

# Microbox 2K2 User Guide

+++ Mon09 Ver 6.0 D.A.Rumball 2020 +++  
Booting internal FLEX....  
6809 FLEX V3.01

15:20:19 Wednesday 4th March 2020  
SYSTEM DRIVE IS #0  
WORK DRIVE IS #1  
Microbox ]l auto setup of ASN and TTYSET.  
+++  
+++allocate  
Drive 0 is the PROMdisk  
Drive 1 is the RAMdisk  
Drive 2 is FlexNet  
Drive 3 is unassigned  
+++

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## Acknowledgements

I'd like to acknowledge and say thank you to all those in the FLEX User's Group who have been preserving and documenting these early 6809 FLEX based systems and especially Michael Evenson for the NetPC/FLEXNet protocols and utilities used in the development of the MB2K2 and Hermann Seib for the A09 assembler.

D.A.Rumball - Hinxworth, UK - April 2020

The project is covered under the permissive version of the CERN Open Hardware Licence Version 2 a copy of which is part of the package.

"If I have seen further, it is by standing on the shoulders of giants."  
- Isaac Newton

"We in computer software insist on stepping on the toes of those who came before us instead of climbing on their shoulders".  
- Dan Ingalls

"Myopia is still a problem even where there are giants' shoulders to stand on"  
- Alan C. Kay



## Section 1 Introduction

A long time ago in a galaxy really quite close by I designed a single board computer called the Microbox 2 (MB2) which was based around the 6809 and FLEX OS. It had a number of advanced (for 1982) features such as integrated EPROMdisk and RAMdisk, hi-res hardware accelerated graphics with a bitmapped text display that could use different languages and character sets (even Arabic), and a battery backed RTC and PRAM. As it had FLEX compatible drivers in EPROM, it could boot from any configured or un-configured copy of FLEX. It sold quite well, (I believe a few hundred were shipped worldwide), and launched my design career.

Not quite so long ago (2005), I revisited the MB2 design with a version built around a Xilinx ‘Spartan’ FPGA dev kit and although this worked well I wasn’t happy with the design as it only kept to the spirit of the MB2 and couldn’t run much of the original’s software. Also due to a lack of space in the FPGA it wasn’t possible to emulate the uPD7220A Graphics Display Controller (GDC) which was one of the defining features of the MB2.

Recent events have given me time to look once again at an updated version of the MB2 and the Microbox 2020 (MB2K2) is the result. This time there is a combination of custom hardware and software that aims be a complete emulation of the MB2 to the point of running the original’s software without modifications.

The MB2K2 is a hardware based emulator built around an Xmos XU216 SoC where each of the 16 RISC cores in the XU216 map onto one of the individual LSI chips in the system being emulated, CPU, PIA, ACIA, GDC etc. The XU216 has 512KB of internal RAM and boots from an external QSPI serial flash device that holds the Xmos firmware and the promdisk for the 6809. As well as the XU216 the PCB includes a battery backed RTC, LEDs and DIP switches, VGA based video out, PS/2 keyboard interface and a USB connector for power and dual high speed serial ports which appear as CDC class virtual com ports to a Windows, MacOS or Linux based host computer.

The PCB has an abundance of test points and features to aid firmware development and is designed with an eye to easy manual assembly.

The MB2K2 is highly customisable. Xmos supply a free Eclipse toolchain that includes an IDE, compilers and debuggers that work with a low cost USB to JTAG debug interface allowing the user to change the MB2K2’s firmware. Although initially the MB2K2 has been used to emulate the MB2, there’s nothing to stop the emulation of other systems, processors and LSI devices.

The initial firmware release supports:-

- MC6809 processor emulation running at approx 8MHz equiv
- 64KB of 6809 RAM with MON09 and OS-9 L1 in ‘ROM’
- 200KB ramdisk + 128KB non-volatile ramdisk & 3MB promdisk
- WD2123 DUART emulation with twin serial ports to the host computer as VCPs via USB, one can be used with FLEXNet for remote storage on FLEX and OS-9
- MC146818 RTC emulation via a physical battery backed RTC/PRAM on the PCB
- MC6821 PIA emulation for the MB2’s bell and option switches and PS/2 keyboard interface (replaces the MB2’s parallel keyboard)
- uPD7220A hardware graphics accelerator emulation, 768x576 ‘VGA’
- PS/2 keyboard interface
- 80x80mm double sided 4 layer PCB which is designed to be assembled by hand with few fine pitch components and ‘large’ (0805) discrete throughout etc.

### Changelog

Ver 0.90 - 2020-04-30 - Initial pre-release.

Ver 0.91 - 2020-07-30 - Add changes for OS-9 support.

Ver 0.95 - 2023-05-10 - PCB converted to KiCAD, add F-RAM based RAMdisk.

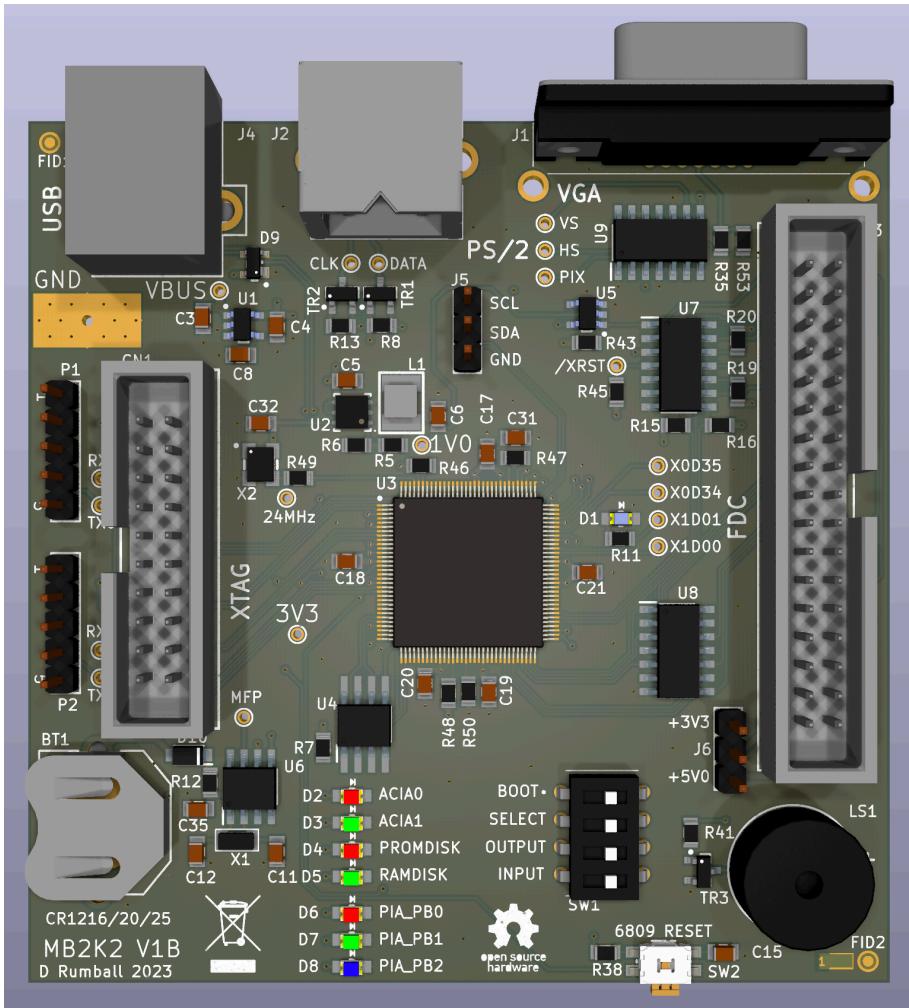
### Known Issues

### Todo List

This early release of the MB2K2 firmware is fully functional and runs the MB2 graphics demo software, but there are some unfinished parts and in later releases I hope to :-

- Improve the uPD7220A emulation for greater compatibility with MB2 software.
- Implement the WD1770 floppy disk controller

## Section 2 - Hardware notes



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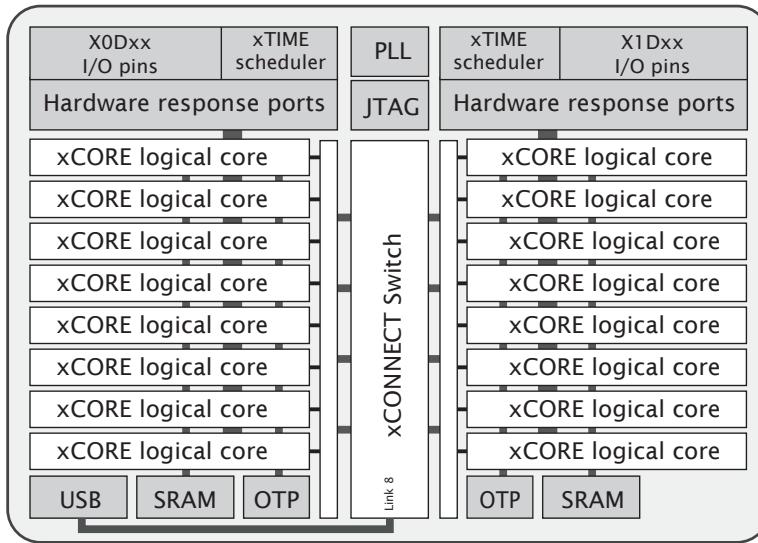
original

