

Richard Homan

Dr. Joonwan Kim

Microcomputer Design

17 April 2024

Microcomputer Design: My Final Product

I. Description of Project

The Microcomputer Design class offers students the opportunity to design a programmable single board computer. This computer must:

1. Be able to communicate with a personal computer via a serial port or similar
2. Have an 8-bit data bus or wider
3. At least 64K RAM
4. Have capability of 64K address space
5. Run a monitor program stored on-board

The computer's monitor program must:

1. Examine the contents of a specified memory location
2. Change the contents of any RAM location
3. Be able to load a machine coded program into memory
4. Be able to execute a loaded machine coded program from memory

Students must design the computer circuit, as well as research and implement parts compatible with the requirements. Students must also keep track of their time spent and the total monetary cost of the project. The instructor is informed of student's progress through weekly progress reports, which outline what was done in that week, and what the student is planning to do the next week. Once the board has been completed, the student must present the product and write a report.

II. Hardware Description

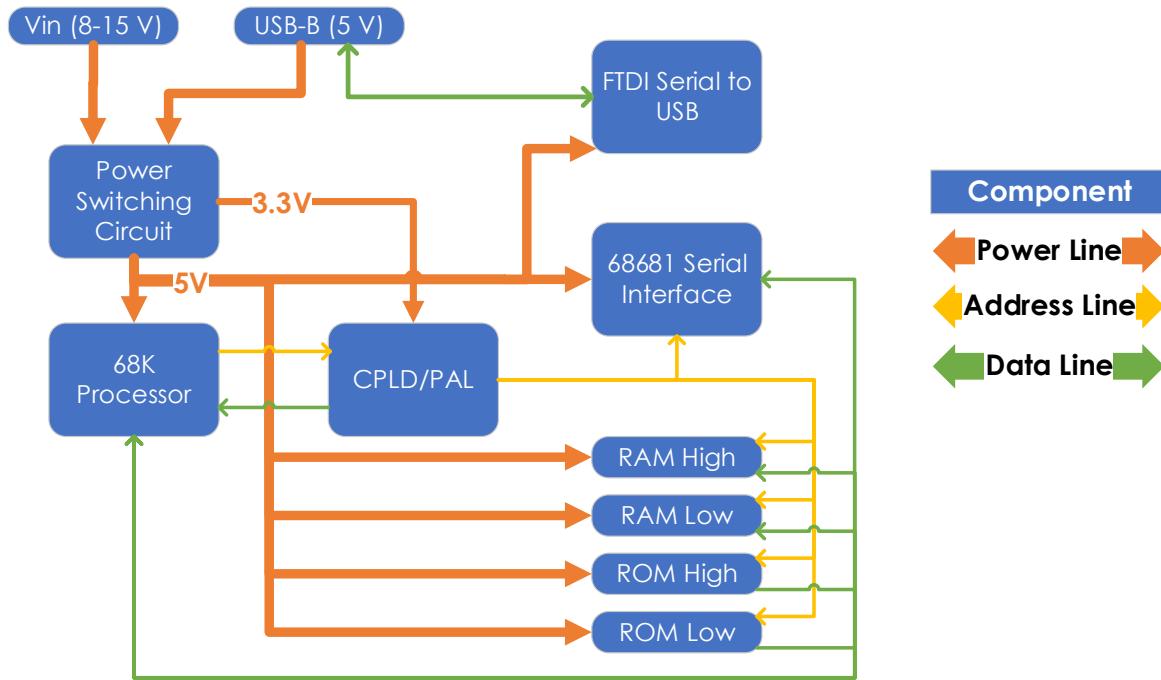
1. General Introduction

The MCD project, while time intensive also gives the student many freedoms in design. I took advantage of these freedoms to direct the product to my liking. As such, I created 3 design rules for my project: the design should be compact, debuggable, and as professional as possible. To try and fit these requirements as best I could, I spent lots of time during the early weeks to plan my hardware.

To make my design as professional as possible, I tried to eliminate as many unknowns, as unknowns can lead to "jank" fixes in hardware. I made sure I understood the hardware well before attempting to create a schematic. At one point, I made a manually controlled SRAM circuit to tinker with to better understand how it worked. To make my design as debuggable as possible, I made sure to include test points on control lines as well as use as many through-hole components as possible, as the exposed metal makes probing much easier. Finally, to make the design compact, I spent a great

deal of time manually routing PCB traces and trying different combinations of orientations of chips to find the ideal routing. Once the PCB was complete, I had the board fabricated in Germany for a higher cost, but it was worth it for the professional and robust finished PCB.

2. Hardware Block Diagram

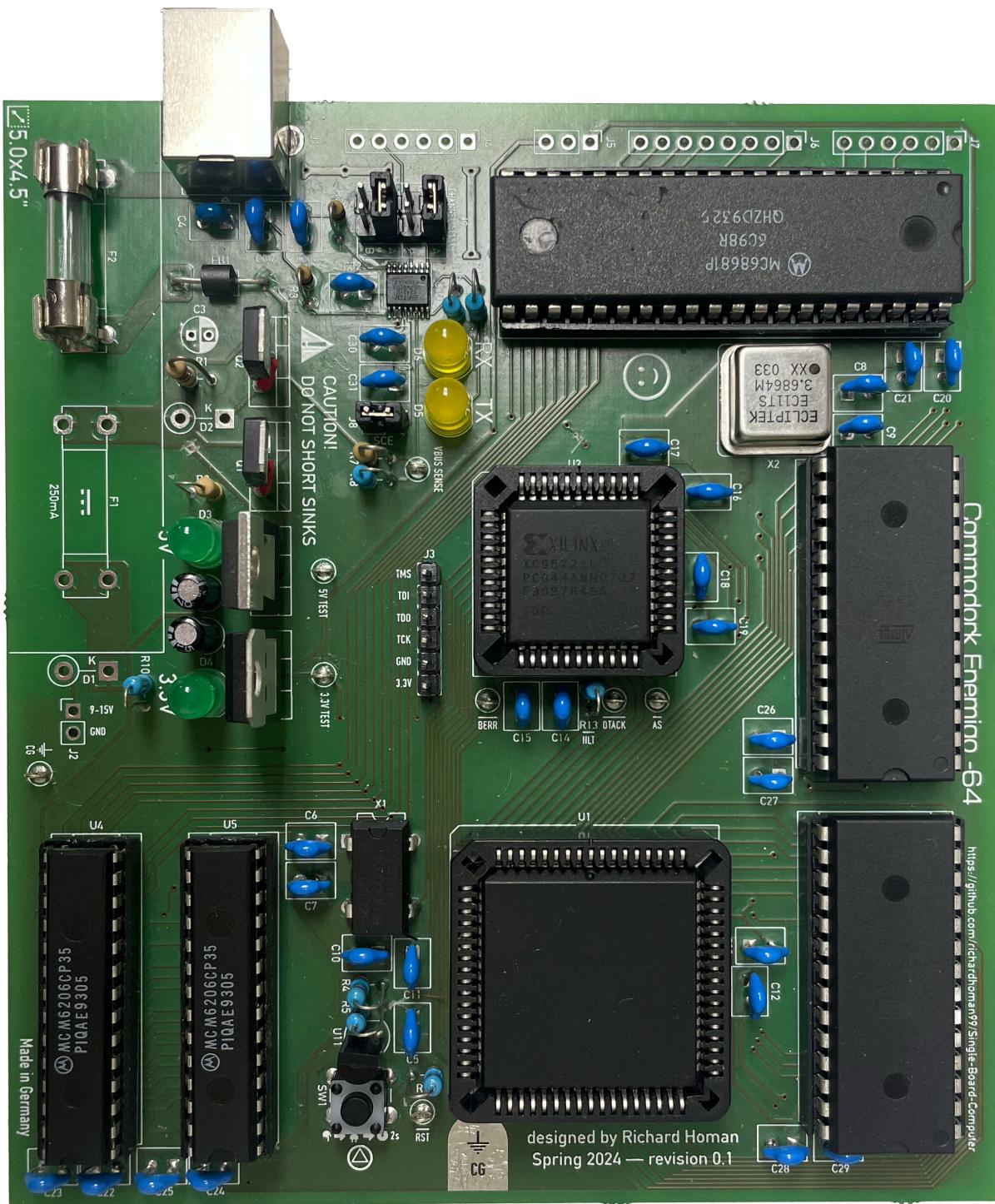


3. Device and Chip specifications

MPU	Motorola 68000
MPU Clock Speed	10 MHz
RAM	2x Motorola MCM6206CP35 32KB
ROM	2x Atmel AT28C256 32KB
Interface	Motorola 68681 & FTDI FT230X
Connectivity	USB type B
Power Consumption (Average)	1.02 W

One of the main contributors to my parts selection was parts availability. The M68k MPU was selected because it was provided, and the RAM, ROM, DUART, and MPU Clock items were found in the lab.

