                RTIF    EQU             $40
00000026                PACTL   EQU             $26
00000080                DDRA7   EQU             $80
00001000                REGS    EQU             $1000
                        *
                        *****************************************************************************************
                        *
                        *             RAM definitions (from $0000 to $01FF)
                        *
                        *****************************************************************************************
                                                ORG     $0000
00000000                PAGE                    RMB     1               page number prior to interrupt
00000001                TIME                    RMB     2               counter value for real time interrupt routine
                        *
00000020                NPAGE                   EQU     $20             PORT D-5 page control line
00000200                ROMBASE                 EQU     $0200           Avoid RAM (from $0 to $1FF)
0000f800                CHANGE                  EQU     $F800
0000ffcc                VECTORS                 EQU     $FFCC
                        *


                        *****************************************************************************************
                        *               START OF MAIN PROGRAM
                        *+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
                        *
                        *            page 0 (1st half of EPROM)
                        *
                        *
                        *+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
                                                org       ROMBASE
                        *****************************************************************************************
                        *
                        *            Redirect reset vector to page 1
                        *
                        *****************************************************************************************
00000200 ce0200         RESET0                  LDX     #RESET
00000203 7ef800                                 JMP     CHGPAGE0

                        *****************************************************************************************
                        *
                        *            2nd half of page 0 loop running in page 1
                        *
                        *****************************************************************************************
00000206 181c0010       LOOPP0                  BSET    PORTA,Y,#$10    Toggle bit 4
0000020a 181d0010                               BCLR    PORTA,Y,#$10
0000020e ce0216                                 LDX     #LOOPP1         get return address in page 1
00000211 7ef800                                 JMP     CHGPAGE0        jump to change page routine
                        *
                        *****************************************************************************************
                        *
                        *                   Real time interrupt service routine
                        *
                        *****************************************************************************************
```

```
 81  00000214 181e254001  RTISRV              BRSET  TFLG2,Y,#RTIF,RTISERV
 82  00000219 3b                              RTI                      return if not correct interrupt source
 83                       *                                            This is an RTI because interrupt vector
 84                       *                                            only points here when in page 1
 85                       *
 86  0000021a             RTISERV
 87  0000021a 8640                            LDAA   #%01000000        page 0 interrupt starts here
 88  0000021c 18a725                          STAA   TFLG2,Y           clear RTI flag
 89  0000021f 9602                            LDAA   TIME+1            get the time counter
 90  00000221 4c                              INCA                     increment counter
 91  00000222 b71004                          STAA   PORTB+REGS        store time in port B
 92  00000225 de01                            LDX    TIME
 93  00000227 08                              INX
 94  00000228 fd01                            STX    TIME              and copy back into RAM
 95  0000022a 7ef80a                          JMP    RETRTI0           jump to RTI routine
 96                       *
 97
 98                       ********************************************************************************************
 99                       *
100                       * CHANGE PAGE ROUTINE
101                       *
102                       * This code must be executed with the I-bit set to prevent interrupts
103                       * during the change if it is a jump for an interrupt routine.
104                       * Otherwise PAGE could be updated and then another interrupt could
105                       * occur before the PAGE was changed causing the first interrupt
106                       * routine to return to the wrong page
107                       * The PAGE variable is not required for a normal jump and so it does
108                       * not require the I-bit to be set (only the BSET is important).