Microbox 2, the MB2K2 is based around a single PCB that carries the circuitry for the entire system. As well as the Xmos SoC the PCB includes :-

- 1V and 3.3V power supplies
- Power sequencing and reset circuitry
- 24MHz system clock from which all timing is derived
- 8M bit QSPI flash device for firmware and PROMdisk
- Buffering for the VGA, floppy disk and PS/2 interfaces
- Battery backed RTC including persistent RAM/EEPROM
- 4 way DIP switch used for MON09 settings
- LEDs that show drive and serial port activity
- Sounder
- ‘Soft’ reset switch for the emulated processor
- Connectors for JTAG debug, USB, PS/2 keyboard, Floppy disk and VGA
- Multiple test points and test connectors for ease of development

A few concessions to the 21st century have been made due to the scarcity of monitors supporting analogue video, host computers with RS-232 serial ports and parallel 5V logic level keyboards. So the 15KHz interlaced video out of the MB2 has been replaced by a VGA compatible output, the serial ports are now CDC class virtual com ports via USB and the keyboard interface supports the ubiquitous PS/2 standard.

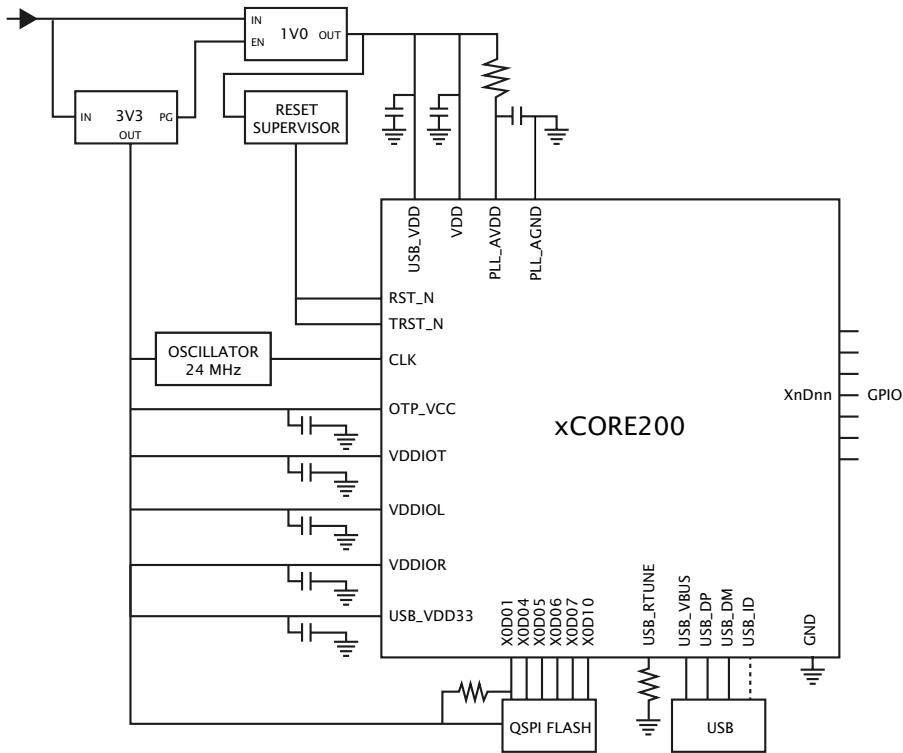
## 2.2 - XU216 SoC



The MB2K2 is based around an XU216-512 SoC (part of the xCORE200 series) which has all of the processing and RAM required for the emulated system. Unlike conventional microcontrollers the XU216 runs multiple realtime tasks simultaneously and communicates between these tasks using an internal high speed network. xCORE microcontrollers are completely deterministic, so it's possible to code in software hard realtime functions that traditionally require dedicated hardware such as USB or video interfaces.

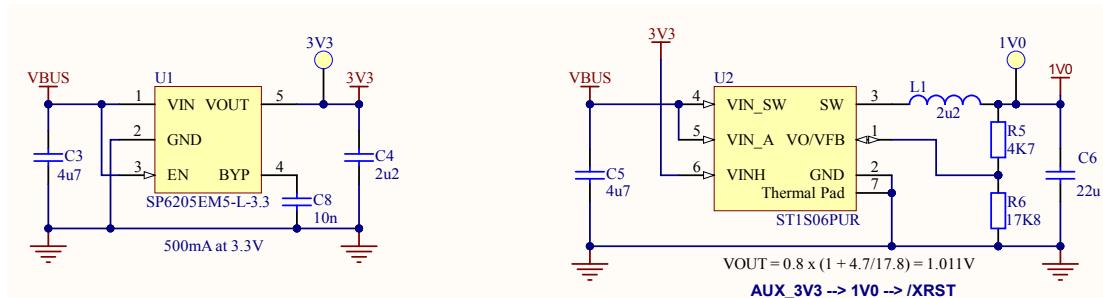
Key features of the XU216-512-TQ128 include:-

- Two tiles containing 8 32-bit 125MHz RISC cores with highly integrated I/O and on-chip memory
- A hardware based scheduler which performs functions similar to an RTOS. It services and synchronises events in a core and triggers cores on events generated by hardware resources such as the I/O pins, communication channels and timers. Once triggered, a core runs independently and concurrently to the other cores.
- Channels and channel ends allowing tasks running on cores to communicate using channels formed between two channel ends.
- A switch and links between tiles allowing channel communications to be routed. One channel travels off chip to the XTAG connector allowing real time debugging of running tasks.
- I/O pins connected to the processing cores by hardware response ports. The port logic can drive pins or sample the value on a pin optionally waiting for a particular condition.
- A set of programmable clock blocks that can be used to govern the rate at which ports execute.
- Each tile integrates a bank of SRAM for instructions and data, and a block of one-time programmable (OTP) memory that can be configured for system wide security features.
- A PLL used to create the core's processor clock given a low frequency external oscillator.
- A USB PHY providing High-Speed and Full-Speed, device, host, and on-the-go functionality.



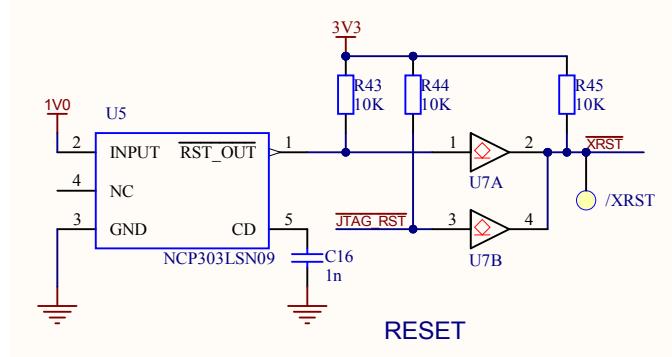
The MB2K2 is a simple implementation of the standard Xmos reference design for the XU216 only adding an external battery backed RTC, buffering or level shifting where necessary for the external ports together with option switches and indicator LEDs.

## 2.2 - Power



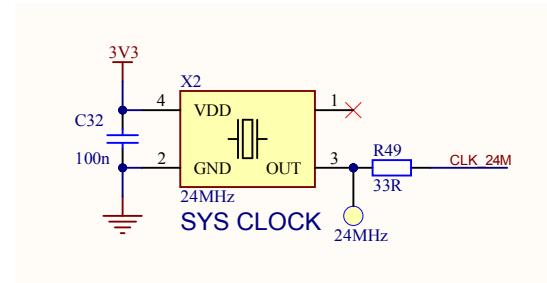
The MB2K2 is powered entirely via the USB connector and requires a notional 5V supply at a maximum of 250mA (approx 150mA nominal). The 5V supply powers the VGA video buffer and is passed to the PS/2 connector for the external keyboard. Two further power rails are derived from the 5V supply, 3.3V (via a linear regulator) which is used for I/O on the XU216, VDD for the QSPI flash, FDC buffers and the RTC and 1.0V (via a switch mode buck regulator) which is used for the XU216 core logic. The 1V rail is enabled by the 3.3V rail thus ensuring that the correct power sequence of 3.3V rising before 1V that is required by the XU216 is followed.