4. Hardware Layout



5. Schematics

(See Appendix A)

6. Parts List

Component	Item	Price	Count	Subtotal
Processor	MC68HC000FN10	\$0.00	1	\$0.00
CPLD	XC9572XL	\$0.00	1	\$0.00
RAM	MCM6206CP35	\$0.00	2	\$0.00
ROM	AT28C256	\$0.00	2	\$0.00
Serial Peripheral	MC68681	\$0.00	1	\$0.00
USB to Serial Interface	FT230XS-R	\$2.26	3	\$6.78
MPU Oscillator	SG531P 10.0000M	\$0.00	2	\$0.00
DUART Oscillator	EC11TS 3.6864M	\$0.00	2	\$0.00
Supervisor	MC34064P	\$0.00	1	\$0.00
Reset Button	6mm Tact Button	\$0.00	1	\$0.00
Regulator 5	MC7805ACT	\$0.00	2	\$0.00
Regulator 3.3	LD1117AV33	\$0.79	2	\$1.58
Switching Mosfets	AOI21357	\$0.72	3	\$2.16
USB Port Socket	USB-B-S-RA	\$0.49	2	\$0.98
Processor Socket	PLCC68	\$2.94	2	\$5.88
CPLD Socket	PLC44 (4x11)	\$2.36	2	\$4.72
Fuse Holder	507-FC-203BRIGHTTIN-ND	\$0.10	8	\$0.80
Ferrite Bead		\$0.00	1	\$0.00
Jumpers	QPC02SXGN-RC	\$0.10	6	\$0.60
Test Points	Keystone 5021	\$0.25	8	\$2.00
Diode	SB160	\$0.24	3	\$0.72
Fuse 250	5ST 250-R	\$0.63	3	\$1.89
Fuse 315	5ST 315-R	\$0.63	3	\$1.89
Fuse 400	5ST 400-R	\$0.63	3	\$1.89
Capacitor 47p	BC1009CT-ND	\$0.27	4	\$1.08
Capacitor .1μ	399-4264-ND	\$0.24	20	\$4.80
Capacitor 1μ	399-C410C105K3R5TA-ND	\$0.35	16	\$5.60
Capacitor 10μ	445-181284-1-ND	\$0.52	5	\$2.60
Resistor 27	CF14JT27R0CT-ND	\$0.10	4	\$0.40
Resistor 5.6k	CF14JT5K60CT-ND	\$0.10	3	\$0.30

Component	Item	Price	Count	Subtotal
Resistor 1M	CF14JT1M00CT-ND	\$0.10	2	\$0.20
Serial USB Cable	TTL-234X-5V	\$20.25	0.33	\$6.68
				\$53.55
Final Parts Cost (shipping & tax)				\$63.04

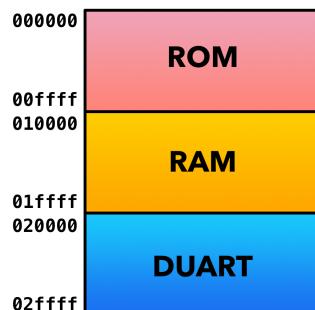
Note: Items with a price of \$0 are parts that were either given or found in the lab.

III. Software Description

1. General Introduction

I wanted my monitor program to be easily readable, modifiable, reliable, and user friendly. I am very familiar with the C language, and so I researched and found a GCC to be a reliable C cross compiler for the project. To make the program reliable and user-friendly, I chose to create a command-line style interface which can intuitively handle the common input-output style of choosing commands. The monitor program is capable of running 7 commands: help, dump registers, dump memory, change register, change memory, load S-Record executable, and run loaded executable.

2. Memory Mapping



3. Detailed Description

The core code is split up into X modules: the entry point, the command lookup, the working commands, the universal prompt, the serial manager, and the S-Record parser.

a. Entry Point

Upon resetting the computer, the program counter is moved to the entry point. On first run, initialization code is run for the serial and working command modules. The module then goes into an infinite loop which is known as the monitor prompt. This activates the prompt module to wait and get user input. Once the user has given input and pressed the return key, the module activates the command lookup module to get the function pointer to the appropriate working command. Once the

working command is fetched, it is executed. An appropriate error message is printed if the working command exited with an error. The monitor prompt then repeats.

b. Command Lookup

The command lookup module has two jobs: to split the single line of user input into an argument vector, and to fetch the appropriate command for the given user input. To split arguments, the module simply converts all delimiting spaces with the null character, and then generates an array of string pointers which point to positions in the input buffer. To determine the proper command function pointer, the first argument in the argument list (the command name) is hashed. The hashed value is then used as an index to an array with the function pointers of the working commands.

c. Working Commands

The working commands module is really a set of the 7 possible commands: help, dump registers, dump memory, change register, change memory, load S-Record executable, and run loaded executable.

d. Universal Prompt

The universal prompt module is a subroutine which handles displaying a prompt and getting user input. This module handles displaying characters, delete/backspace events, and prevents buffer overflow. This module is used by the entry point and load S-Record working command modules.

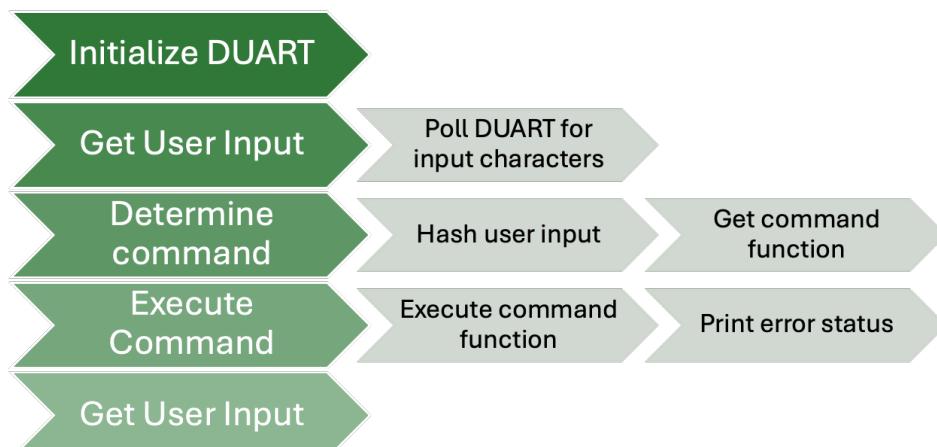
e. Serial Manager

The serial manager module handles serial initialization, receiving and sending characters through the serial interface, and sending strings through the serial interface. This module contains two sections: a section for the hardware, and a section for the simulator (EASy68K) as these targets have different methods of interface.

f. S-Record Parser

The S-Record parser module takes in an S-Record file line-by-line and parses it. The module has functionality that checks the checksum and verifies that the program doesn't run out-of-bounds.

4. Flow Chart



5. Source Code Listing

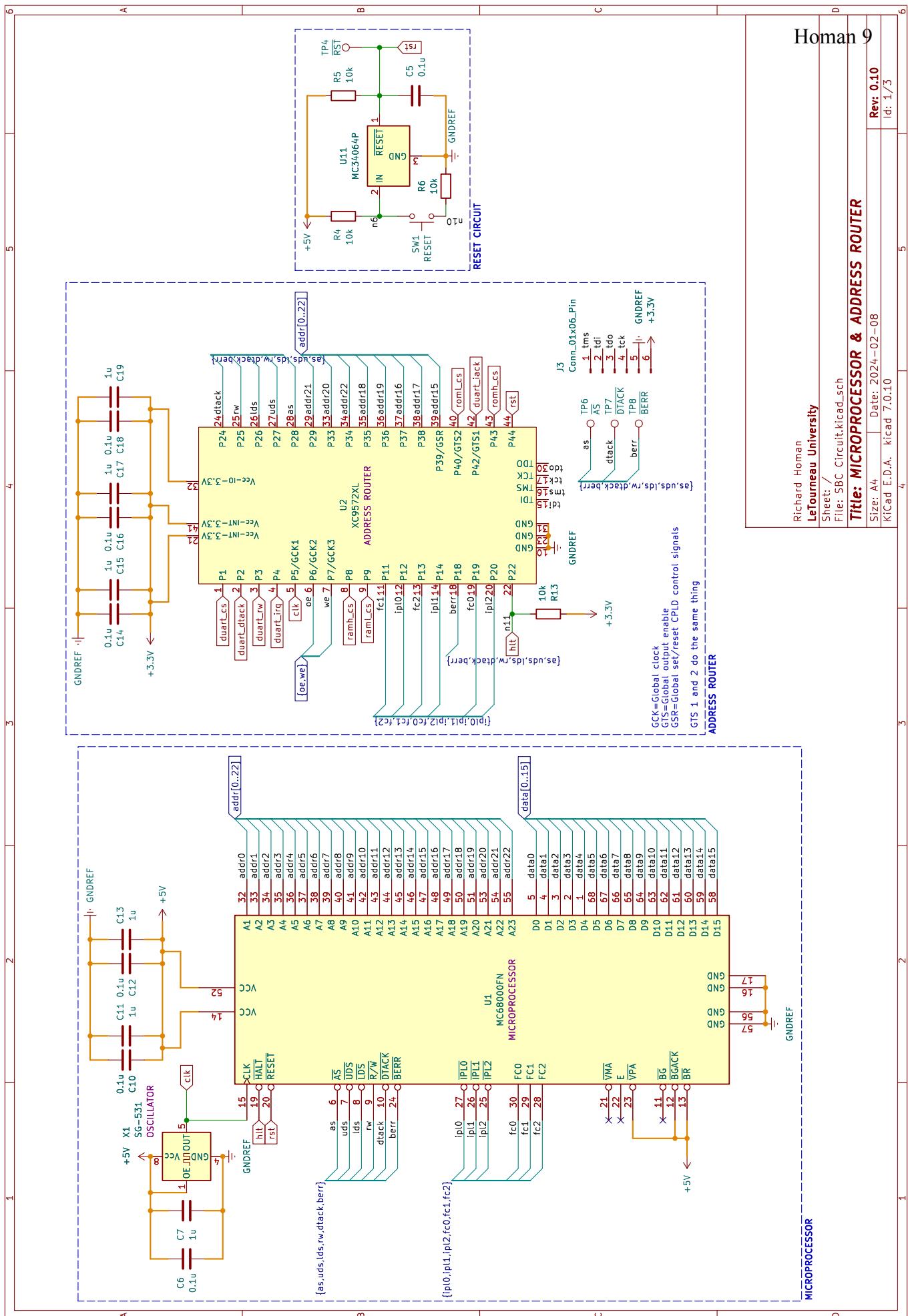
(See Appendix B)