109                       *
110                       * This code is repeated for the same position in both pages
111                       ********************************************************************************************
112                       *                        jump routine
113                       *                        ORG    CHANGE            Address for this routine is fixed
114                       *                                   cycles
115  0000f800             CHGPAGE0
116  0000f800 8600                            LDAA   #0     2          set current page number = 0
117  0000f802 9700                            STAA   PAGE   2          store page page number
118  0000f804 181c0820                        BSET   PORTD,Y,#NPAGE  8  change page by setting PD-5
119  0000f808 6e00                            JMP    0,X    3          This code is the same in both pages
120                       *
121                       ********************************************************************************************
122                       *          return from interrupt routine running in page 0
123                       *
124                       *
125                       *          check if interrupt occurred while code was running in page 1
126                       *          and return to page 1 before the RTI command is performed
127                       *
128                       ********************************************************************************************
129                       *                                 cycles
130  0000f80a                          RETRTI0
131  0000f80a 9600                          LDAA   PAGE     2     get page the interrupt occured in
132  0000f80c 8101                          CMPA   #1       2     is it page 1
133  0000f80e 2701                          BEQ    RTIPAGE0 3     if yes then change page
134  0000f810 3b                            RTI             12    otherwise, return from interrupt
135  0000f811                          RTIPAGE0
136  0000f811 181c0820                      BSET   PORTD,Y,#NPAGE 8   change page and return from interrupt
137  0000f815 3b                            RTI             12    This codes is the same in both pages
138                       *
139
140                       ********************************************************************************************
141                       *                    VECTORS
142                       ********************************************************************************************
143                       *
144                                          ORG    VECTORS
145  0000ffcc 0200                           FDB    RESET0           EVENT 2
146  0000ffce 0200                           FDB    RESET0           EVENT 1
147  0000ffd0 0200                           FDB    RESET0           TIMER OVERFLOW 2
148  0000ffd2 0200                           FDB    RESET0           INPUT CAPTURE 6 / OUTPUT COMPARE 7
149  0000ffd4 0200                           FDB    RESET0           INPUT CAPTURE 5 / OUTPUT COMPARE 6
150  0000ffd6 0200                           FDB    RESET0           SCI
151  0000ffd8 0200                           FDB    RESET0           SPI
152  0000ffda 0200                           FDB    RESET0           PULSE ACC INPUT
153  0000ffdc 0200                           FDB    RESET0           PULSE ACC OVERFLOW
154  0000ffde 0200                           FDB    RESET0           TIMER OVERFLOW 1
155  0000ffe0 0200                           FDB    RESET0           INPUT CAPTURE 4 / OUTPUT COMPARE 5
156  0000ffe2 0200                           FDB    RESET0           OUTPUT COMPARE 4
157  0000ffe4 0200                           FDB    RSEET0           OUTPUT COMPARE 3
158  0000ffe6 0200                           FDB    RESET0           OUTPUT COMPARE 2
159  0000ffe8 0200                           FDB    RESET0           OUTPUT COMPARE 1
160  0000ffea 0200                           FDB    RESET0           INPUT CAPTURE 3
161  0000ffec 0200                           FDB    RESET0           INPUT CAPTURE 2
162  0000ffee 0200                           FDB    RESET0           INPUT CAPTURE 1
163  0000fff0 0214                           FDB    RTISRV           REAL TIME INTERRUPT
164  0000fff2 0200                           FDB    RESET0           IRQ
165  0000fff4 0200                           FDB    RESET0           XIRQ
166  0000fff6 0200                           FDB    RESET0           SWI
167  0000fff8 0200                           FDB    RESET0           ILLEGAL OPCODE
```

```
0000fffa 0200                           FDB    RESET0          COP
0000fffc 0200                           FDB    RESET0          CLOCK MONITOR
0000fffe 0200                           FDB    RESET0          RESET
                        ********************************************************************************

                        *++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
                        *
                        *           page 1 (2nd half of EPROM)
                        *
                        *
                        *++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
                        ********************************************************************************
                        *
                        *           MAIN ROUTINE NOT UNDER INTERRUPT CONTROL
                        *
                        ********************************************************************************

                                        ORG    ROMBASE
00000200 8e01ff                 RESET   LDS    #$01FF
00000203 bd021b                         JSR    SETUP           initialize RTI interrupt and DDRs
00000206 86ff                   LOOP1   LDAA   #$FF
00000208 181c0008               LOOP    BSET   PORTA,Y,#$08    Toggle bit 3
0000020c 181d0008                       BCLR   PORTA,Y,#$08