## 2.3 - Reset



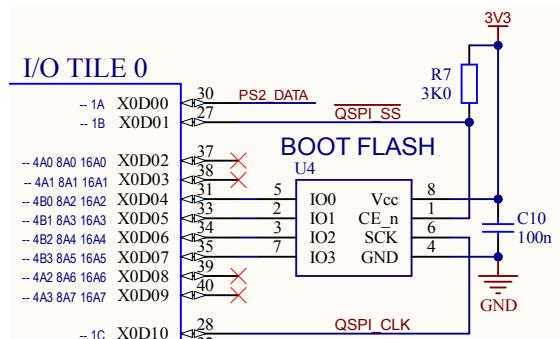
The Xu216 is reset on power up by a NCP303 series voltage detector which releases reset when the 1V rail has stabilised. A separate tact switch at the edge of the PCB is connected to the XU216 I/O and can be used as a ‘soft’ reset for the emulated processor.

## 2.4 - Clocks



All the clocks used in the MB2K2 (with the exception of the 32,768 Hz RTC clock) are derived from a single 24 MHz clock oscillator. Internally to the XU216 this 24 MHz clock is multiplied by a PLL to 48 MHz for the USB PHY, 125 MHz for the core logic and 31.25 MHz for the VGA pixel clock.

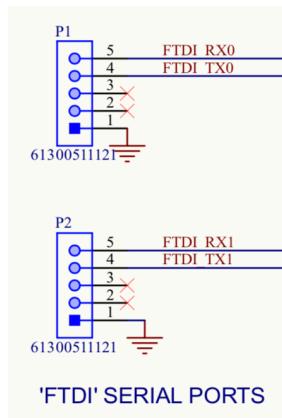
## 2.5 - Boot Flash



An 8-32 Mbit QSPI flash device is used to store the firmware for the XU216 and optionally in a separate data portion the PROMdisk for the emulated processor. This flash device is initially programmed by the Xmos toolchain via an ‘XTAG’ debug interface plugged into the PCB but may

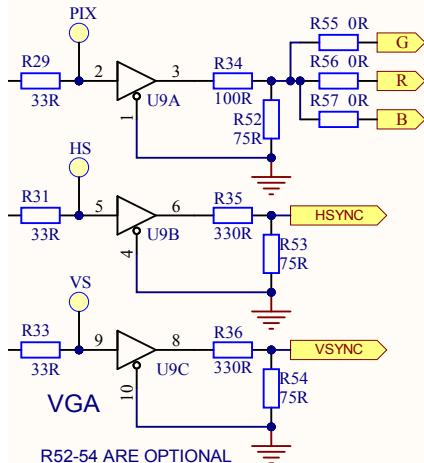
subsequently be read and written to programmatically by the running firmware.

## 2.6 - Optional serial ports ('FTDI')



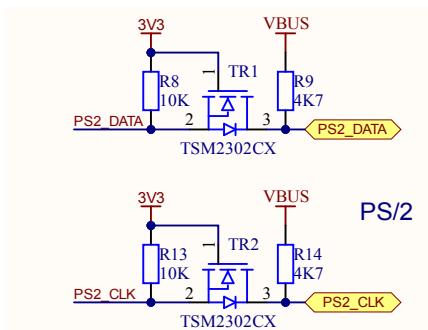
The MB2K2 design has connectors for two optional 3V logic level serial ports that are designed to connect to USB/serial cables such as the FTDI TTL-232R-3V3. Note that only Tx/Rx and GND are connected and care should be taken to ensure that any adapter cable uses 3V logic levels to avoid damage to the MB2K2.

## 2.7 - VGA interface



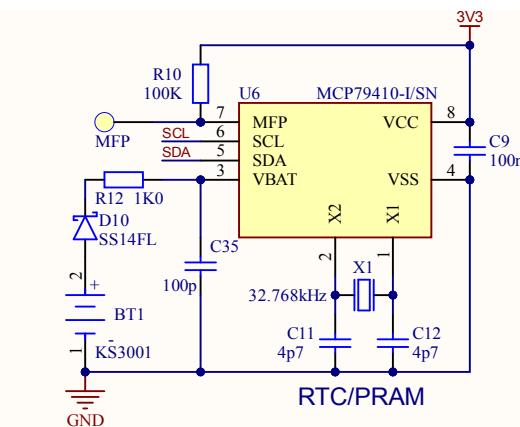
The VGA pixel and timing logic is contained purely in the XU216 and so only a simple buffer is required to drive the VGA 75Ω RGB and sync lines. Each output has a series current limiting R and an option termination R which is not required in most situations. The monochrome pixel output drives the R,G, and B lines equally for a White on Black display however removing one or more of the 0Ω links will allow other colours to be chosen such as Yellow or Green for a 'retro' phosphor CRT display look. :-)

## 2.8 - PS/2 keyboard interface



To replace the ‘hard to obtain’ parallel TTL keyboard of the MB2 the MB2K2 has an interface compatible with most PS/2 PC style standard keyboards. There are a pair of bi directional level shifters used to convert the 5V logic levels of the keyboard to the 3V logic levels of the XU216.

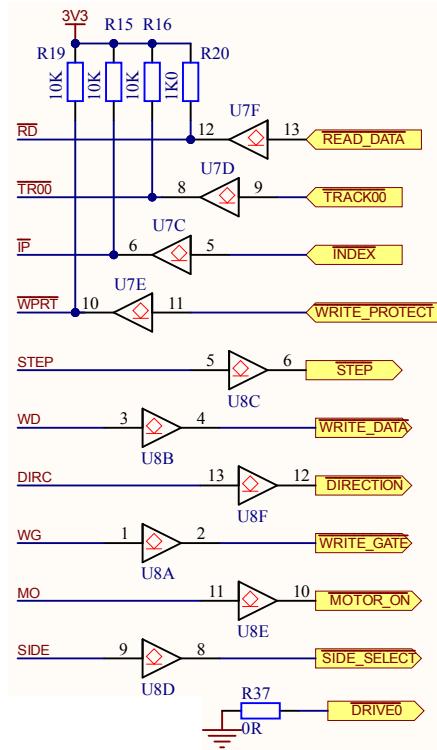
## 2.9 - Real Time Clock



The one significant piece of logic which cannot fit into the XU216 due to standby power concerns is the real time clock (RTC). This is implemented on the MB2K2 using a common MCP79410 variant from Microchip. This device includes a low power 64 byte SRAM and a 128 byte EEPROM that retains data even when the battery is disconnected. Timing for the RTC is provided by an internal oscillator driving a 32,768Hz crystal. The RTC is powered by either the 3.3V supply during operation or a PCB mounted 3V Lithium coin cell when the USB power is disconnected. The coin cell holder will accept either a CR1261, CR1220 or CR1225 cell. During standby the RTC clock keeps time and the contents of the SRAM are preserved.

As in the MB2, the RTC is used to automatically set the OS date (both for FLEX and OS-9) and the SRAM stores system parameters such as the allocation of logical to physical drive types and FLEX’s ASN and TTYSET values. The MFP output of the RTC can be used for calibration of the crystal oscillator for more accurate timekeeping.

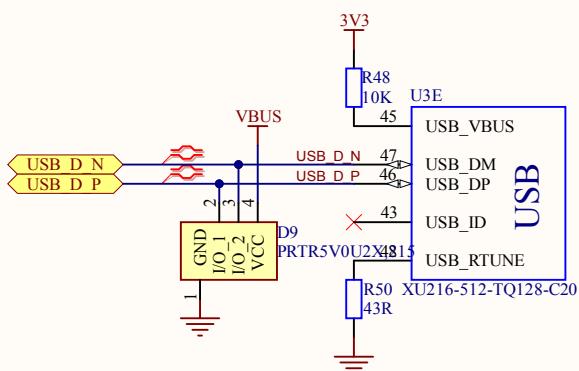
## 2.10 - Floppy disk interface



The MB2K2 supports the connection of a single 3/12" floppy drive with a standard 34 way .1" header and a pin out that matches the MB2. Simple open collector buffers are used that allow translation between the 3V logic levels of the XU216 and 5V logic levels of the floppy drive.