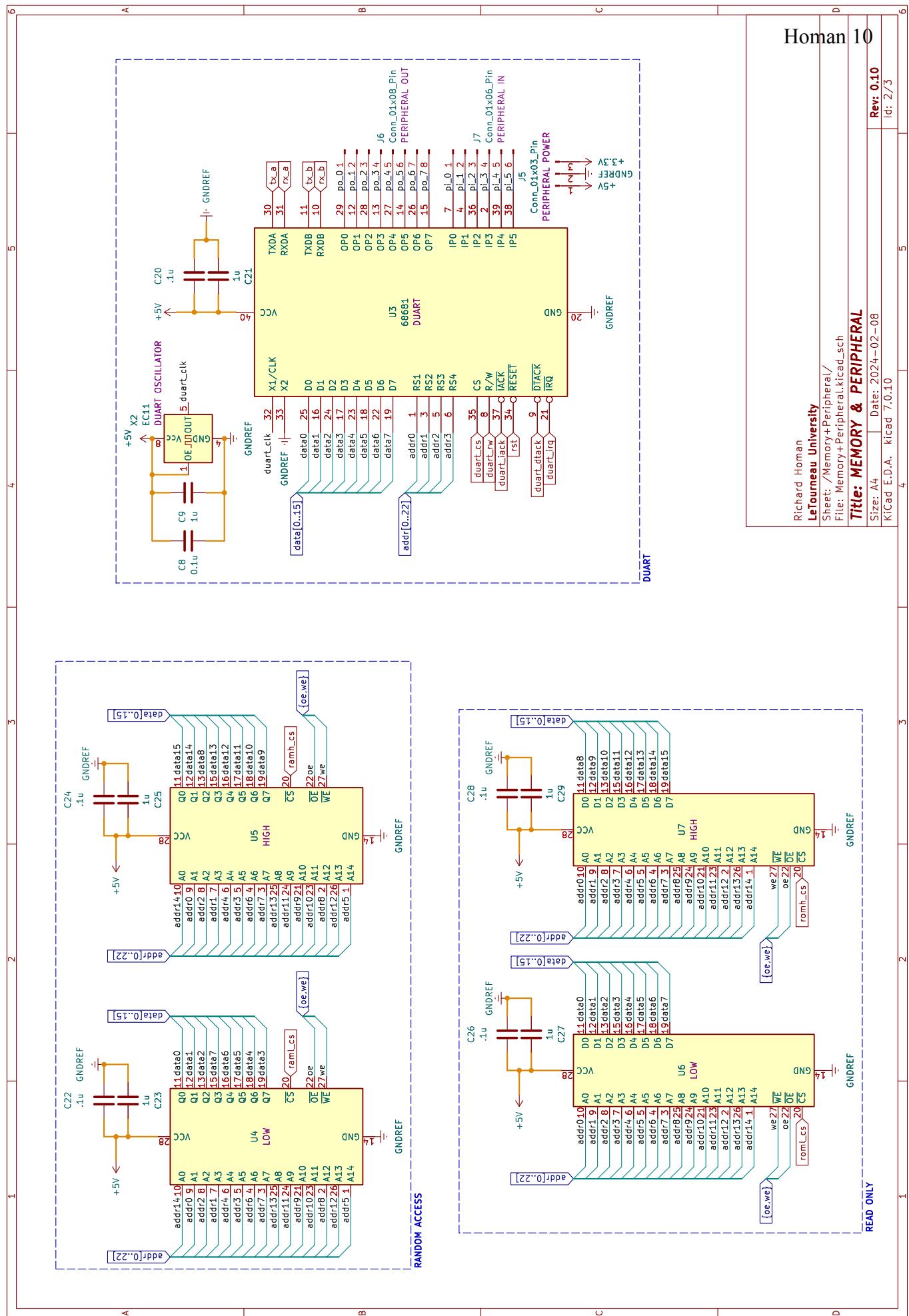
IV. Troubleshooting

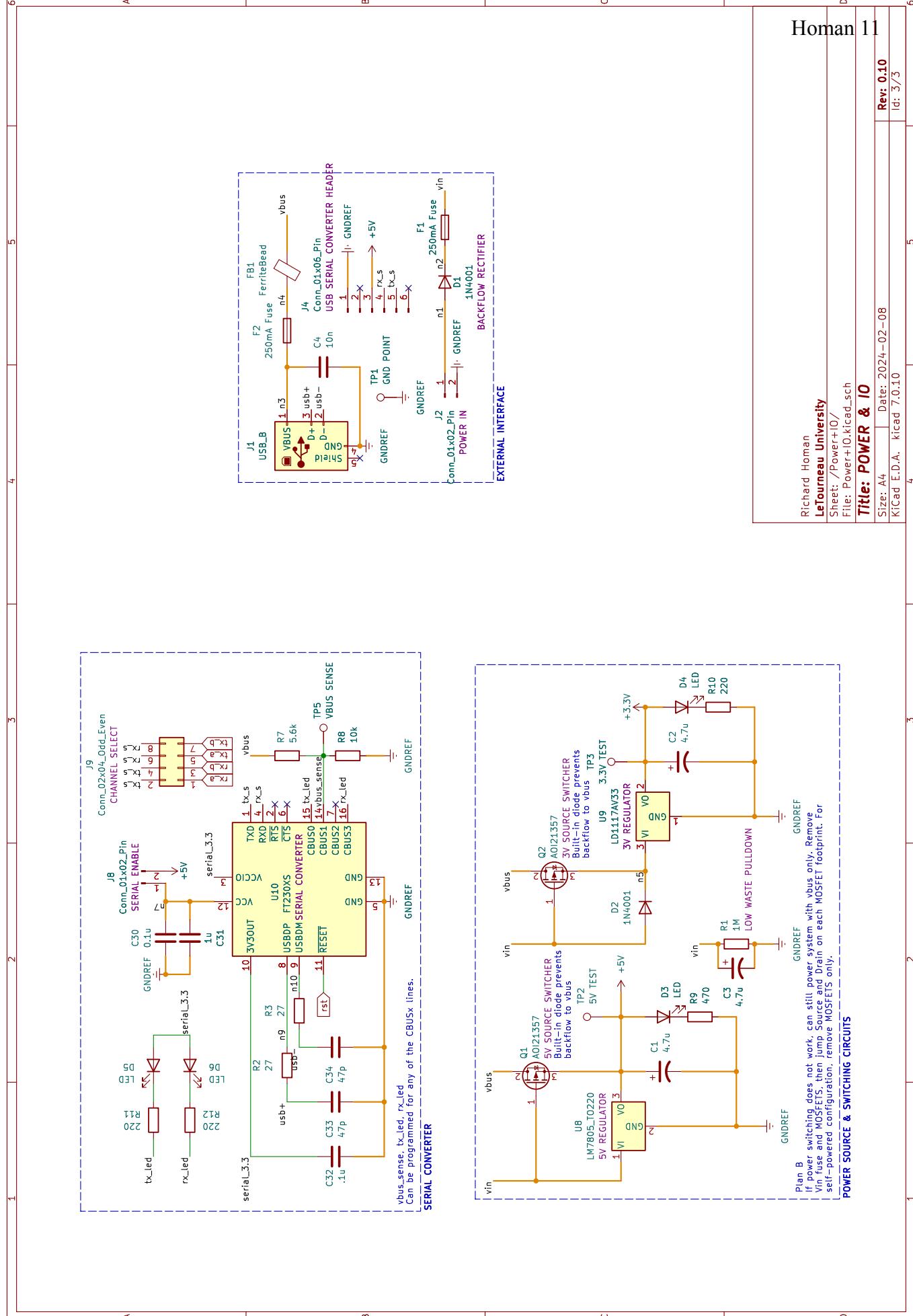
V. Suggestions

VI. Appendices

A. Schematics







B. Source Code

```
/*
 * command.h
 * Richard Homan
 * 02/17/2024
 * Command determination for Enemigo Monitor System
 */

#include "err.h"

#ifndef COMMAND_H
#define COMMAND_H

typedef int (*command_func)(const char **argv, int argc) ;

int ems_cr(const char **argv, int argc);
int ems_cm(const char **argv, int argc);
int ems_dr(const char **argv, int argc);
int ems_dm(const char **argv, int argc);
int ems_l (const char **argv, int argc);
int ems_r (const char **argv, int argc);
int ems_h (const char **argv, int argc);

int invalid_command(const char **argv, int argc);

int split_args(char *in, int len, char **argv, int *argc, int argm);
command_func gcommand(const char *commandname);

#endif
```

```

/*
 * def_68681.c
 * Richard Homan
 * 02/11/2024
 * Definitions of the 68681 DUART as connected on Commodore Enemigo -64
 */

/*
 * Important info:
 * DUART RS1-4 lines are connected to M68K A1-A4 respectively. DUART D0-D7 lines
 * are connected to M68K D0-D7 respectively. This means that we need to have
 * each register address spaced in multiples of two and have each on odd
 * addresses.
 */

#ifndef DEF_68681_H
#define DEF_68681_H

#define DUART_PTR 0x20000 // location of DUART

// offsets
#define MR1A_OFF (0x0 * 2) + 1
#define MR2A_OFF MR1A_OFF
#define SRA_OFF (0x1 * 2) + 1
#define CSRA_OFF SRA_OFF
#define CRA_OFF (0x2 * 2) + 1
#define RBA_OFF (0x3 * 2) + 1
#define TBA_OFF RBA_OFF
#define IPCR_OFF (0x4 * 2) + 1
#define ACR_OFF IPCR_OFF
#define ISR_OFF (0x5 * 2) + 1
#define IMR_OFF ISR_OFF
#define CUR_OFF (0x6 * 2) + 1
#define CTUR_OFF CUR_OFF
#define CLR_OFF (0x7 * 2) + 1
#define CTLR_OFF CLR_OFF
#define MR1B_OFF (0x8 * 2) + 1
#define MR2B_OFF MR1B_OFF
#define SRB_OFF (0x9 * 2) + 1
#define CSRB_OFF SRB_OFF
#define CRB_OFF (0xa * 2) + 1
#define RBB_OFF (0xb * 2) + 1
#define TBB_OFF RBB_OFF
#define IVR_OFF (0xc * 2) + 1
#define IPR_OFF (0xd * 2) + 1
#define OPCR_OFF IPR_OFF
#define OPRLS_OFF (0xe * 2) + 1
#define OPRC_OFF (0xf * 2) + 1

// pointer definitions
#define MR1A_PTR (ubyte * const)(DUART_PTR + MR1A_OFF)
#define MR2A_PTR (ubyte * const)(DUART_PTR + MR2A_OFF)
#define SRA_PTR (ubyte * const)(DUART_PTR + SRA_OFF)
#define CSRA_PTR (ubyte * const)(DUART_PTR + CSRA_OFF)
#define CRA_PTR (ubyte * const)(DUART_PTR + CRA_OFF)
#define RBA_PTR (ubyte * const)(DUART_PTR + RBA_OFF)
#define TBA_PTR (ubyte * const)(DUART_PTR + TBA_OFF)
#define IPCR_PTR (ubyte * const)(DUART_PTR + IPCR_OFF)
#define ACR_PTR (ubyte * const)(DUART_PTR + ACR_OFF)
#define ISR_PTR (ubyte * const)(DUART_PTR + ISR_OFF)
#define IMR_PTR (ubyte * const)(DUART_PTR + IMR_OFF)
#define CUR_PTR (ubyte * const)(DUART_PTR + CUR_OFF)
#define CTUR_PTR (ubyte * const)(DUART_PTR + CTUR_OFF)
#define CLR_PTR (ubyte * const)(DUART_PTR + CLR_OFF)
#define CTLR_PTR (ubyte * const)(DUART_PTR + CTLR_OFF)
#define MR1B_PTR (ubyte * const)(DUART_PTR + MR1B_OFF)
#define MR2B_PTR (ubyte * const)(DUART_PTR + MR2B_OFF)
#define SRB_PTR (ubyte * const)(DUART_PTR + SRB_OFF)
#define CSRB_PTR (ubyte * const)(DUART_PTR + CSRB_OFF)
#define CRB_PTR (ubyte * const)(DUART_PTR + CRB_OFF)
#define RBB_PTR (ubyte * const)(DUART_PTR + RBB_OFF)
#define TBB_PTR (ubyte * const)(DUART_PTR + TBB_OFF)
#define IVR_PTR (ubyte * const)(DUART_PTR + IVR_OFF)
#define IPR_PTR (ubyte * const)(DUART_PTR + IPR_OFF)
#define OPCR_PTR (ubyte * const)(DUART_PTR + OPCR_OFF)
#define OPRLS_PTR (ubyte * const)(DUART_PTR + OPRLS_OFF)
#define OPRC_PTR (ubyte * const)(DUART_PTR + OPRC_OFF)

#endif

```

```
/*
 * ems_cm.c
 * Richard Homan
 * 02/17/2024
 * Change memory logic for Enemigo Monitor System
 */

#include "err.h"
#include "types.h"
#include "convert.h"

// argv[1] = address, argv[2] = value
int ems_cm(const char **argv, int argc)
{
    ulword addr;
    byte b, val;
    register int i, r;

    if (argv[1][6] != '\0' || // address not len 6
        argv[2][2] != '\0') // value not len 2