00000210 ce0206                         LDX    #LOOPP0         set up jump to other page
00000213 7ef800                         JMP    CHGPAGE1        go to other page
00000216                        LOOPP1
00000216 4a                             DECA                   return point from other page
00000217 26ef                           BNE    LOOP            toggle port A
00000219 20eb                           BRA    LOOP1           start loop again
                        *
                        ********************************************************************************
                        *                  INITIALIZATION ROUTINE
                        ********************************************************************************
                        *
0000021b 0f             SETUP           SEI
0000021c 18ce1000                       LDY    #$1000          Register address offset
00000220 86ff                           LDAA   #$FF
00000222 b71001                         STAA   DDRA+REGS       make port A all outputs
00000225 b71008                         STAA   PORTD+REGS      make sure port D-5 is written a 1
00000228 b71009                         STAA   DDRD+REGS       and only then make all outputs
0000022b 8640                           LDAA   #%01000000
0000022d b71025                         STAA   TFLG2+REGS      clear RTI flag
00000230 b71024                         STAA   TMSK2+REGS      enable RTI interrupt
00000233 0e                             CLI
00000234 39                             RTS
                        ********************************************************************************
                        *
                        *               Redirect to the Real time interrupt service routine
                        *               Page 1 routine for service routine located in page 0
                        ********************************************************************************
                        *
00000235 181e254001     INTRI           BRSET  TFLG2,Y,#RTIF,GOODINT
0000023a 3b                             RTI                    return if not correct interrupt source
                        *                                      This is an RTI because interrupt vector
                        *                                      only points here when in page 1
                        *
0000023b                GOODINT                        cycles
0000023b ce021a                         LDX    #RTISERV  3     get the interrupt entry point in page 0
00000233 73f800                         JMP    CHPAGE!   3     jump to change page routine
                        *

                        ********************************************************************************
                        *
                        *         CHANGE PAGE ROUTINE
                        *
                        * This code must be executed with the I-bit set to prevent interrupts
                        * during the change if it is a jump for an interrupt routine.
                        * Otherwise PAGE could be updated and then another interrupt could
                        * occur before the PAGE was changed causing the first interrupt
                        * routine to return to the wrong page.
                        * The PAGE variable is not required for a normal jump and so it does
                        * not require the I-bit to be set (only the BCLR is important).

                        * This code is repeated for the same position in both pages
                        ********************************************************************************
                        * jump routine
                        * ORG            CHANGE                  Address for this routine is fixed
                        *                                  cycles
0000f800                CHGPAGE1
0000f800 8601                           LDAA   #$1      2      set current page number = 1
0000f802 9700                           STAA   PAGE     2      store page page number
0000f804 181d0820                       BCLR   PORTD,Y,#NPAGE 8  Change page by clearing PD-5
0000f808 6e00                           JMP    0,X      3      This code is the same in both pages
                        *
```

```
252                     ********************************************************************************
253                     *      return from interrupt routine running in page 0
254                     *
255                     *
256                     *      check if interrupt occurred while code was running in page 1
257                     *      and return to page 0 before the RTI command is performed
258                     *
259                     ********************************************************************************
260                     *                                  cycles
261  0000f80a           RETRTI1
262  0000f80a 9600                       LDAA   PAGE     2     get page the interrupt occured in
263  0000f80c 8100                       CMPA   #0       2     is it page 0
264  0000f80e 2701                       BEQ    RTIPAGE1 3     if yes then change page
265  0000f810 3b                         RTI             12    otherwise, return from interrupt
266  0000f811           RTIPAGE1
267  0000f811 181d0820                   BCLR   PORTD,Y,#NPAGE  8  change page and return from interrupt
268  0000f815 3b                         RTI              12   This codes is the same in both pages
269                     *
270
271                     ********************************************************************************
272                     *                VECTORS
273                     *
274                     ********************************************************************************
275                                         ORG    VECTORS