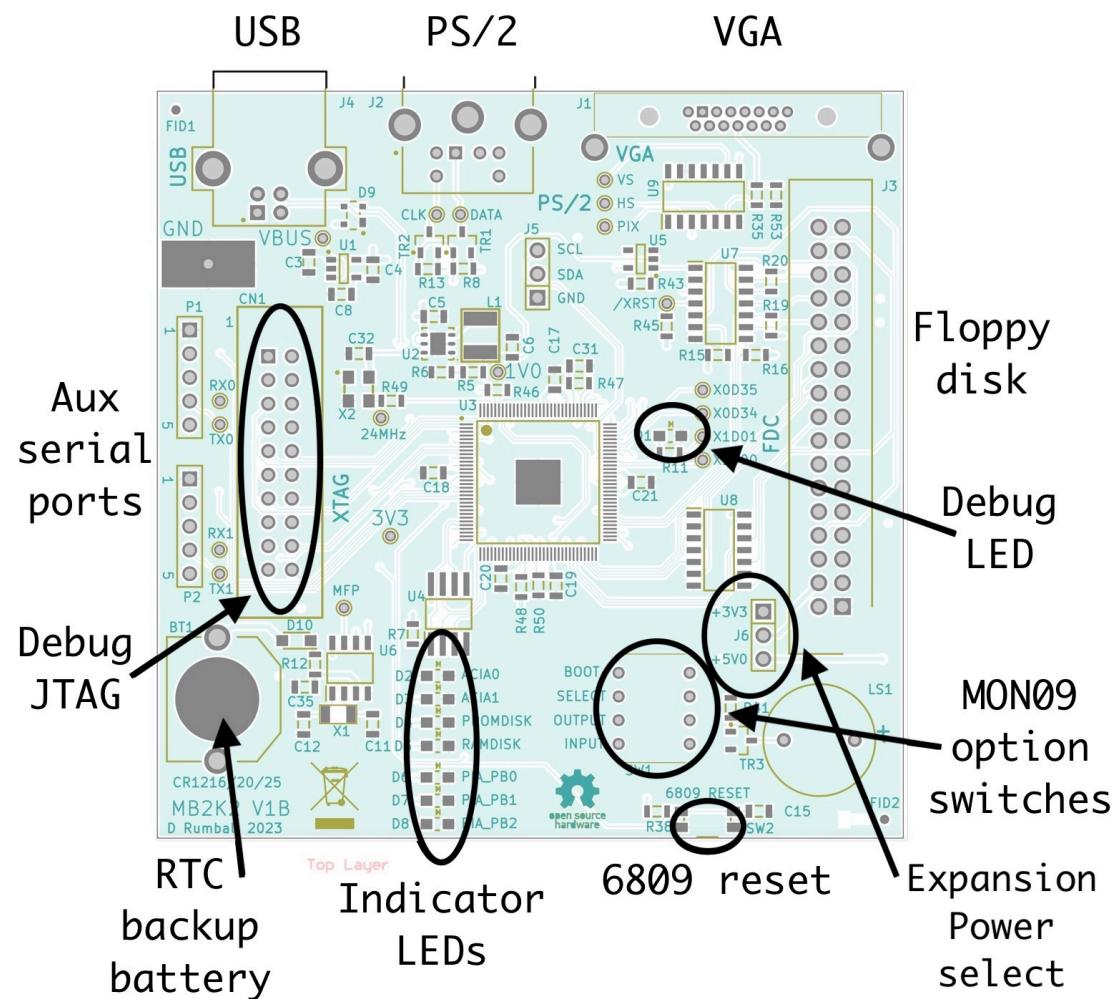
Note that the floppy disk interface emulation (WD1770) of the MB2K2 is not yet complete and will be included in a later release.

## 2.11 - USB interface

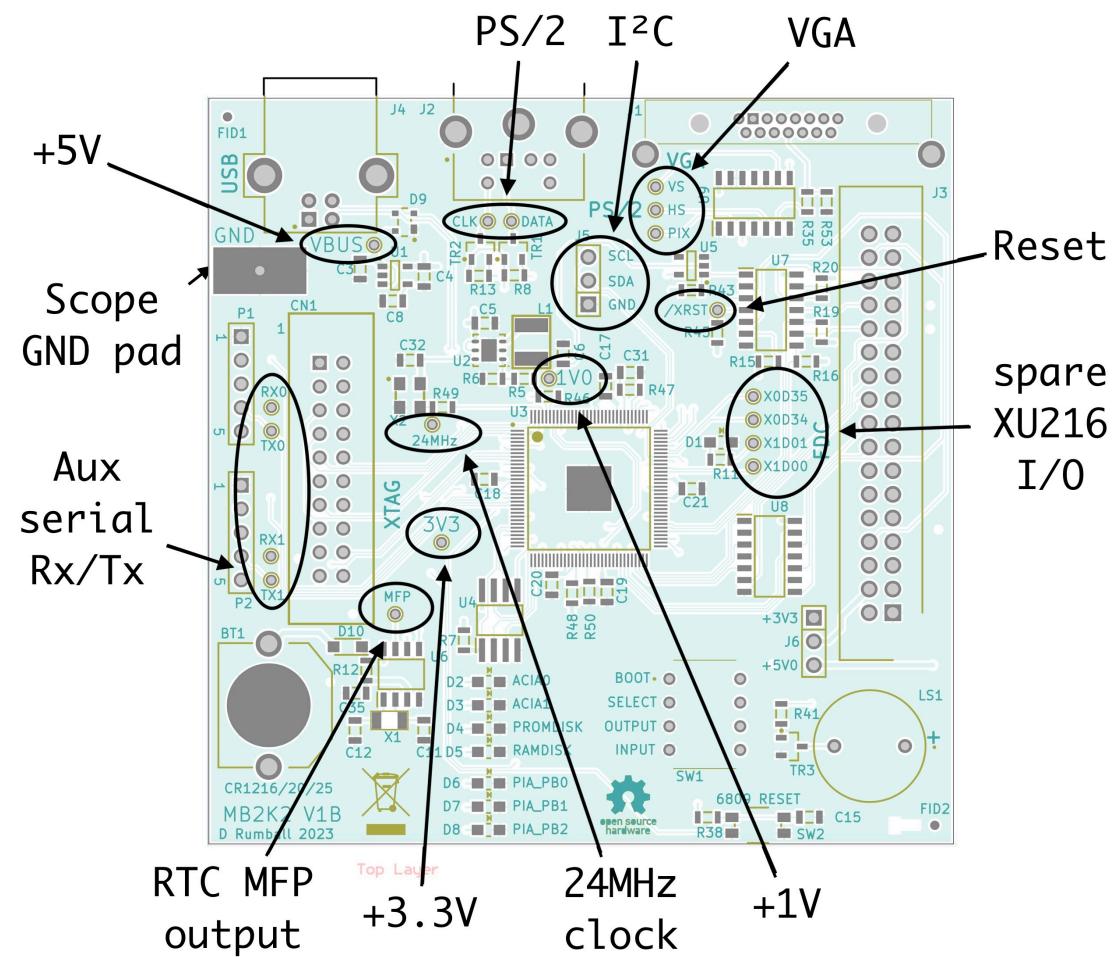


As the XU216 contains the USB PHY and all support logic, the USB interface hardware of the MB2K2 consists only of ESD protection.

## 2.12 - Connector, switches and LED locations



## 2.13 - Test point locations





## Section 3 - Firmware notes

As the MB2K2 hardware is fairly simple and generic, the emulation of the MB2 or other systems is defined entirely by the firmware running on the XU216. However the resulting code looks quite different from a ‘pure’ PC based software emulation and indeed has a hardware like architecture that looks very different from usual.

The MB2K2 project grew from the thought that the RISC processor cores and connecting hardware of the xCORE SoCs could map quite elegantly onto the LSI devices and busses of the MB2 where each core would emulate the internal operation of each LSI chip of the original and the channels connecting each core would map onto the address/data busses.

I’d recommend that the reader have a basic understanding of the xCORE architecture and XC language before reading this section. The firmware documentation of this release includes copies of the Xmos programming guide and XTIMEcomposer IDE/toolchain user guide to help with this.

The experienced Xmos developer might wonder why I haven’t used some of the more modern abstract features of the XC language such as combinable and distributable processes and interfaces which would potentially make the code more compact. This was a purely an aesthetic decision on my part as these higher level abstractions would blur the boundaries between the discrete mapping mentioned above and I really wanted to keep that.

### 3.1 - Project structure

The source file structure consists of a number of Xmos lib projects together with the MB2K2 project folder :-



There are two classes of build configurations in the project, ‘usb’ which uses the USB connection for serial connections and ‘ftdi’ which replaces the USB interface with a pair of buffered UARTs. Each is further split into ‘debug’ which has optimisation set to -O0 and adds support for the use of debugPrintf() and ‘release’ which has optimisation set to -O3 and removes all debugging support.

The release configs should be used when not debugging as the compiled code runs 3-5 times faster than the debug configs!