        return EMS_BAD_ARG;

    addr = 0;
    val = 0;
    for (i = 0; i < 6; i+=2)
    {
        r = ahtob(&(argv[1][i]), &b);
        if (r != 0)
            return r;
        addr = (addr << 8) | b;
    }

    r = ahtob(argv[2], &b);
    if (r != 0)
        return r;
    val = b;

    *(byte *)addr = val;
    return 0;
}
```

```

/*
 * ems_cr.c
 * Richard Homan
 * 02/17/2024
 * Change register logic for Enemigo Monitor System
 */

#include "err.h"
#include "types.h"
#include "convert.h"
#include "serial.h"

// argv[1] = register num, argv[2] = value
int ems_cr(const char **argv, int argc)
{
    register int i, r;
    byte b;
    lword val;

    if (argv[1][2] != '\0' || // arg 1 isn't len 2
        argv[2][8] != '\0') // arg 2 isn't len 8
        return EMS_BAD_ARG;

    val = 0;
    for (i = 0; i < 8; i+=2)
    {
        r = ahtob(&(argv[2][i]), &b);
        if (r != 0)
            return r;
        val = (val << 8) | (ubyte)b;
    }

    if (argv[1][0] == 'd')
    {
        switch(argv[1][1])
        {
        case '0':
            __asm__ ("move.l    %0,%d0\n" :: "m" (val) : "cc");
            break;
        case '1':
            __asm__ ("move.l    %0,%d1\n" :: "m" (val) : "cc");
            break;
        case '2':
            __asm__ ("move.l    %0,%d2\n" :: "m" (val) : "cc");
            break;
        case '3':
            __asm__ ("move.l    %0,%d3\n" :: "m" (val) : "cc");
            break;
        case '4':
            __asm__ ("move.l    %0,%d4\n" :: "m" (val) : "cc");
            break;
        case '5':
            __asm__ ("move.l    %0,%d5\n" :: "m" (val) : "cc");
            break;
        case '6':
            __asm__ ("move.l    %0,%d6\n" :: "m" (val) : "cc");
            break;
        case '7':
            __asm__ ("move.l    %0,%d7\n" :: "m" (val) : "cc");
            break;
        default:
            return -1;
        }
    }
    else if (argv[1][0] == 'a')
    {
        switch(argv[1][1])
        {
        case '0':
            __asm__ ("move.l    %0,%a0\n" :: "m" (val) : "cc");
            break;
        case '1':
            __asm__ ("move.l    %0,%a1\n" :: "m" (val) : "cc");
            break;
        case '2':
            __asm__ ("move.l    %0,%a2\n" :: "m" (val) : "cc");
            break;
        case '3':
            __asm__ ("move.l    %0,%a3\n" :: "m" (val) : "cc");
            break;
        case '4':
            __asm__ ("move.l    %0,%a4\n" :: "m" (val) : "cc");
            break;
        case '5':
            __asm__ ("move.l    %0,%a5\n" :: "m" (val) : "cc");
            break;
        default:
            return -1;
        }
    }
    else
        return EMS_BAD_ARG;
}

```

```
    return 0;  
}
```

```

/*
 * ems_dm.c
 * Richard Homan
 * 02/17/2024
 * Dump memory logic for Enemigo Monitor System
 */

#include "err.h"
#include "types.h"
#include "convert.h"
#include "strings.h"
#include "serial.h"

// argv[1] = address, argv[2] = n lines of 16 bytes
int ems_dm(const char **argv, int argc)
{
    char header[9];
    char sbyte[4];
    ulword addr;
    byte b, len;
    register int i, j, r;

    if (argv[1][6] != '\0' || argv[2][2] != '\0')
        return EMS_BAD_ARG;

    addr = 0;
    for (i = 0; i < 6; i+=2)
    {
        r = ahtob(&(argv[1][i]), &b);
        if (r != 0)
            return r;
        addr = (addr << 8) | b;
    }

    r = ahtob(argv[2], &len);
    if (r != 0)
        return r;

    header[6] = ':';
    header[7] = ' ';
    header[8] = '\0';
    sbyte[2] = ' ';
    sbyte[3] = '\0';

    addr -= addr % 16; // align to 0x10
    for (i = 0; i < len; i++)
    {
        btoah((addr >> 16) & 0xff, &(header[0]));
        btoah((addr >> 8) & 0xff, &(header[2]));
        btoah((addr >> 0) & 0xff, &(header[4]));
        serial_puts(header, ARR_LEN(header));

        for (j = 0; j < 16; j++)
        {
            btoah(*((byte *)((ulword)addr), &(sbyte[0])));
            serial_puts(sbyte, ARR_LEN(sbyte));
            addr++;
        }

        serial_puts(nl_str, NL_STR_LEN);
    }

    return 0;
}