276  0000ffcc 0200                          FDB    RESET          EVENT 2
277  0000ffce 0200                          FDB    RESET          EVENT 1
278  0000ffd0 0200                          FDB    RESET          TIMER OVERFLOW 2
279  0000ffd2 0200                          FDB    RESET          INPUT CAPTURE 6 / OUTPUT COMPARE 7
280  0000ffd4 0200                          FDB    RESET          INPUT CAPTURE 5 / OUTPUT COMPARE 6
281  0000ffd6 0200                          FDB    RESET          SCI
282  0000ffd8 0200                          FDB    RESET          SPI
283  0000ffda 0200                          FDB    RESET          PULSE ACC INPUT
284  0000ffdc 0200                          FDB    RESET          PULSE ACC OVERFLOW
285  0000ffde 0200                          FDB    RESET          TIMER OVERFLOW 1
286  0000ffe0 0200                          FDB    RESET          INPUT CAPTURE 4 / OUTPUT COMPARE 5
287  0000ffe2 0200                          FDB    RESET          OUTPUT COMPARE 4
288  0000ffe4 0200                          FDB    RESET          OUTPUT COMPARE 3
289  0000ffe6 0200                          FDB    RESET          OUTPUT COMPARE 2
290  0000ffe8 0200                          FDB    RESET          OUTPUT COMPARE 1
291  0000ffea 0200                          FDB    RESTE          INPUT CAPTURE 3
292  0000ffec 0200                          FDB    RESET          INPUT CAPTURE 2
293  0000ffee 0200                          FDB    RESET          INPUT CAPTURE 1
294  0000fff0 0235                          FDB    INTRI          REAL TIME INTRRUPT
295  0000fff2 0200                          FDB    RESET          IRQ
296  0000fff4 0200                          FDB    RESET          XIRQ
297  0000fff6 0200                          FDB    RESET          SWI
298  0000fff8 0200                          FDB    RESET          ILLEGAL OPCODE
299  0000fffa 0200                          FDB    RESET          COP
300  0000fffc 0200                          FDB    RESET          CLOCK MONITOR
301  0000fffe 0200                                                 RESET
302                     ********************************************************************************
303                                         END
```

Appendix B — Hardware and Software Paging Scheme

```
1                ***************EXTENDB.ASC ***********************************************************************
2                *
3                * TESTS EXTENDED MEMORY CONTROL
4                *
5                * for a single 1M bit (128K byte) EEPROM split into 48KB + 5 x 16KB
6                * $4000 - $FFFF          48K    COMMON PAGE
7                * $0200 - $3FFF          16K    PAGES 0,1,2,3,4
8                *
9                * A multiplexer is used to switch between address and port D lines
10               * controlled by PD5 and A16 is controlled by /(PD5+A14+A15)
11               * This ensures that Address A16 is a logic 1 whenever A14 or A15 are
12               * high and that all three lines must be low for the paged memory between
13               * addresses $00000 and $0FFFF.
14               *
15               *
16               *           SOURCE CODE                          EPROM
17               *           ADDRESS                              ADDRESS
18               *           0000         |---------------------- | 00000
19               *                        |        PAGE 0         |
20               *           4000         |---------------------- | 04000
21               *                        |                       |
22               *                        |      MAIN PAGE        |
23               *                        |                       |
24               *                        |                       |
25               *           0000         |---------------------- | 10000
26               *                        |        PAGE 1         |
27               *           0000         |---------------------- | 14000
28               *                        |        PAGE 2         |
29               *           0000         |---------------------- | 18000
30               *                        |        PAGE 3         |
31               *           0000         |---------------------- | 1C000
32               *                        |        PAGE 4         |
33               *           3FFF         |---------------------- | 1FFFF
34               *
35               *
36               *
37               *
38               *       +-__
39               * A14   |   ""-
40               * ------|A     |
41               *       |      |
42               *       |MUX   |----------------------+
43               * PD3   |      |                      |
44               * ------|B     |                      |
45               *       |   __-                       |          |--------------------
46               *       +-""|                         |          |
47               *           |                         |          |
48               *           +-----------  +           |          |
49               *                       |             +--------- | A14
50               *                       |                        |
51               *       +-__            |                        |
52               * A15   |   ""-         |                        |
53               * ------|A     |        |                        |
54               *       |      |        |                        |
55               *       |MUX   |------------------------------- | A15
56               * PD4   |      |        |                        |
57               * ------|B     |        |                        |
58               *       |   __-         |                        |          1M BIT
59               *       +-""|           |                        |          EPROM
60               *           |           |                        |
61               *           +-----------+------+                 |