### 3.2 - Architecture and plumbing

Below is the ‘par’ statement that shows the placement of tasks on the tiles/cores and the channel connections between them (the ‘plumbing’).

```

par {
    on tile[0]: cpu_execute(c_addrData); // (6809)
    on tile[0]: decodeMem(c_addrData, c_acia, c_rtc, // (MC6883)
                           c_pia, c_ramdisk, c_promdisk,
                           c_gdc);

    on tile[0]: rtc(c_rtc); // (MC146818) I2C -> external RTC/EEPROM
    on tile[0]: pia(c_pia); // (MC6821) includes PS/2 keyboard interface
    on tile[0]: promdisk(c_promdisk); // external QSPI flash (1/2MB -> 3MB)
    on tile[0]: gdc(c_disp, c_gdc); // (uPD7220A) graphics engine
    on tile[0]: gdcDisplay(c_disp); // (uPD7220A) display interface
    //on tile[0]: fdc(c_fdc); // (WD1770)

    on tile[1]: DasBlinkenLights(p_debug_led);
    on tile[1]: ramdisk(c_ramdisk); // 40track DS/SD emulation (200KB)
    on tile[1]: acia(cdc_data[0], cdc_data[1], c_acia); // (WD2123)

    // USB interface
    on tile[1]: xud(c_ep_out, XUD_EP_COUNT_OUT, c_ep_in, XUD_EP_COUNT_IN, null, XUD_SPEED_HS, XUD_PWR_SELF);
    on tile[1]: Endpoint0(c_ep_out[0], c_ep_in[0]);
    on tile[1]: CdcEndpointsHandler(c_ep_in[CDC_NOTIFICATION_EP_NUM1],
                                    c_ep_out[CDC_DATA_RX_EP_NUM1],
                                    c_ep_in[CDC_DATA_TX_EP_NUM1],
                                    cdc_data[0]);
    on tile[1]: CdcEndpointsHandler(c_ep_in[CDC_NOTIFICATION_EP_NUM2],
                                    c_ep_out[CDC_DATA_RX_EP_NUM2],
                                    c_ep_in[CDC_DATA_TX_EP_NUM2],
                                    cdc_data[1]);
}

// of par

```

The tasks are distributed between the tiles to balance memory usage and MIPs.

Tile 1 is defined as having the USB interface and this forces XUD, endpoint0 and the two CDC handlers plus the ACIA code to be on that tile as they share memory via interfaces. This also limits the number of tasks so as not to starve the hard real time task XUD of MIPs. Since the RAM usage of tile 1 will be low the RAMdisk task (which uses 200KB of memory) is placed here also. Finally the ‘blinky’ debug LED task is also placed on tile. Note that the compiler will warn that more cores than the limit of six for a USB tile are allocated but this is fine as the debug LED task uses minimal RAM/MIPs.

Tile 0 holds the remaining tasks with one core free for the future floppy disk controller interface emulation. Note that the uPD7220 emulation is split between two cores, one for the display interface that generates the hard real time VGA pixel and sync signals and a second for the drawing engine. These two tasks must be on the same tile as they share access to the approx 50KB frame buffer between them. The remaining RAM is used by the decode/mem task (64KB emulated RAM and 4KB shadow RAM) and code space for the remaining tasks.

The firmware can be customised with the free Xmos ‘xTIMEcomposer’ toolchain. Details on this are contained in the ‘Getting Started’ and ‘Firmware build & flashing’ documents included with this release.

### 3.3 - cpu\_execute()

The 6809 code comes from an open source emulation by Arto Salmi, Jozef Fabcic and Brian Dominy. This was chosen more or less at random and most likely is not the fastest or most compact example. However, it does work! Note that this is an implementation in ‘C’ rather than ‘XC’ and as such needs to use an external library to support channels and other XC features. This lib is called ‘xcore-c’ and features support for channel and streaming channels, ports and clock blocks, timers, hardware locks , select and interrupt events.

The CPU communicates via a channel with the decodeMem task. For a read transaction, the CPU’s reset switch state is read from bit 31 of the word and used to reset the CPU if asserted.

### 3.4 - decodeMem()

The decodeMem task emulates the 6883 ‘SAM’ chip of the MB2 and as such controls access to the CPU’s 64KB address space. In this implementation it also decodes addresses from the CPU and handles access to the peripheral devices such as the PIA and DUART (ACIA) via channels to the tasks emulating those devices.

A simple transaction protocol is used where the 32 bit word transferred from the CPU has the address in the low 16 bits, data in the next 8 bits and a transaction type flag in the upper 8 bits. This flag is 0x00 for a read cycle and 0xFF for write. This data is then written to RAM or if the access is in a peripheral address range, the word is passed to the peripheral. For a read transaction, the byte read from RAM or the peripheral device is sent back along the same channel in the lowest 8 bits.

For CPU read transactions, the decodeMem task reads the ‘soft’ CPU reset switch and if the switch input is low (switch pressed) the task debounces the input and waits for the switch to be released then sends the reset to the CPU by setting bit 31 of the returned word.

The CPU memory is reset after power up and two sections are initialised, the first contains an image of the OS-9 kernel and boot modules from \$0000-\$2FFF and the second contains the MON09 ‘eprom’ image from \$E000-\$FFFF. This initial data is added to the source by means of a header file. This file is generated by a batch command that should be run after the MON09 or os9 6809 sources are modified. Details of this procedure may be found in section 4.

In the same manner as the MB2 a 4KB section of RAM at \$E000 may be remapped from ‘eprom’ to RAM. This area is called the ‘shadow RAM’ and is mapped in whenever control is passed from MON09 to FLEX. In the MB2, this area was used by several programs and FLEX utilities so is emulated in the MB2K2. A portion of the shadow RAM is initialised after reset in the same way as the main RAM. In this case a bit mapped character set is placed from \$E400 up and this is used by some versions of the MON09 ‘GDCOUT’ character drawing routine. See the GDC description for more details. As for the main RAM, this initialisation is defined by a header file more details of which may be found in section 4.

MB2K2 address map

-- RAM \$0000 - \$AFFF (\$0000 - \$BFFF for FLEX)

-- OS-9 modules \$B000 - \$DDFF

-- MON09  
\$E000 - \$EFFF monitor commands (switched out when FLEX running)  
\$F000 - \$FFFF monitor subroutines and drivers  
\$DE00 Scratch RAM + stack space.  
(RAM+127-16) Top of system stack.  
(RAM+384) Start of scratch space.

-- I/O space  
\$FF00 I/O base address.

PIA1  
KEYREG EQU \$FF00  
PIACA EQU \$FF01  
SYSREG EQU \$FF02  
PIACB EQU \$FF03

DUART  
UARTD1 EQU \$FF08  
UARTC1 EQU \$FF09  
UARTD2 EQU \$FF04  
UARTC2 EQU \$FF05  
BAUD1 EQU \$FF0C  
BAUD2 EQU \$FF0D

FDC  
COMREG EQU \$FF10  
TRKREG EQU \$FF11  
SECREG EQU \$FF12  
DATREG EQU \$FF13

GDC  
GDCPRM EQU \$FF14  
GDCCOM EQU \$FF15

RTC  
RTCADD EQU \$FF18  
RTCDAT EQU \$FF19

RDC (ramdisk controller)  
COMREG EQU \$FF20  
TRKREG EQU \$FF21  
SECREG EQU \$FF22  
DATREG EQU \$FF23  
MODREG EQU \$FF24

PDC (promdisk controller)  
COMREG EQU \$FF30  
TRKREG EQU \$FF31  
SECREG EQU \$FF32  
DATREG EQU \$FF33  
MODREG EQU \$FF34

### 3.5 - rtc()

The RTC task emulates the 146818 RTC used on the MB2. The code passes RTC register accesses to an external Microchip MCP7941 series device via a simple ‘bit banging’ I<sup>2</sup>C interface. The emulation involves register address remapping, transposition from binary to BCD formats and spoofing of power fail detection.

One thing to note is that there is a calibration value defined in the code which allows adjustment of the RTC frequency as per section 5.2.3 of the MCP7941X data sheet.

```
#define CALIBRATION_VALUE 0x7D // + 250 32.768KHz clocks/min
```

This value should be calculated from the time drift measured over a period of days for each individual system for increased RTC accuracy.

### 3.6 - pia()

The PIA task emulates the 6821 PIA used on the MB2 for keyboard input on port A and the system register on port B that had the following bit mappings:-

PIA port B definitions (SYSREG)

- \* bit 0 - 3 are outputs
- \* 0 - DRV (DRV and /DDEN are used by the floppy disk interface)
- \* 1 - /DDEN
- \* 2 - MAP bit (maps out bottom 4K of monitor (\$E000-\$FFFF) when 0)
- \* 3 - BELL
- \* bit 4 - 7 are inputs
- \* 4 - Initial input port
- \* 5 - Initial output port
- \* 6 - Select OS to autoboot
- \* 7 - Auto boot OS

The MB2K2 has a 4 way DIP switch to match the MB2 and the switches have the following functions:-

Switch 0 Sets the auto boot function.

on = Auto boot into FLEX or OS-9 on reset  
off = run MON09 on reset

Switch 1 Selects the OS to boot into.

on = Auto boot into OS-9 on reset  
off = Auto boot into FLEX on reset

Switch 2 Sets the initial output port to be used after reset

on = PORT 1 (serial port 0) - USB  
off = PORT 0 (GDC screen)

Switch 3 Sets the initial input port to be used after reset

on = PORT 1 (serial port 0) - USB  
off = PORT 0 (PS/2 keyboard)

As it is now difficult to obtain parallel TTL keyboards this is emulated by including a PS/2 compatible keyboard interface in the PIA task. Keypress messages from the keyboard are mapped to ASCII values by tracking the key up/key down and shift states and applying these states and the raw key value to a pre defined look up table. This table is composed of four sections, one each for shift and shift lock on/off. This mapping is defined in the keycap header file and this file can be simply edited to change the key mapping as detailed in section 4. The default mapping is included in appendix 3 and is defined to be compatible with the ‘CEDRIC’ screen text editor which is included as part of the standard PROMdisk.