```

```

/*
 * ems_dr.c
 * Richard Homan
 * 02/17/2024
 * Dump registers logic for Enemigo Monitor System
 */

#include "types.h"
#include "convert.h"
#include "strings.h"
#include "serial.h"

const char d0_str[] = "d0";
const char d1_str[] = "d1";
const char d2_str[] = "d2";
const char d3_str[] = "d3";
const char d4_str[] = "d4";
const char d5_str[] = "d5";
const char d6_str[] = "d6";
const char d7_str[] = "d7";
const char a0_str[] = "a0";
const char a1_str[] = "a1";
const char a2_str[] = "a2";
const char a3_str[] = "a3";
const char a4_str[] = "a4";
const char a5_str[] = "a5";
const char fp_str[] = "fp";
const char sp_str[] = "sp";

const char * const reg_str[] =
{
    d0_str,    a0_str,
    d1_str,    a1_str,
    d2_str,    a2_str,
    d3_str,    a3_str,
    d4_str,    a4_str,
    d5_str,    a5_str,
    d6_str,    fp_str,
    d7_str,    sp_str
};

#define GET_REG(r, o) __asm__ ("move.l %/"#r",%0\n :=""m" (o) :: "cc");

// no arguments
int ems_dr(const char **argv, int argc)
{
    lword v[16];
    char out[26];
    register int i, j;

    GET_REG(d0, v[ 0]); GET_REG(a0, v[ 1]);
    GET_REG(d1, v[ 2]); GET_REG(a1, v[ 3]);
    GET_REG(d2, v[ 4]); GET_REG(a2, v[ 5]);
    GET_REG(d3, v[ 6]); GET_REG(a3, v[ 7]);
    GET_REG(d4, v[ 8]); GET_REG(a4, v[ 9]);
    GET_REG(d5, v[10]); GET_REG(a5, v[11]);
    GET_REG(d6, v[12]); GET_REG(fp, v[13]);
    GET_REG(d7, v[14]); GET_REG(sp, v[15]);

    out[2] = ':';
    out[3] = ':';
    out[12] = ' ';
    out[15] = ':';
    out[16] = ' ';
    out[25] = '\0';
    for (i = 0; i < 16; )
    {
        // set reg names to out string
        out[0] = reg_str[i][0];
        out[1] = reg_str[i][1];
        out[13] = reg_str[i+1][0];
        out[14] = reg_str[i+1][1];

        for (j = 6; j >= 0; j-=2)
        {
            btoah(v[i] & 0xff, &(out[j+4]));
            v[i] = v[i] >> 8;
        }
        i++;
        for (j = 6; j >= 0; j-=2)
        {
            btoah(v[i] & 0xff, &(out[j+17]));
            v[i] = v[i] >> 8;
        }
        i++;
    }

    serial_puts(out, ARR_LEN(out));
    serial_puts(nl_str, NL_STR_LEN);
}

return 0;
}

```

```

/*
 * ems_h.c
 * Richard Homan
 * 02/17/2024
 * Help menu logic for Enemigo Monitor System
 */

#include "types.h"
#include "strings.h"
#include "serial.h"

const char help_str0[] = "cr reg val : change register";
const char help_str1[] = "cm loc val : change memory";
const char help_str2[] = "dr      : dump registers";
const char help_str3[] = "dm loc len : dump memory";
const char help_str4[] = "l       : load srecord executable";
const char help_str5[] = "r       : run srecord executable";
const char help_str6[] = "h       : display this message";

const char * const help_str[] =
{
    help_str0,
    help_str1,
    help_str2,
    help_str3,
    help_str4,
    help_str5,
    help_str6
};

const int help_str_len[] =
{
    ARR_LEN(help_str0),
    ARR_LEN(help_str1),
    ARR_LEN(help_str2),
    ARR_LEN(help_str3),
    ARR_LEN(help_str4),
    ARR_LEN(help_str5),
    ARR_LEN(help_str6)
};

// no arguments
int ems_h(const char **argv, int argc)
{
    register int i;
    for (i = 0; i < ARR_LEN(help_str); i++)
    {
        serial_puts((const char *)help_str[i], (ubyte)help_str_len[i]);
        serial_puts(nl_str, NL_STR_LEN);
    }

    return 0;
}

```

```

/*
 * ems_l.c
 * Richard Homan
 * 02/17/2024
 * Load record logic for Enemigo Monitor System
 */

#include "err.h"
#include "convert.h"
#include "strings.h"
#include "exec.h"
#include "lsrec.h"
#include "serial.h"
#include "prompt.h"
// #include "debug_prog.h"

#define INBUF_SIZE 64
static char inbuf[INBUF_SIZE];

// no arguments
int ems_l(const char **argv, int argc)
{
    int r, inbuf_len;

    lsrec_init();

    has_exec = 0;
    exec_entry_ptr = 0x0;
    // keep accepting input until entry addr is given
    while (exec_entry_ptr == 0x0)
    {
        // no prompt string, cancel on ^
        inbuf_len = user_prompt(inbuf, INBUF_SIZE, 0x0, 0, '\x03');
        if (inbuf_len == 0)
            return 0;

        inbuf_len--;
        r = lsrec_in(inbuf, inbuf_len, &(exec_entry_ptr));

        if (r != 0)
            return r;
    }

    has_exec = 1;
    // print out entry address, reuse inbuf as output
    btoah(((lword)exec_entry_ptr >> 0) & 0xff, &(inbuf[6]));
    btoah(((lword)exec_entry_ptr >> 8) & 0xff, &(inbuf[4]));
    btoah(((lword)exec_entry_ptr >> 16) & 0xff, &(inbuf[2]));
    btoah(((lword)exec_entry_ptr >> 24) & 0xff, &(inbuf[0]));
    inbuf[8] = '\0';
    serial_puts(inbuf, 8);
    serial_puts(nl_str, NL_STR_LEN);

    // for (int i = 0; i < ARR_LEN(debug_prog_l); i++)
    // {
    //     r = lsrec_in(debug_prog[i], debug_prog_l[i], &(exec_entry_ptr));
    //     if (r != 0)
    //     {
    //         serial_puts(err_str, ERR_STR_LEN);
    //         btoah(r, inbuf);
    //         inbuf[2] = '\0';
    //         serial_puts(inbuf, 2);
    //         serial_puts(nl_str, NL_STR_LEN);
    //         return r;
    //     }
    //
    //     if (exec_entry_ptr != 0x0)
    //     {
    //         has_exec = 1;
    //     }
    // }
    // }

    return 0;
}

```

```
/*
 * ems_r.c
 * Richard Homan
 * 02/17/2024
 * Run executable logic for Enemigo Monitor System
 */

#include "err.h"
#include "types.h"
#include "convert.h"
#include "strings.h"
#include "exec.h"
#include "serial.h"

const char exit_code_str[] = "exit status: ";

// no arguments
int ems_r(const char **argv, int argc)
{
    char n[9];
    register int i, r;

    if (!has_exec)
        return EMS_NO_EXEC;

    r = exec_entry_ptr(); // run program
    for (i = 6; i >= 0; i-=2)
    {
        btoah(r & 0xff, &(n[i]));
        r = r >> 8;
    }
    n[9] = '\0';
    serial_puts(exit_code_str, ARR_LEN(exit_code_str));
    serial_puts(n, 8);
    serial_puts(nl_str, NL_STR_LEN);

    return 0;
}
```

```
/*
 * exec.h
 * Richard Homan
 * 02/18/2024
 * Loaded executable shared entrypoint for Enemigo Monitor System
 */

#ifndef EXEC_H
#define EXEC_H

#include "types.h"

extern byte has_exec;
extern int (*exec_entry_ptr)(void);

#endif
```

```

/*
 * isv.s
 * Richard Homan
 * 02/11/2024
 * m68k interrupt vector definitions
 */

.macro SLOT,n,prefix=,suffix=
.long __\prefix\n\suffix
.endm

.macro ISR n
SLOT \n,interrupt,
.endm

.macro TRAP n
SLOT \n,trap,
.endm

.macro FP n
SLOT \n,fp_,
.endm

.macro UNIMP_OPCODE n
SLOT \n,unimplemented_,_opcode
.endm

.macro BREAKPOINT_DEBUG n
SLOT \n,,_breakpoint_debug_interrupt
.endm

.section .isv,"a"
.globl      __interrupt_vector
__interrupt_vector:
.long __stack          /* 0 */
.long __reset          /* 1 */
.long __access_error   /* 2 */
.long __address_error  /* 3 */
.long __illegal_instruction /* 4 */
.long __divide_by_zero  /* 5 */
ISR 6
ISR 7
.long __privilegeViolation /* 8 */
.long __trace           /* 9 */
UNIMP_OPCODE line_a    /* 10 */
UNIMP_OPCODE line_f    /* 11 */
BREAKPOINT_DEBUG non_pc /* 12 */
BREAKPOINT_DEBUG pc    /* 13 */
.long __format_error   /* 14 */
.ipr N,15,16,17,18,19,20,21,22,23
ISR \N                  /* [15,24] */
.endr
.long __spurious_interrupt /* 24 */
.ipr N,25,26,27,28,29,30,31
ISR \N                  /* [25,32] */
.endr
.ipr N,0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15
TRAP \N                 /* [32,48] */
.endr
FP branch_unordered    /* 48 */
FP inexact_result       /* 49 */
FP divide_by_zero        /* 50 */
FP underflow            /* 51 */
FP operand_error         /* 52 */
FP overflow              /* 53 */
FP input_not_a_number   /* 54 */
FP input_denormalized_number /* 55 */
.ipr N,56,57,58,59,60
ISR \N                  /* [56,61] */
.endr
.long __unsupported_instruction /* 61 */
.ipr N,62,63
ISR \N                  /* [62,64] */
.endr
.ipr N,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79
ISR \N                  /* [64,80] */
.endr
.ipr N,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95
ISR \N                  /* [80,96] */
.endr
.ipr N,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111
ISR \N                  /* [96,112] */
.endr
.ipr N,112,113,114,115,116,117,118,119,120,121,122,123,124,125,126,127
ISR \N                  /* [112,128] */
.endr
.ipr N,128,129,130,131,132,133,134,135,136,137,138,139,140,141,142,143
ISR \N                  /* [128,144] */
.endr
.ipr N,144,145,146,147,148,149,150,151,152,153,154,155,156,157,158,159
ISR \N                  /* [144,160] */
.endr