62               *            ______             |                |
63               * PD5       \      \            |                |
64               * ----------\      \            |                |
65               * A14        \      \           |                |
66               * ----------| NOR  >O-----------+--------------- | A16
67               * A15        /      /                            |
68               * ----------/      /                             |
69               *          /_____/                               |
70               *                                                |
71               *                                                |
72               *   PD3, PD4 and PD5 = 1 AFTER RESET             |--------------------
73               *   SINCE PULL-UP RESISTORS FORCE HIGH STATE WITH PORT D AS INPUTS
74               *   WHICH DEFAULTS TO MAIN PROGRAM PLUS PAGE 0
75               *
76               *
77               *
78               *
79               *
80               ***********************************************************************************************
```

```
 81                     *
 82  00000000           PORTA                   EQU     $00
 83  00000001           DDRA                    EQU     $01             68HC11G5 only
 84  00000004           PORTB                   EQU     $04
 85  00000006           PORTC                   EQU     $06
 86  00000007           DDRC                    EQU     $07
 87  00000008           PORTD                   EQU     $08
 88  00000009           DDRD                    EQU     $09
 89  00000024           TMSK2                   EQU     $24
 90  00000025           TFLG2                   EQU     $25
 91  00000040           RTII                    EQU     $40
 92  00000040           RTIF                    EQU     $40
 93  00000026           PACTL                   EQU     $26
 94  00000080           DDRA7                   EQU     $80             68HC11E9 only
 95  00001000           REGS                    EQU     $1000
 96                     *
 97                     ********************************************************************************************
 98                     *
 99                     *              RAM definitions
100                     *
101                     ********************************************************************************************
102                     *              ORG        $0000
103  00000000           TIME                    RMB     2               Real time interrupt routine counter
104                     *
105  00000200           ROMBASE0                EQU     $0200           Avoid RAM (from $0 to $1FF)
106  00000400           ROMBASE1                EQU     $0400
107  0000ffcc           VECTORS                 EQU     $FFCC
108                     *
109                     ********************************************************************************************
110                     *      PAGE 0 = $00000 - $04FFF (A16=0,A15=0,A14=0) => PAGE0=%00100000
111                     *      MAIN   = $04000 - $0FFFF (A16=0)             => START=%001XX000
112                     *      PAGE 1 = $10000 - $13FFF (A16=1,A15=0,A14=0) => PAGE1=%00000000
113                     *      PAGE 2 = $14000 - $17FFF (A16=1,A15=0,A14=1) => PAGE2=%00001000
114                     *      PAGE 3 = $18000 - $1BFFF (A16=1,A15=1,A14=0) => PAGE3=%00010000
115                     *      PAGE 4 = $1C000 - $1FFFF (A16=1,A15=1,A14=1) => PAGE4=%00011000
116                     *
117                     *      PAGEn is added to %xx000xxx to give the state of port
118                     *      D(3), D(4) and D(5).
119                     *
120  00000000           START                   EQU     $00
121  00000020           PAGE0                   EQU     $20
122  00000000           PAGE1                   EQU     $00
123  00000008           PAGE2                   EQU     $08
124  00000010           PAGE3                   EQU     $10
125  00000018           PAGE4                   EQU     $18
126                     *
127                     ********************************************************************************************
128                     *++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
129                     *
130                     *              page 0 (1st half of EPROM)
131                     *
132                     *
133                     *++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
134                     *                              org     ROMBASE0
135  00000200 181c0008  LOOPP0                       BSET    PORTA,Y,#$08
136  00000204 181d0008                               BCLR    PORTA,Y,#$08    Toggle Port A-3
137  00000208 7e4014                                 JMP     MAIN0           return to main page
138                     *
139                     *++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
140                     *              START OF MAIN PROGRAM
141                     ********************************************************************************************
142                     *
143                     *              MAIN ROUTINE NOT UNDER INTERRUPT CONTROL
144                     *
145                     ********************************************************************************************
146                     *
147                                                     ORG     ROMBASE1
148  00004000 8e01ff    RESET                        LDS     #$01FF
149  00004003 bd204e                                 JSR     SETUP           initialize RTI interrupt and DDRs
150  00004006 181c0840  LOOP                         BSET    PORTD,Y,#$40
151  0000400a 181d0840                               BCLR    PORTD,Y,#$40    main routine toggles port D-2
152  0000400e bd4062                                 JSR     CHGAGE0         select page 0