### 3.7 - promdisk()

The PROMdisk task functionally emulates the EPROMdisk of the MB2 but doesn’t directly emulate the 8255 PIA in the original design. Instead this task acts as an interface to the external QSPI flash that is used as the boot image for the XU216. This flash is split into two partitions, the first holds one or more boot images and the second holds a combined disk image (.DSK) file containing the MB2K2’s system volume for FLEX followed by the boot volume for OS-9. Typically for a 4MB flash device the first 1MB is dedicated to the XU216 boot images and the remainder for the PROMdisk.

The promdisk image is loaded into the data portion as part of the firmware flashing process as mentioned in section 4 of this guide and the separate ‘Firmware build and flashing’ guide.

The format of each PROMdisk defaults to a 192 track single sided/single density disk of approx 1.44MB.

```
#define SECTORS_PER_TRACK 30
#define TRACKS_PER_DISK 192
#define BYTES_PER_SECTOR 256
#define PROMDISK_SIZE 1474560
```

Note that this is not one of the standard FLEX formats and will not be compatible with certain FLEX diagnostic utilities that require a drive to be one of a limited number of standard formats.

Other formats may be used for user defined PROMdisks as the firmware reads the System Information Record (SIR) of the FLEX disk image in flash and uses this to define the correct offsets into the image. The combined FLEX/OS-9 PROMdisk may be any size up to 3MB.

Under FLEX the PROMdisk is by default read only and any attempt to write to the disk will return an error. However there is a flag in MON09’s memory that can be set to allow writes to the PROMdisk by FLEX and this flag is set by the ‘PDRW’ (Promdisk read/Write) command and reset by ‘PDRO’ (PROMdisk read only). A reset will set the default to read only.

Under OS-9 the PROMdisk is set to r/w always.

Note that there is no wear levelling and repeated writes (10,000’s) will eventually ‘wear out’ the part of the flash image containing frequently written sectors.

### 3.8 - `gdcDisplay()`

The GDC emulation consists of two separate tasks, the first (`gdcDisplay()`) converts the the graphics and text frame store data to a VGA compatible serial data stream and sync signals whilst the second interprets commands from the 6809 and emulates the drawing engine of the 7220A.

The display timings are all derived from the XU216's 125MHz core logic clock. This is divided by four to give a pixel clock of 31.25MHz which then drives the output ports for the pixel data and sync signals.

```
// outputs are all clocked at pixel rate
// pixel clock = 31.25MHz (1/4 of 125MHz system clock)
configure_clock_rate(pixel_clk, 125, 4);
configure_out_port(p_pix, pixel_clk, 0);
configure_out_port(p_hs, pixel_clk, 1);
configure_out_port(p_vs, pixel_clk, 1);
start_clock(pixel_clk);
```

The ports are configured to accept 32 data writes which are then buffered and serialised using the pixel clock.

```
on tile[0] : buffered out port:32 p_pix = XS1_PORT_1M;
on tile[0] : buffered out port:32 p_hs = XS1_PORT_1N;
on tile[0] : out port p_vs = XS1_PORT_10;
```

In this way it's possible to run a real time display with a simple code loop and the hardware task switching inherent in the XU216 architecture ensures that the timing of the video outputs cannot be disturbed by the other tasks running on the device.

The code to generate a line of video then is just a few simple statements :-

```
// partition 1
if (lengthPart1 != 0) {
    h = startPart1;

    for(l=0; l < lengthPart1; l++) {

        // horizontal front porch
        p_hs <: 0xFFFFFFFF;
        p_pix <: 0x00000000;

        // horizontal sync
        p_hs <: 0x00000000;
        p_pix <: 0x00000000;

        // horizontal back porch
        #pragma loop unroll
        for (i=0; i<HBP_WORDS; i++ ) {
            p_hs <: 0xFFFFFFFF;
            p_pix <: 0x00000000;
        }

        // active line
        #pragma loop unroll
        for (i=0; i<HAL_WORDS; i++ ) {
            p_hs <: 0xFFFFFFFF;
            p_pix <: bitrev(((vram[h] & 0x0000FFFF) << 16) | ((vram[h] & 0xFFFF0000) >> 16)) & blank;
            h++;
        }

        // if repeat field at end of even lines step pointer back a line
        if ((repeatLine) && ((l/2)*2 == 1)) {
            h -= HAL_WORDS;
        }

        // of active lines for
    } // of partition 1
}
```

Note that the bit order of the 32 bit word needs to be reversed and the two 16 bit sub words swapped so as to output bits in the correct order for display.

As per the 7220A two display partitions are supported and the starting addresses and lengths of these portions are passed to the display task from the drawing engine task over a channel which is synchronised to the vertical blanking intervals so that partition changes do not disturb the display.

Because the VGA output is non interlaced there is no need for the interlaced/non interlaced display switching on the MB2. Instead the text display mode simply emulates a ‘repeat field’ display by repeating each scan line to give the same effect. The repeat field parameter is passed into the display task along with a ‘display on/off’ parameter together with the partition information.

Note that the frame store memory is shared between the display and drawing engine tasks and unlike normal ‘C’ this is treated as an error by the XC compiler. This may be circumvented by using the ‘unsafe’ pragma that informs the compiler that we really do know what we’re doing and that it should allow memory sharing.

### 3.9 - gdc()

This is the second task of the GDC emulation which handles communication with the 6809 and implements the drawing engine of the 7220A. The emulation of the drawing engine is not complete as of the time of writing (ver 0.9) but it is sufficient to work with MON09’s graphics drivers and the majority of the MB2’s software including the large graphics demo. The missing parts include the general purpose ‘fill’, zoom, rectangle and circle drawing and any operation that reads data back from the GDC. These missing parts are planned to be implemented in later versions.

The GDC emulation also doesn’t have the command and parameter FIFOs of the 7220A, however this is a deliberate omission as the channel used to communicate between the decodeMem task and the GDC task inherently contains buffering and the blocking nature of the channel communication protocol means that the FIFOs are unnecessary. Likewise the ‘busy’ bit of the GDC’s stays register isn’t implemented as the channel will just harmlessly stall if the graphics engine is busy.

There is one significant difference between the emulation and the 7220A and that is the addition of a new command and corresponding sub commands not in the original chip. This command is designed to act as an accelerator for various ‘bottleneck’ routines such as cursor location generation and graphics character drawing.

The base command is 0xDx and the sub commands are listed below :-

```
// command is of form Dx where x is the four bit sub command :-
// x = 0 - draw char at existing eAD/dAD
//      1 - draw inverse char at existing eAD/dAD
//      2 - process char in terminal emulator using embedded char set *
//      3 - cursor off
//      4 - cursor on
//      5 - toggle cursor
```

```
//      6 - calculate eAD/dAD from row, col and offset
//      7 - calculate eAD/dAD from x,y (SETCRG replacement)
```

Sub commands 0 and 1 are faster versions of the 7220A's 'GCHRD' that use the internal char set and assume a fixed character cell size and drawing direction while sub command 2 implements a full terminal emulator that just takes a stream of ASCII characters and control codes. The control codes match those of the terminal emulator in MON09 and are listed in appendix 1. Before using this internal terminal emulator it should be initialised by sending it a 0x0C (CLEARSCREEN) character.

Note that the terminal emulator character set is defined in `char_set.h` where after an initial eight bytes that describe the character set attributes each character is represented by an 11 byte byte sequence thus :-

```
// character set attributes
84, // screen chars/row
24, // screen rows
7, // char x pixels
11, // char y rows
9, // bounding box pixels
12, // bounding box rows
4, // initial attributes
11 // char spacing (pixels)

.
.

.

,
0b00111000 //Character = '&'
,
0b01000100
,
0b01000100
,
0b00101000
,
0b00010000
,
0b00101001
,
0b01000110
,
0b01000110
,
0b00111001
,
0b00000000
,
0b00000000
.
.
.
```

The graphics display resolution is 768 1 bit pixels by 576 lines whilst the text display resolution is 768 1 bit pixels by 288 lines and the two frame stores exist as a contiguous section of RAM of  $(768*576/16)*3/2$  words or approx 81KB. This is defined as a array of 'short' (16 bit) words to match the 7220A's memory width. The base address of the graphics display is 0x0000, the text display starts at 0x6C00 (16 bit words) and the top of the frame store is 0xA1FF (16 bit words).