```

```
*      .irp N,160,161,162,163,164,165,166,167,168,169,170,171,172,173,174,175      /* [160,176) */
*      ISR \N
*      .endr
*      .irp N,176,177,178,179,180,181,182,183,184,185,186,187,188,189,190,191      /* [176,192) */
*      ISR \N
*      .endr
*      .irp N,192,193,194,195,196,197,198,199,200,201,202,203,204,205,206,207      /* [192,208) */
*      ISR \N
*      .endr
*      .irp N,208,209,210,211,212,213,214,215,216,217,218,219,220,221,222,223      /* [208,224) */
*      ISR \N
*      .endr
*      .irp N,224,225,226,227,228,229,230,231,232,233,234,235,236,237,238,239      /* [224,240) */
*      ISR \N
*      .endr
*      .irp N,240,241,242,243,244,245,246,247,248,249,250,251,252,253,254,255      /* [240,256) */
*      ISR \N
*      .endr
*
```

```

/*
 * lsrec.c
 * Richard Homan
 * 02/12/2024
 * Parser and loader of srec executables for Enemigo Monitor System
 */

#include "lsrec.h"
#include "serial.h"
#include "convert.h"

static dword drec_count;
static ubyte has_entry;
static ulword dbegin_addr;
static ulword dend_addr;
static lword err;

int srec_gtype(const char *, ubyte *); // get type
int srec_gcount(const char *, ubyte *); // get count
int srec_gaddr(const char *, ulword *); // get address
int srec_gdatab(const char *, ubyte, byte *); // gets one byte from data section

void lsrec_init()
{
    drec_count = 0;
    dbegin_addr = LSREC_MAX_ADDR;
    dend_addr = LSREC_MIN_ADDR;
    has_entry = 0;
    err = 0;
}

int lsrec_in(const char *recstr, ubyte len, int (**entry_func)(void))
{
    register int i, r;
    ubyte type, count;
    byte calc_chksum, checksum;
    ulword addr;

    err = 0;
    if (len < 10) // absolute minimum length is 10
    {
        err = LSREC_ERR_NOT_SREC_FORMAT;
        return err;
    }

    if (has_entry) // entry should be the last value given, if we get any more
        // records, give an error
    {
        err = LSREC_ERR_DATA_GIVEN_AFTER_ENTRY;
        return err;
    }

    // get type value
    r = srec_gtype(recstr, &type);
    if (r < 0)
    {
        err = r;
        return r;
    }

    switch (type) // don't support S1, S3, S4, S5, S7, S9
    {
    case 0:
        err = LSREC_SUCCESS;
        return LSREC_SUCCESS;
    case 1:
        err = LSREC_ERR_UNSUPPORTED_TYPE_S1;
        break;
    case 3:
        err = LSREC_ERR_UNSUPPORTED_TYPE_S3;
        break;
    case 4:
        err = LSREC_ERR_UNSUPPORTED_TYPE_S4;
        break;
    case 5:
        err = LSREC_ERR_UNSUPPORTED_TYPE_S5;
        break;
    case 7:
        err = LSREC_ERR_UNSUPPORTED_TYPE_S7;
        break;
    case 9:
        err = LSREC_ERR_UNSUPPORTED_TYPE_S9;
        break;
    default:
        break;
    }
    if (err != 0)
        return err;

    // get count value
    r = srec_gcount(recstr, &count);
    if (r < 0)

```

```

{
    err = r;
    return r;
}

if (count * 2 != len - 4) // check that actual length matches said count
{
    err = LSREC_ERR_LENGTH_NONEQUAL;
    return err;
}

// get address value
r = srec_gaddr(recstr, &addr);
if (r != 0)
{
    err = r;
    return r;
}

if (type == 6) // verify that we got the number of S2 records specified
                // in S6
{
    if (count != 3) // S6 record count should only be 4
    {
        err = LSREC_ERR_INVALID_FORMAT;
        return err;
    }

    if (addr != drec_count) // value is contained in address
    {
        err = LSREC_ERR_RECORD_COUNT_NONEQUAL;
        return err;
    }

    drec_count = 0;
    return LSREC_SUCCESS;
}
if (type == 8) // entry is specified
{
    if (count != 4) // S8 record count should only be 4
    {
        err = LSREC_ERR_INVALID_FORMAT;
        return err;
    }

    if (addr < dbegin_addr || addr > dend_addr)
    {
        err = LSREC_ERR_ENTRY_OUT_OF_BOUNDS;
        return err;
    }

    // cast to ulword then to func pointer
    *entry_func = (int (*)(void))addr;
    return LSREC_SUCCESS;
}

drec_count++; // if we got to this point, then we have a data record
// verify that the address isn't out of bounds
if (addr < LSREC_MIN_ADDR || addr > LSREC_MAX_ADDR)
{
    err = LSREC_ERR_ADDRESS_OUT_OF_BOUNDS;
    return err;
}
// subtract out address and checksum and verify that memory doesn't go out
// of bounds
if (addr + count - 2 - 1 > LSREC_MAX_ADDR)
{
    err = LSREC_ERR_LENGTH_EXTENDS_OUT_OF_BOUNDS;
    return err;
}
// update min and max given values
if (addr < dbegin_addr)
    dbegin_addr = addr;
else if (addr > dend_addr)
    dend_addr = addr;

// initialize calculated checksum
calc_chksum = count +
                ((addr >> 16) & 0xff) + // add addr high
                ((addr >> 8) & 0xff) + // add addr semi
                ((addr >> 0) & 0xff); // add addr low
for (i = 0; i < count-2-1; i++)
{
    byte *baddr;
    byte b;

    r = srec_gdatab(recstr, i, &b);
    if (r != 0)
    {
        err = r;
        return r;
    }
}

```

```

    calc_chksum += b;
    baddr = (byte *) (addr + (ulword)i);
    *baddr = b;
}

calc_chksum = 0xff - (calc_chksum & 0xff); // do final calculation
r = srec_gdatab(recstr, count-4, &chksum);
if (r != 0)
{
    err = r;
    return r;
}

return LSREC_SUCCESS;
}

int srec_gtype(const char *recstr, ubyte *ret)
{
    if ((recstr[0] != 'S') || !(recstr[1] >= '0' && recstr[1] <= '9'))
    {
        err = LSREC_ERR_NOT_SREC_FORMAT;
        return err;
    }

    *ret = (byte)(recstr[1] - '0');
    return 0;
}

int srec_gcount(const char *recstr, ubyte *ret)
{
    byte b;
    int r;

    r = ahtob(&(recstr[2]), &b);
    if (r != 0)
        return r;

    *ret = (ubyte)b;
    return 0;
}

int srec_gaddr(const char *recstr, ulword *ret)
{
    byte b;
    ulword addr;
    register int i, r;

    addr = 0;
    for (i = 4; i < 10; i+=2)
    {
        r = ahtob(&(recstr[i]), &b);
        if (r != 0)
            return r;
        addr = (addr << 8) | (ubyte)b;
    }

    *ret = addr;
    return 0;
}

int srec_gdatab(const char *recstr, ubyte byte_num, byte *ret)
{
    const ubyte b_idx = 2+2+6+(byte_num*2);
    byte b;
    register int r;

    r = ahtob(&(recstr[b_idx]), &b);
    if (r != 0)
        return r;

    *ret = b;
    return 0;
}

```

```

/*
 * lsrec.h
 * Richard Homan
 * 02/12/2024
 * Parser and loader of srec executables for Enemigo Monitor System
 */

#include "types.h"

#ifndef LSREC_H
#define LSREC_H

#define LSREC_MIN_ADDR      0x10000 // start of ram
#define LSREC_MAX_ADDR      0x20000 // start of duart

#define LSREC_SUCCESS 0
#define LSREC_ERR_NOT_SREC_FORMAT -101 // below minimum length, or doesn't start with 'S'
#define LSREC_ERR_UNSUPPORTED_TYPE_S1 -102
#define LSREC_ERR_UNSUPPORTED_TYPE_S3 -103
#define LSREC_ERR_UNSUPPORTED_TYPE_S4 -104
#define LSREC_ERR_UNSUPPORTED_TYPE_S5 -105
#define LSREC_ERR_UNSUPPORTED_TYPE_S7 -106
#define LSREC_ERR_UNSUPPORTED_TYPE_S9 -107
#define LSREC_ERR_ADDRESS_OUT_OF_BOUNDS -108 // valid address from 0x10000-0x20000
#define LSREC_ERR_LENGTH_NONEQUAL -109 // given srec len does not equal actual len
#define LSREC_ERR_LENGTH_EXTENDS_OUT_OF_BOUNDS -110
#define LSREC_ERR_INVALID_CHECKSUM -111 // checksum invalid
#define LSREC_ERR_RECORD_COUNT_NONEQUAL -112 // the count of S1, S2, and S3 records given in S5 is incongruent to received
#define LSREC_ERR_ENTRY_OUT_OF_BOUNDS -113 // entry point specified in S7, S8, or S9 is not defined in the address of the data
#define LSREC_ERR_DATA_GIVEN_AFTER_ENTRY -114 // S1, S2, S3 after S7, S8, S9
#define LSREC_ERR_INVALID_FORMAT -115 // if S5 len is not 3
#define LSREC_ERR_INVALID_HEX -116

// must be called before calling lsrec_in
void lsrec_init();
// line is null terminated, returns the entry function when it gets it
// receiving the entry function means the end of the srec
int lsrec_in(const char *recstr, ubyte len, int (**entry_func)(void));

#endif