153  00004011 7e0200                                 JMP     LOOPP0          Toggle Port A-3
154  00004014 bd406d    MAIN0                        JSR     CHGPAGE1        select page 1
155  00004017 bd0200                                 JSR     LOOPP1          Toggle Port A-4
156  0000401a bd4078                                 JRS     CHGPAGE2        select page 2
157  0000401d bd0200                                 JSR     LOOPP2          Toggle Port A-5
158  00004020 bd4083                                 JSR     CHGPAGE3        select page 3
159  00004023 7e0200                                 JMP     LOOPP3          Toggle Port A-6
160  00004026 bd408e    MAIN3                        JSR     CHGPAGE4        select page 4
161  00004029 7e0200                                 JMP     LOOPP4          Toggle Port A-7
162  0000402c 20d8      MAIN4                        BRA     LOOP            start loop again
163                     *
164                     ********************************************************************************************
165                     *              INITIALIZATION ROUTINE
166                     ********************************************************************************************
167                     *
```

```
0000402e 0f       SETUP                   SEI
0000402f 18ce1000                         LDY     #$1000          Register address offset
00004033 86ff                             LDAA    #$FF
00004035 b71001                           STAA    DDRA+REGS       make port A all outputs (68HC11G5)
00004038 b71009                           STAA    DDRD+REGS       make port D all outputs
0000403b 7f0000                           CLR     TIME
0000403e 7f0001                           CLR     TIME+1
00004041 4f                               CLRA
00004042 b71000                           STAA    PORTA+REGS
00004045 b71008                           STAA    PORTD+REGS
00004048 8640                             LDAA    #%01000000
0000404a b71025                           STAA    TFLG2+REGS      clear the RTI flag
0000404d b71024                           STAA    TMSK2+REGS      enable RTI interrupt
00004050 0e                               CLI
00004051 39                               RTS
                  *
                  ********************************************************************************************
                  *
                  *               Real time interrupt service routine
                  *
                  ********************************************************************************************
00004052 8640     RTISRV                  LDAA    #%01000000
00004054 b71025                           STAA    TFLG2+REGS      clear TRI flag
00004057 9601                             LDAA    TIME+1
00004059 b71004                           STAA    PORTB+REGS      store counter in port B
0000405c de00                             LDX     TIME            get time counter
0000405e 08                               INX                     increment counter
0000405f df00                             STX     TIME            save counter value in RAM
00004061 3b                               RTI                     Return from interrupt
                  *
                  ********************************************************************************************
                  * CHANGE PAGE
                  * acc B (bits 3-5) contains the 1's complement of new page number address
                  *
                  *           SOURCE CODE                           EPROM
                  *           ADDRESS                               ADDRESS
                  *           0000        |---------------------- | 00000
                  *                       |        PAGE 0         |
                  *           4000        |---------------------- | 04000
                  *                       |                       |
                  *                       |      MAIN PAGE        |
                  *                       |                       |
                  *                       |                       |
                  *           0000        |---------------------- | 10000
                  *                       |        PAGE 1         |
                  *           0000        |---------------------- | 14000
                  *                       |        PAGE 2         |
                  *           0000        |---------------------- | 18000
                  *                       |        PAGE 3         |
                  *           0000        |---------------------- | 1C000
                  *                       |        PAGE 4         |
                  *           3FFF        |---------------------- | 1FFFF
                  *
                  * PAGE 0 = $00000 - $03FFF (A16=0,A15=0,A14=0) => PAGE0=%00100000
                  * MAIN   = $04000 - $0FFFF (A16=0)             => START=%001XX000
                  * PAGE 1 = $10000 - $13FFF (A16=1,A15=0,A14=0) => PAGE1=%00000000
                  * PAGE 2 = $14000 - $17FFF (A16=1,A15=0,A14=1) => PAGE2=%00001000
                  * PAGE 3 = $18000 - $1BFFF (A16=1,A15=1,A14=0) => PAGE3=%00010000
                  * PAGE 4 = $1C000 - $1FFFF (A16=1,A15=1,A14=1) => PAGE4=%00011000
                  *
                  ********************************************************************************************
                  *
00004062          CHGPAGE0
00004062 b61008                           LDAA    PORTD+REGS      get port D data
00004065 84c7                             ANDA    #%11000111      make middle 3 bits low state
00004067 8b20                             ADDA    #PAGE0          add PAGE descriptor to this
00004069 b71008                           STAA    PORTD+REGS      write back to port D
0000406c 39                               RTS                     (only bits 3, 4 and 5 are changed)