The graphic frame store is loaded at startup with an image defined in 'bootImage.h'. This image can be viewed by using the 'graph' command after booting FLEX but before running any other graphics command.

### 3.10 - fdc()

The floppy disk controller will be implemented in a later release.

### 3.11 - DasBlinkenLights()

This task implements a simple ‘breathing’ LED that is used to indicated that the firmware is up and running. It uses a timer to trigger events and so uses the minimum of MIPs.

### 3.12 - ramdisk()

In the same manner as the PROMdisk the RAMdisk task is functionally equivalent to the RAMdisk of the MB2 but doesn’t directly emulate the original design. In the MB2 the RAMdisk uses part of the GDC’s memory but in the MB2K2 the RAMdisk memory is a separate part of the XU216’s RAM.

The RAMdisk’s format is defined in the header file:-

```
#define SECTORS_PER_TRACK 20
#define TRACKS_PER_DISK 40
#define BYTES_PER_SECTOR 256
#define RAMDISK_SIZE 204800
```

After reset the RAMdisk is formatted according to the defined format.

### 3.13 - acia() and USB

The acia task emulates the 2123 DUART used on the MB2. Rather than an implementation of a standard UART however, the MB2K2’s serial ports pass through the USB connection as CDC class virtual com ports. These ports are implemented as per the Xmos app note ‘AN00184 USB CDC Class as Virtual Serial Port’ and use a total of four cores on tile 1:-

- A core running the XUD USB device library.
- A core implementing Endpoint0 responding to both standard and CDC class-specific USB requests.
- Two cores handling the data endpoints and notification endpoints of the CDC ACM class, one for each virtual com port instance.

The acia task communicates with the endpoint handlers by means of an XC interface of type ‘usb\_cdc\_interface’ which has methods to check for received data (available\_bytes) and read/write characters. (get\_char & put\_char). The four USB cores communicate in part using shared memory so need to be placed on the same tile. Note that the virtual com port doesn’t have a defined baud rate associated with it at the device end so the monitor routines and storage associated with that are not implemented on the MB2K2.

It’s recommended that Windows 10 is used for the host computer (if using Windows is required) as this natively supports dual CDC class devices, however if Windows 7 is used then a driver needs installing on the host system. This driver is included in the release and is located in the MB2K2 project folder. No driver is of course required for MacOS or Linux.

The firmware also supports replacing the USB interface with a pair of UARTs which are attached to the auxiliary serial connectors on the PCB. These are intended to be used with USB to serial conversion cables such as

the FTDI ‘TTL-232R-3V3’ in situations where the USB connection is used for power only.

The UARTs are configured for baud rate of 115200 with eight bit data, no parity and one stop bit and have 1KB buffers on the receive side.

## Section 4 - Customisation

In essence the entirety of the MB2K2 firmware is customisable as the full source code is available in the releases however within the existing MB2 emulation there are also sections that can be customised without changing the underlying firmware and these are detailed in this section.

### 4.1 - MON09

The source of the embedded 6809 assembly language MON09 monitor is located in the ‘mon09’ folder in the `mB2K2 project. After modifying the source it needs to be assembled and then merged into the 64KB memory array together with the FLEX image.

To assist with this process there is a batch file in the MON09 folder which will run the assembler (A09), merge the generated SREC file and FLEX SREC file into the memory array definition then copy the resultant header file into the source files. When the project is subsequently built the new version of MON09 will be included.

Included with the MON09 sources are optional versions of the GDC drivers that use the new additions to the GDC’s command set mentioned in the firmware description section.

GDCSUBS\_V1.TXT - use the original unmodified GDC commands  
GDCSUBS\_V2.TXT - use the new versions of SETCRG, POINT and LINE (faster)  
GDCOUTV1.TXT - use the original unmodified GDC commands for text display  
GDCOUTV2.TXT - use the versions of RCTOCR and PUTCHAR (faster)  
GDCOUTV3.TXT - use the new GDC internal terminal emulator (fastest)

### 4.2 - O/S images

The source code for the OS-9 kernel and core modules that are pre loaded into RAM is in the ‘os9’ folder in the project. After modifying any of these files it is necessary to run the ‘build’ script in the os9 folder followed by the ‘build’ script in the ‘MON09’ folder in order to merge the assembled files into the RAM image.

To use a different version of FLEX simply replace the ‘flex.cor’ file on the PROMdisk image (FLEXPD.dsk) with the new version and then run the ‘build’ script in the PROMdisk folder to merge the FLEX and OS-9 PROMdisk images into the single MB2K2PD.dsk image that is used by xFlash.

### 4.3 - GDCOUT character set

The character set used by MON09’s native terminal emulation (not the GDC’s internal version) is pre loaded into the 6809’s ‘shadow RAM’ by a header file in the RAM folder in the MB2K2 project. After the initial padding bytes there are eight bytes that describe the character set attributes and after that each character is represented by an 11 byte byte sequence thus :-

```

// character set attributes
84, // screen chars/row
24, // screen rows
7, // char x pixels
11, // char y rows
9, // bounding box pixels
12, // bounding box rows
4, // initial attributes
11 // char spacing (pixels)

.
.

.
.

, 0b00111000 //Character = '&'
, 0b01000100
, 0b01000100
, 0b00101000
, 0b00010000
, 0b00101001
, 0b01000110
, 0b01000110
, 0b00111001
, 0b00000000
, 0b00000000
.
.
.
.
```

#### 4.4 - PS/2 keyboard mapping

Keypress messages from the PS/2 keyboard are mapped to ASCII values by tracking the key up/key down and shift states and applying these states and the raw key value to a pre defined look up table. This table is composed of four sections, one each for shift and shift lock on/off. This mapping is defined in the ‘keymap.h’ header file located in the PIA folder in the MB2K2 project and this file can be simply edited to change the key mapping. An example of the mapping is shown below.

0x00	//Scancode = \$00		
,0x05	//Scancode = \$01	F9	CEDRIC - delete char
,0x00	//Scancode = \$02		
,0x19	//Scancode = \$03	F5	CEDRIC - cut
,0x0E	//Scancode = \$04	F3	CEDRIC - search and replace
,0x03	//Scancode = \$05	F1	CEDRIC - search forward
,0x1A	//Scancode = \$06	F2	CEDRIC - search back
,0x08	//Scancode = \$07	F12	CEDRIC - delete left (backspace)
,0x00	//Scancode = \$08		
,0x17	//Scancode = \$09	F10	CEDRIC - delete word
,0x13	//Scancode = \$0A	F8	CEDRIC -
,0x10	//Scancode = \$0B	F6	CEDRIC - paste
,0x01	//Scancode = \$0C	F4	CEDRIC - global replace
,0x09	//Scancode = \$0D	Tab	
'`'	//Scancode = \$0E	'`'	
,0x00	//Scancode = \$0F		
,0x00	//Scancode = \$10		
,0x00	//Scancode = \$11		
,0x00	//Scancode = \$12		
,0x00	//Scancode = \$13		
,0x00	//Scancode = \$14		
, 'q'	//Scancode = \$15	q	

```

,'1'      //Scancode = $16      1
,0x00    //Scancode = $17
,0x00    //Scancode = $18
,0x00    //Scancode = $19
,'z'      //Scancode = $1A      z
,'s'      //Scancode = $1B      s
,'a'      //Scancode = $1C      a
,'w'      //Scancode = $1D      w
,'2'      //Scancode = $1E      2
,0x00    //Scancode = $1F

.
.
.
```

#### 4.5 - RTC PRAM defaults

These are loaded if MON09 detects that power has been lost to the battery backed RTC and are defined in the MON09 file ‘minit.txt’ as the table ‘RTCTAB’ and the values here can be simply edited to change the defaults.

```

RTCTAB FCB %00001111 MB2 values, not used in the MB2K2.
FCB $AA powerfail flag
FCB 0,1,$FF,$FF promdisk, ramdisk, unassigned, unassigned
FCB $7F,0,$3A,$18,$50,0,0,$08,0,0,$1B TTYSET parameters.
FCB 0,1 ASN parameters.
FCB $00,$00,$00,$00,$00,$00,$00 GDC timing parameters
FCB 0,0,0,0,0,0 reserved
FCB $00,$11,$22,$33,$44,$55,$66,$77,$88,$99,$AA,$BB,$CC,$DD,$EE,$FF user
params
```

#### 4.6 - PROMdisk image

The PROMdisk .DSK disk image that is loaded into flash is stored in the ‘promdisk’ folder in the MB2K2 project. It is formed by running the ‘build’ script in the PROMdisk folder to merge the FLEX and OS-9 PROMdisk images into the single MB2K2PD.dsk image that is used by xFlash.