```

```

/*
 * main.c
 * Richard Homan
 * 02/11/2024
 * Entry point for Enemigo Monitor System
 */

#include "types.h"
#include "convert.h"
#include "strings.h"
#include "command.h"
#include "exec.h"
#include "serial.h"
#include "prompt.h"

#define INBUF_SIZE 16
#define ARG_MAX 3

const char parse_err_str[] = "error parsing arguments";
const char inv_comm_str[] = "unknown command";
const char bad_arg_str[] = "bad argument";
const char noexecload_str[] = "no executable loaded";

const char pmt_str[] = "ems% ";

static char inbuf[INBUF_SIZE];
static char *argv[ARG_MAX];

byte has_exec;
int (*exec_entry_ptr)(void);

int main(void)
{
    int r;
    int inbuf_len;
    int argc;
    command_func command;

    has_exec = 0;
    exec_entry_ptr = 0x0;
    serial_init();

    serial_puts(welcome_str, WELCOME_STR_LEN);

mpmt:
    inbuf_len = user_prompt(inbuf, INBUF_SIZE, pmt_str, ARR_LEN(pmt_str), 0);

    r = split_args(inbuf, inbuf_len, argv, &argc, ARG_MAX);
    if (r != 0) // inform about error and return to prompt
    {
        serial_puts(parse_err_str, ARR_LEN(parse_err_str));
        serial_puts(nl_str, NL_STR_LEN);
        goto mpmt;
    }

    if (inbuf_len > 0)
    {
        command = gcommand(argv[0]);
        // serial_puts(argv[0], INBUF_SIZE);
        // goto mpmt;

        r = command((const char **)argv, argc);
    }
    else
        r = EMS_INV_COMM;

    switch (r)
    {
    case 0:
        break;
    case EMS_INV_COMM:
        serial_puts(inv_comm_str, ARR_LEN(inv_comm_str));
        break;
    case EMS_BAD_ARG:
        serial_puts(bad_arg_str, ARR_LEN(bad_arg_str));
        break;
    case EMS_NO_EXEC:
        serial_puts(noexecload_str, ARR_LEN(noexecload_str));
        break;
    default:
        serial_puts(err_str, ERR_STR_LEN);
        btolah(byte)(r & 0xff), &(inbuf[0]));
        serial_puts(inbuf, 2);
        break;
    }
    if (r != 0)
        serial_puts(nl_str, NL_STR_LEN);

    goto mpmt; // never exit
}

// we should never get to this point, but if we do, loop
while (1)

```

```
        return 0; __asm__ __volatile__ ("nop");
}

__attribute__ ((interrupt_handler))
void __access_error(void)
{
    serial_putchar('~');

    while (1) // infinite loop trap
        __asm__ __volatile__ ("nop");
}
```

```

/*
 * command.c
 * Richard Homan
 * 02/17/2024
 * Command determination for Enemigo Monitor System
 */

#include "command.h"
#include "types.h"
// #include "convert.h"
// #include "serial.h"

// 16 bins
// 10 = cr
// 15 = cm
// 9 = dr
// 14 = dm
// 3 = l
// 13 = r
// 7 = h
const command_func command_vec[16] =
{
    ems_cm,    // 00
    ems_dm,    // 01
    ems_r,     // 02
    invalid_command, // 03
    invalid_command, // 04
    ems_cr,    // 05
    ems_dr,    // 06
    invalid_command, // 07
    ems_h,     // 08
    invalid_command, // 09
    invalid_command, // 10
    invalid_command, // 11
    ems_l,     // 12
    invalid_command, // 13
    invalid_command, // 14
    invalid_command, // 15
};

int invalid_command(const char **argv, int argc) { return EMS_INV_COMM; }

// kind of cheats. since (for this application) we don't care what happens
// to in, this function delimits the input by ' ' and then replaces the spaces
// with '\0'. this way we don't have to copy the strings and can use in
// as the storage for argv
int split_args(char *in, int len, char **argv, int *argc, int argm)
{
    register int i;
    register int next; // flag to indicate that next char is a new arg
    char c;

    *argc = 0;
    next = 1;
    for (i = 0; i < len; i++)
    {
        if (*argc > argm) // past arg max, don't parse anymore
            break;
        c = in[i];
        if (c == '\0') // found end early, break out
            break;
        if (c == ' ')
        {
            in[i] = '\0';
            next = 1;
        }
        else if (next)
        {
            argv[*argc] = &(in[i]); // set next argument
            (*argc)++;
            next = 0;
        }
    }
    // make sure that last arg is null terminated
    in[len-1] = '\0';
}

return 0;
}

// performs the hashing function on the command name to get the command function
// pointer
command_func gcommand(const char *commname)
{
    char c;
    ubyte index;
    int i;
    command_func command;

    command = &invalid_command;
    c = commname[0];
    index = 0;
    i = 0;
}

```

```
while (c != '\0')
{
    index += c;
    i++;
    c = commname[i];
}

index = index % 16;

// char debug_buf[5];
// btoah(index, debug_buf);
// debug_buf[2] = '\r';
// debug_buf[3] = '\n';
// debug_buf[4] = '\0';
// serial_puts(debug_buf, 5);

command = command_vec[index];

return command;
}
```

```
/*
 * mem.c
 * Richard Homan
 * 02/15/2024
 * Batch memory functions for Enemigo Monitor System
 */

#include "mem.h"

lword
strncpy (char *__restrict dst0,
         const char *__restrict src0,
         lword count)
{
    char *dscan;
    const char *sscan;
    lword r = count;

    dscan = dst0;
    sscan = src0;
    while (count > 0)
    {
        --count;
        if ((*dscan++ = *sscan++) == '\0')
            break;
    }
    r -= count;
    while (count-- > 0)
        *dscan++ = '\0';
}

return r;
}
```

```
/*
 * mem.h
 * Richard Homan
 * 02/15/2024
 * Batch memory functions for Enemigo Monitor System
 */

#include "types.h"

#ifndef MEM_H
#define MEM_H

#define STRLEN(s) (sizeof(s)/sizeof(s[0]))

// returns new length of string
lword strncpy(char *dest, const char *src, lword n);

#endif
```

```

/*
 * prompt.c
 * Richard Homan
 * 04/03/2024
 * String input prompt routine for Enemigo Monitor System
 */

#include "strings.h"
#include "serial.h"
#include "convert.h"

int user_prompt(char *inbuf,           int inbuf_size,
                const char *pmt_str, int pmt_str_len,
                char esc)
{
    int inbuf_len;
    char inchar;

    inbuf_len = 0;
    serial_puts(pmt_str, pmt_str_len);
#ifndef SIM
    serial_puts(cur_str, CUR_STR_LEN);
#endif

waitc:
    while (!serial_isc()) // wait for next character
        __asm__ __volatile__ ("nop");

    inchar = serial_getc();
    if (inchar == esc)
    {
        serial_puts(nl_str, NL_STR_LEN);
        return 0;
    }
    if (inchar == '\r') // on return key
    {
        inbuf[inbuf_len++] = ' ';
        inbuf[inbuf_len] = '\0'; // add null terminator
#ifndef SIM
        serial_puts(nl_str, NL_STR_LEN);
#endif
        inbuf[inbuf_len] = '\0'; // add null terminator
        return inbuf_len;
    }
    if (inchar == '\x7f' || inchar == '\b') // on delete or backspace key
    {
        if (inbuf_len > 0)
        {
            inbuf_len--;
            serial_puts(del_str, DEL_STR_LEN);
        }
    }
    else // any other input
    {
        if (inbuf_len < inbuf_size-1) // buffer overflow protection
        {
            // sub 1 because we add '\0' at end
            inbuf[inbuf_len] = inchar;
            inbuf_len++;
#ifndef SIM
            serial_putc(inchar);
            // btoah(inchar, &(inbuf[0]));
            // inbuf[2] = '\0';
            // serial_puts(inbuf, 2);
            // inbuf_len = 0;
#endif
        }
        else // prevent overflow
        {
#ifndef SIM
            serial_putc(del_str, DEL_STR_LEN); // eat char off terminal
#endif
        }
    }
#ifndef SIM
    serial_puts(cur_str, CUR_STR_LEN);
#endif
    goto waitc;
}

```

```
/*
 * prompt.h
 * Richard Homan
 * 04/03/2024
 * String input prompt routine for Enemigo Monitor System
 */

#ifndef PROMPT_H
#define PROMPT_H

// inbuf: buffer to put users string into
// size : size of input buffer
// escc : optional escape character ('\0' or 0 for none)
// ret : the length of the buffer written or an error code
int user_prompt(char *inbuf,           int inbuf_size,
                const char *pmt_str, int pmt_str_len,
                char escc);

#endif
```

```

/*
 * serial.c
 * Richard Homan
 * 02/11/2024
 * Implementations for serial control
 */

#include "serial.h"

#ifndef SIM
#include "def_68681.h"
#endif

#define MR1A_VAL (ubyte)0x13
#define MR2A_VAL (ubyte)0x07
// #define MR2A_VAL (ubyte)0x47 // enable automatic echo
#define CSRA_VAL (ubyte)0xbb

#define CRA_VAL0 (ubyte)0x30 // reset transmitter
#define CRA_VAL1 (ubyte)0x20 // reset receiver
#define CRA_VAL2 (ubyte)0x01 // enable receiver
#define CRA_VAL3 (ubyte)0x05 // enable transmitter and receiver

#define ACR_VAL (ubyte)0x00 // clock set select 1

inline
void serial_init()
{
    *CRA_PTR = CRA_VAL0;
    *CRA_PTR = CRA_VAL1;
    *CRA_PTR = CRA_VAL2;
    *ACR_PTR = ACR_VAL;
    *CSRA_PTR = CSRA_VAL;
    *MR1A_PTR = MR1A_VAL;
    *MR2A_PTR = MR2A_VAL;
    *CRA_PTR = CRA_VAL3;
    return;
}

void serial_puts(const char *in, int len)
{
    register int i;
    char c;

    for (i = 0; i < len; i++)
    {
        c = in[i];
        if (c == '\0') break;
        serial_putc(c);
    }
    return;
}

inline
void serial_putc(char c)
{
    while ((*SRA_PTR & 0x4) == 0) ;
    *TBA_PTR = (ubyte)c;
    return;
}

inline
byte serial_isc()
{
    return (*SRA_PTR & 0x1);
}

inline
char serial_getc()
{
    return *(char *)RBA_PTR;
}

#else
void serial_init()
{
    return;
}

// trap 15, d0=1, a1=string, d1=string len
void serial_puts(const char *in, int len)
{
    __asm__ __volatile__ ("move.l %/a1,-(%/sp)\n" // save registers
                        "move.l %/d1,-(%/sp)\n"
                        "move.l %/d0,-(%/sp)\n"
                        "move.l %0,%/a1\n" // address of string to a1
                        "move.l %1,%/d1\n" // len to d1
                        "move.b #1,%/d0\n" // task 1
                        "trap    #15\n" // trap 15: SIM tasks
                        "move.l (%/sp)+,%/d0\n" // restore registers
                        "move.l (%/sp)+,%/d1\n"
}