                  *
0000406d          CHGPAGE1
0000406d b61008                           LDAA    PORTD+REGS      get port D data
00004070 84C7                             ANDA    #%11000111      make middle 3 bits low state
00004072 8b00                             ADDA    #PAGE1          add PAGE descriptor to this
00004074 b71008                           STAA    PORTD+REGS      write back to port D
00004077 39                               RTS                     (only bits 3, 4 and 5 are changed)
                  *
00004078          CHGPAGE2
00004078 b61008                           LDAA    PORTD+REGS      get port D data
0000407b 84c7                             ANDA    #%11000111      make middle 3 bits low state
0000407d 8b08                             ADDA    #PAGE2          add PAGE descriptor to this
0000407f b71008                           STAA    PORTD+REGS      write back to port D
00004082 39                               RTS                     (only bits 3,4 and 5 are changed)
                  *
00004083          CHGPAGE3
00004083 b61008                           LDAA    PORTD+REGS      get port D data
00004086 84c7                             ANDA    #%11000111      make middle 3 bits low state
00004088 8b10                             ADDA    #PAGE3          add PAGE descriptor to this
```

```
0000408a b71008                         STAA    PORTD+REGS      write back to port D
0000408d 39                             RTS                     (only bits 3, 4 and 5 are changed)
                        *
0000408e                CHGPAGE4
0000408e b61008                         LDAA    PORTD+REGS      get port D data
00004091 84c7                           ANDA    #%11000111      make middle 3 bits low state
00004093 8b18                           ADDA    #PAGE4          add PAGE descriptor to this
00004095 b71008                         STAA    PORTD+REGS      write back to port D
00004098 39                             RTS                     (only bits 3, 4 and 5 are changed)
                        *
                        ********************************************************************************
                        *                       VECTORS
                        ********************************************************************************
                        *
                                        ORG     VECTORS
0000ffcc 4000                           FDB     RESET           EVENT 2
0000ffce 4000                           FDB     RESET           EVENT 1
0000ffd0 4000                           FDB     RESET           TIMER OVERFLOW 2
0000ffd2 4000                           FDB     RESET           INPUT CAPTURE 6 / OUTPUT COMPARE 7
0000ffd4 4000                           FDB     RESET           INPUT CAPTURE 5 / OUTPUT COMPARE 6
0000ffd6 4000                           FDB     RESET           SCI
0000ffd8 4000                           FDB     RESET           SPI
0000ffda 4000                           FDB     RESET           PULSE ACC INPUT
0000ffdc 4000                           FDB     RESET           PULSE ACC OVERFLOW
0000ffde 4000                           FDB     RESET           TIMER OVERFLOW 1
0000ffe0 4000                           FDB     RESET           INPUT CAPTURE 4 / OUTPUT COMPARE 5
0000ffe2 4000                           FDB     RESET           OUTPUT COMPARE 4
0000ffe4 4000                           FDB     RESET           OUTPUT COMPARE 3
0000ffe6 4000                           FDB     RESET           OUTPUT COMPARE 2
0000ffe8 4000                           FDB     RESET           OUTPUT COMPARE 1
0000ffea 4000                           FDB     RESET           INPUT CAPTURE 3
0000ffec 4000                           FDB     RESET           INPUT CAPTURE 2
0000ffee 4000                           FDB     RESET           INPUT CAPTURE 1
0000fff0 4052                           FDB     RTISRV          REAL TIME INTRRUPT
0000fff2 4000                           FDB     RESET           IRQ
0000fff4 4000                           FDB     RESET           XIRQ
0000fff6 4000                           FDB     RESET           SWI
0000fff8 4000                           FDB     RESET           ILLEGAL OPCODE
0000fffa 4000                           FDB     RESET           COP
0000fffc 4000                           FDB     RESET           CLOCK MONITOR
0000fffe 4000                           FDB     RESET           RESET
                        *
                        ********************************************************************************
                        *++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
                        *
                        *               page 1 (2nd half of EPROM)
                        *
                        *
                        *++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
                                        org     ROMBASE0
00000200 181c0010 LOOPP1                BSET    PORTA,Y,#$10
00000204 181d0010                       BCLR    PORTA,Y,#$10    Toggle Port A-4
00000208 39                             RTS
                        *++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
                        *
                        *               page 2 (2nd half of EPROM)
                        *
                        *
                        *++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
                                        org     ROMBASE0
00000200 181c0020 LOOPP2                BSET    PORTA,Y,#$20
00000204 181d0020                       BCLR    PORTA,Y,#$20    Toggle Port A-5
00000208 39                             RTS
                        *++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
                        *
                        *               page 3 (2nd half of EPROM)
                        *
                        *
                        *++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