```

```

        "move.l (%/sp)+,%/a1\n"
        :: "rm" (in), "rm" (len) : "cc", "memory");
    }

// trap 15, d0=6, d1=c
void serial_putc(char c)
{
    __asm__ __volatile__ ("move.l %/d1,-(%/sp)\n" // save registers
                          "move.l %/d0,-(%/sp)\n"
                          "move.b %0,%/d1\n" // load c
                          "move.b #6,%/d0\n" // task 6
                          "trap      #15\n"   // trap 15: SIM tasks
                          "move.l (%/sp)+,%/d0\n" // restore registers
                          "move.l (%/sp)+,%/d1\n"
                          :: "rm" (c) : "cc", "memory");
    return;
}

// trap 15, d0=7, d1.b = return
byte serial_isc()
{
    byte r;
    __asm__ __volatile__ ("move.l %/d1,-(%/sp)\n" // save registers
                          "move.l %/d0,-(%/sp)\n"
                          "move.b #7,%/d0\n" // task 7
                          "trap      #15\n"   // trap 15: SIM tasks
                          "move.b %/d1,%0\n" // get return value
                          "move.l (%/sp)+,%/d0\n" // restore registers
                          "move.l (%/sp)+,%/d1\n"
                          : "=m" (r) :: "cc", "memory");
    return r;
}

// trap 15, d0=5, d1.b = return
char serial_getc()
{
    char r;
    __asm__ __volatile__ ("move.l %/d1,-(%/sp)\n" // save registers
                          "move.l %/d0,-(%/sp)\n"
                          "move.b #5,%/d0\n" // task 5
                          "trap      #15\n"   // trap 15: SIM tasks
                          "move.b %/d1,%0\n" // get return value
                          "move.l (%/sp)+,%/d0\n" // restore registers
                          "move.l (%/sp)+,%/d1\n"
                          : "=m" (r) :: "cc", "memory");
    return r;
}

#endif

```

```
/*
 * serial.h
 * Richard Homan
 * 02/11/2024
 * Declarations for serial control. Uncomment the SIM variable directive to
 *      apply simulator (SIM68K) serial functions.
 */
#include "types.h"
// #define SIM
#ifndef SERIAL_H
#define SERIAL_H
void serial_init();
void serial_puts(const char *, int);
void serial_putc(char);
byte serial_isc();
char serial_getc();
#endif
```

```
/*
 * strings.c
 * Richard Homan
 * 04/03/2024
 * Common strings for Enemigo Monitor System
 */

#include "strings.h"

const char welcome_str[] =
"Enemigo Monitor System\r\n\
r" REVISION " @ " __TIME__ " " __DATE__ "\r\n\
Designed by Richard Homan\r\n";
const int WELCOME_STR_LEN = ARR_LEN(welcome_str);

const char nl_str[] = "\r\n";
const int NL_STR_LEN = ARR_LEN(nl_str);

const char err_str[] = "error ";
const int ERR_STR_LEN = ARR_LEN(err_str);

#ifndef SIM
const char cur_str[] = "\b";
const int CUR_STR_LEN = ARR_LEN(cur_str);

const char del_str[] = "\b \b\b";
const int DEL_STR_LEN = ARR_LEN(del_str);
#else
const char del_str[] = "\b \b";
const int DEL_STR_LEN = ARR_LEN(del_str);
#endif
```

```
/*
 * strings.h
 * Richard Homan
 * 02/18/2024
 * Common strings for Enemigo Monitor System
 */

#ifndef STRINGS_H
#define STRINGS_H

#define REVISION "0.02"

#define ARR_LEN(a) sizeof(a)/sizeof(a[0])

extern const char welcome_str[];
extern const int WELCOME_STR_LEN;

extern const char nl_str[];
extern const int NL_STR_LEN;

extern const char err_str[];
extern const int ERR_STR_LEN;

extern const char del_str[];
extern const int DEL_STR_LEN;

#endif SIM
extern const char cur_str[];
extern const int CUR_STR_LEN;
#endif

#endif
```

```
/*
 * types.h
 * Richard Homan
 * 02/11/2024
 * Refer to units as byte, word, and longword for m68k language
 */

#ifndef TYPES_H
#define TYPES_H

typedef char byte;
typedef short word;
typedef int lword;

typedef unsigned char ubyte;
typedef unsigned short uword;
typedef unsigned int ulword;

#endif
```

```

/*
 * ems.ld
 * Richard Homan
 * 02/11/2024
 * Linker script for Enemigo Monitor System
 */

ENTRY(main)

MEMORY
{
    rom      (rx)      :      ORIGIN = 0x00000, LENGTH = 0x10000
    ram      (rwx)     :      ORIGIN = 0x10000, LENGTH = 0x10000
}

/* reset vector points to main */
PROVIDE(__reset = main);
/* stack begins at bottom of ram */
PROVIDE(__stack = 0x10000 + 0x10000);

/*
 * text & data in ROM
 * stack in RAM
 */
SECTIONS
{
    .text :
    {
        *(.isv);
        FILL(0xFF)
        . = 0x400; /* incase isv is not defined, seek */
        *(.text);
    }> rom

    .rodata :
    {
        . = ALIGN(0x10); /* easy to read alignment */
        *(.rodata);
    }> rom

    .data :
    {
        . = ALIGN(0x10); /* easy to read alignment */
        *(.data);
    }> ram AT> rom

    /* There shouldn't exist a bss section anyway but just in case */
    .bss (NOLOAD) :
    {
        . = ALIGN(0x10); /* easy to read alignment */
        *(.bss);
    }> ram
}

```

```

#makefile
PROG_NAME=ems

PROG_CSRCS = isr.c strings.c prompt.c convert.c serial.c command.c main.c \
             lsrec.c ems_cr.c ems_cm.c ems_dr.c ems_dm.c ems_l.c ems_r.c ems_h.c
PROG_SSRCS= isv.s
PROG_COBJS= $(patsubst %.c,%o,$(PROG_CSRCS))
PROG_SOBJS= $(patsubst %.s,%o,$(PROG_SSRCS))
PROG_LDSRPT= ems.ld

SIM_CSRCS = strings.c prompt.c convert.c serial.c command.c main.c \
             lsrec.c ems_cr.c ems_cm.c ems_dr.c ems_dm.c ems_l.c ems_r.c ems_h.c
SIM_SSRCS=
SIM_COBJS= $(patsubst %.c,%sim.o,$(SIM_CSRCS))
SIM_SOBJS= $(patsubst %.s,%sim.o,$(SIM_SSRCS))
SIM_LDSRPT= ems-sim.ld

CC=m68k-elf-gcc
CCFLAGS=-Wall -nostdlib -nodefaultlibs -m68000
AS=m68k-elf-as
ASFLAGS=
LD=m68k-elf-ld
#LD_OPTS==defsym=_start=main -Ttext=0x2000 -Tdata=0x3000 -Tbss=0x4000 --section-start=.rodata=0x5000
LDFLAGS=
OBJCOPY=m68k-elf-objcopy
OBJCOPYFLAGS=-I elf32-m68k -O srec --srec-len=16

all: stamp_gen $(PROG_COBJS) $(PROG_SOBJS)
      $(LD) $(LDFLAGS) -T ${PROG_LDSRPT} $(PROG_COBJS) $(PROG_SOBJS) -o $(PROG_NAME).out
      $(OBJCOPY) $(OBJCOPYFLAGS) $(PROG_NAME).out $(PROG_NAME).srec

sim: CCFLAGS += -DSIM
sim: stamp_gen $(SIM_COBJS) $(SIM_SOBJS)
      $(LD) $(LDFLAGS) -T ${SIM_LDSRPT} $(SIM_COBJS) $(SIM_SOBJS) -o $(PROG_NAME).sim.out
      $(OBJCOPY) $(OBJCOPYFLAGS) $(PROG_NAME).sim.out $(PROG_NAME).sim.S68

$(PROG_COBJS): %.o: %.c
      $(CC) $(CCFLAGS) -c $< -o $@

$(PROG_SOBJS): %.o: %.s
      $(AS) $(ASFLAGS) -o $@ <

$(SIM_COBJS): %.sim.o: %.c
      $(CC) $(CCFLAGS) -c $< -o $@

$(SIM_SOBJS): %.sim.o: %.s
      $(AS) $(ASFLAGS) -o $@ <

.phony stamp_gen:
      touch strings.c

# generate assembly source for c file
%.s: %.c
      $(CC) $(CCFLAGS) -S $*.c -o $*.c.s

clean:
      rm -rf *.o *.out *.S68 *.srec *.c.s

```