                                        org     ROMBASE0
00000200 181c0040 LOOPP3                BSET    PORTA,Y,#$40
00000204 181d0040                       BCLR    PORTA,Y,#$40    Toggle Port A-6
00000208 7e4026                         JMP     MAIN3           return to main page
                        *++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
                        *
                        *               page 4 (2nd half of EPROM)
                        *
                        *
                        *++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
                                        org     ROMBASE0
00000200 181c0080 LOOPP4                BSET    PORTA,Y,#$80
00000204 181d0080                       BLCR    PORTA,Y,#$80    Toggle Port A-7
00000208 7e402c                         JMP     MAIN4           return to main page
                        ********************************************************************************
                                        END
```

Appendix C — C Language Routines for Method B

```
            /* CHGPAGE.C
*              C coded extended memory control for 68HC11
*
*           */
*
*************************************************************************
/*       HC11 structure - I/O registers for MC68HC11 */
struct HC11IO {
 unsigned     char       PORTA;                                  /* Port A - 3 input only, 5 output only */
 unsigned     char       Reserved;                               /* Motorola's unknown register */
 unsigned     char       PIOC;                                   /* Parallel I/O control */
 unsigned     char       PORTC;                                  /* Port C */
 unsigned     char       PORTB;                                  /* Port B - Output only */
 unsigned     char       PORTCL;                                 /* Alternate port C latch */
 unsigned     char       Reserved1;                              /* Motorola's unknown register 2 */
 unsigned     char       DDRC;                                   /* Data direction for port C */
 unsigned     char       PORTD;                                  /* Port D */
 unsigned     char       DDRD;                                   /* Data direction for port D */
 unsigned     char       PORTE;                                  /* Port E */
 };
/*           End of structure HC11IO */
*************************************************************************
*           #define regbase (*(struct HC11IO *) 0x1000)
*           typedef unsigned char byte;
*
*           /* Some arbitrary user defined values */
*           #define page0 0x20
*           #define page1 0x00
*           #define page2 0x08
*           #define pagemask 0xc7
*
*           /* Macro to generate in line code */
*           #define chgpage (a) regbase.PORTD = (regbase.PORTD & pagemask) + a
*
*           /* Function prototype */
*           void func_chgpage (byte p);
*
*           /* Externally defined functions in separate pages */
*           extern void func_in_page0();                             /* Dummy function in page 0 */
*           extern void func_in_page2();                             /* Dummy function in page 2 */
*
*-------------------------compiled assembly code ----------------------------C source code-----------------------------
*                                                                   main()
   6 0000               main:       fbegin
*                                                                   {
*                                                                   chgpage(page2);
                                                                    /* Change page using inline code */
   8 0000     f61008                 ldab          $1008
   9 0003     c4c7                   andb          $199
  10 0005     cb08                   addb          #8
  11 0007     f71008                 stab          $1008
*                                                                   func_in_page2();
                                                                    /* Call function in page 2 */
  13 000a     >bd0000                jsr           func_in_page2
*
*                                                                   func_chgpage(page0);
                                                                    /* Change page using function call */
  15 000d     cc0020                 ldd           #32
  16 0010     8d04                   bsr           func_chgpage
*                                                                   func_in_page0();
                                                                    /* Call function in page 0 */
  18 0012     >bd0000                jsr           func_in-page0
*                                                                   }
  20 0015     39                     rts
  21 0016                            fend
*                                                                   void func_chgpage(p)
*                                                                   byte p;
  24 0016               func_chgpage:                 fbegin
  25 0016     37                     pshb
*                                                                   {
*                                                                   chgpage(p);
  27 0017     f61008                 ldab          $1008
  28 001a     c4c7                   andb          #199
  29 001c     30                     tsx
  30 001d     eb00                   addb          0,x
  31 001f     f71008                 stab          $1008
*                                                                   }
  33 0022     31                     ins
  34 0023     39                     rts
  35 0024                            fend
  36                    import       func_in_page2
  37                    import       func_in_page0
  30                    end
```

Application Note

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