#### 4.7 - boot image

The graphics frame store is initialised at startup with an image defined in the ‘bootimage.h’ header file in the GDC source folder. This image is formed of a byte array generated using the image2cpp utility at <https://jav1.github.io/image2cpp/>

## Section 5 - MON09 commands

There are fewer commands in the MB2K2 version of MON09 compared to earlier versions. This is because the majority of debugging can now be done directly at the OS level since FLEX is 'built in' to the basic system and so software such as the TSC Debug package can be used instead of the lower level debugger. The space freed up has been used for additional drivers instead of commands. Some basic commands have been left in however, and these are documented below.

There are twenty three monitor commands, each represented by a two letter name. Typing the two letters will invoke that command, which will then prompt for any necessary parameters. There are four types of parameter:-

Four digit hex number.....XXXX  
 Two digit hex number.....YY  
 One digit hex number.....Z  
 Text string or character.....T

All commands case insensitive.

### 5.1 - Memory commands

The first six commands are concerned with examining, modifying and testing memory. Of these, the first two have a common control format where a CR will examine the next location or page, a '-' will examine the previous location or page, and any other character will exit the command.

Command: DU Dump memory  
 Format: Hex and ASCII dump of memory from XXXX  
 Action: Displays a 256 byte block of memory as two digit hex values and ASCII. Any non-printable character will be represented by a '.'.

Command: ME Memory Examine and alter  
 Format: Memory examine and alter from XXXX  
 Action: Displays an address and the contents of that address. The contents may be changed by typing a space followed by the new two digit value. A verify is performed on the location changed.

Command: P0 Poke Memory  
 Format: Poke memory location at XXXX value YY  
 Action: Deposits the data into the location without verifying or reading the next address. Used for testing memory mapped peripheral devices where a read would corrupt data.

Command: PE Peek Memory  
 Format: Peek memory location at XXXX  
 Action: Displays the data stored at location without reading the next address.

Command: TM Test Memory

Format: Test memory from XXXX to XXXX

Action: Tests memory in the range given. Any data in the memory will be overwritten.

Note that ‘TM’ command is largely redundant in the MB2K2 as the RAM is internal to the XU216 and so extremely unlikely to have any errors, however this command has been kept as it provides a handy benchmark of CPU performance between different implementations.

Command: FM Fill Memory with constant

Format: Fill memory with constant from XXXX to XXXX value YY

Action: Fills the indicated memory range with the data.

## 5.2 - I/O commands

The monitor input/output may come independently from one of three sources :-

PORT NUMBER	INPUT	OUTPUT
0	Keyboard	Internal display
1	serial port 0	Serial port 0
2	serial port 1	Serial port 1

The initial ports are set on reset by the configuration switches.

Command: SI Set Input port

Format: Set input port to Z

Action: Sets the active input port

Command: SO Set output port

Format: Set output port to Z

Action: Sets the active output port.

## 5.3 - Debug commands

The next five commands are concerned with running programs directly from within MON09. A breakpoint can be set with the BP command which when reached will return control to MON09 with an automatic display of registers. The register values may be modified using the ME command. (The register values are stored in the 10 bytes below the location pointed to by the stack pointer S.)

Command: DR Display Registers

Format: Display registers

Action: Displays the current program register set.

Command: BR Set breakpoint

Format: Set Breakpoint at XXXX

Action: Replaces the byte pointed to by a SWI (\$3F). The breakpoint is cleared when hit and the saved byte returned.

Command: RP Run Program  
Format: Run program from XXXX  
Action: Loads the processor registers, then jumps to program starting at address given.

Command: CP Continue Program  
Format: Continue program after SWI....  
Action: Continues execution of a program from a breakpoint instruction.

Command: JU Jump to program  
Format: Jump to program at XXXX  
Action: Execute a program starting at the given address without loading the registers first.

#### 5.4 - Disk commands

There are five commands for disk control and testing. Note that any errors reported will be a copy of the emulated disc controller status register.

Command: RS Read Sector  
Format: Read sector on drive Z track YY sector YY to XXXX  
Action: Reads a 256 byte sector from the logical drive to memory.

Command: WS Write sector  
Format: Write sector to drive Z track YY sector YY from XXXX  
Action: Writes a sector from memory to the drive.

Command: TS Test drive Stepping  
Format: Test stepping on drive Z Hit any key to stop. . .  
Action: Selects and steps drive between track 00 and track 39 and back again.

Command: DF Disc Format to FLEX standard  
Format: Disc format on drive Z Scratch disc in drive? T  
Action: Formats a disc to single sided, single density, 40 track FLEX standard (390 sectors free). Note that the date is not set, nor are the sectors tested.

Command: TD Test Drive  
Format: Random sector read on drive Z  
Action: Reads random sectors on the drive.

### 5.5 - FLEX related commands

Command: JF    Jump to FLEX warm start  
 Format: Jump to flex warm start.....  
 Action: Jumps to address \$CD03

Command: BF    Boot FLEX from the system drive  
 Format: Booting FLEX from system drive....  
 Action: FLEX is loaded from logical drive 0 by firstly looking in the directory for either FLEX.SYS or FLEX.COR. Once loaded then the command overlays the console and disk jump tables, disables the date prompt, and sets the TTYSET and ASN parameters from the RTC/PRAM before jumping to the FLEX cold start point.  
 Note that is not necessary to configure and link a version of FLEX as any copy of FLEX regardless of the machine it was designed to run on may be used.

Command: RM    Remote mount PROMdisk image  
 Format: Remote mount PROMdisk image (MB2K2.DSK) to drive 0  
 Action: Mount a FLEXNet connected remote disk image named MB2K2PD.DSK to logical drive 0. This is intended to act as a ‘get out of jail free’ card in case corruption of the PROMdisk image in flash stops the system from booting.

### 5.6 - OS-9 related commands

Command: B0    Boot OS-9 from the internal pre loaded image  
 Format: Booting internal OS-9 L1.....  
 Action: Set up the OS9 interrupt vectors, map in the shadow RAM and move the OS9 boot image with the OS9 kernel and ‘ROM’ memory resident modules from \$0000 -> \$C000, and start the kernel.

### 5.7 - Misc commands

The last two commands are concerned with testing memory and the real time clock.

Command: DC    Display RTC contents  
 Format: Display clock contents  
 Action: Displays the RTC ram in the following way:-

08:55:03 28/04/20	time and date
00 00 00 80	RTC control regs
0F	FDC parameters
AA	RTC powerful flag
00 01 FF FF	logical drive mapping
08 00 3A 18 50 00 00 08 00 00 1B	FLEX ‘TTYSET’ params
00 01	FLEX ‘ASN’ parameters
00 00 00 00 00 00 00 00 00 00 00 00 00 00	reserved for future use
00 11 22 33 44 55 66 77 88 99 AA BB CC DD EE FF	user application bytes

Command: MC    Modify RTC  
 Format: RTC examine and alter from YY

Action: Examine and modify RTC ram contents in the same way as ME.

## Section 6 - FLEX/OS-9 utilities

The section describes the utilities written to support specific features of the MB2K2. For FLEX the utilities are pre installed on the PROMdisk and also on MB2K2\_SRC.DSK in the MB2K2 utilities folder. OS-9 just uses versions of the FLEXNet utilities and these are found on the PROMdisk.

### 6.1 - FLEX specific utilities

TIME.CMD - This program gives the date/time from the RTC if installed. It also updates the FLEX date registers, and so should be included in your startup.txt file to give FLEX the correct date on boot.

SETTIME.CMD - This program sets the RTC time and date and is Y2K compliant.

ALLOCATE.CMD - In the MB2K2 there is no fixed relationship between the logical drive numbers of FLEX and the physical drives. The allocate command sets up this mapping. Running the command without any parameters will give the current mapping. Running the command followed by a space and then four characters from this list will set the allocation:-

- 0.....Drive type 0 is the PROMdisk
- 1.....Drive type 1 is the RAMdisk
- 2.....Drive type 2 is the floppy disk
- 3.....Drive type 3 is the remote FLEXNet drive(s)

If a logical drive is not to be allocated then a '.' should be used. ie

'ALLOCATE 0123' would assign FLEX drive zero to the PROMdisk, drive 1 to the RAMdisk, the floppy disk to drive two and a remote FLEXNet volume to drive three.

'ALLOCATE 20.3' would assign the floppy disk to drive zero, the PROMdisk to drive 1. nothing to drive two, and a remote FLEXNet volume to drive three.

Multiple FLEXNet drives may be allocated, so 'ALLOCATE 3333' would assign all four FLEX drives to FLEXNet. If the RTC/PRAM is not valid (due to failure of the battery supply) then the default allocation is (01..).

TTYSET.CMD and ASN.CMD - These are copies of the standard FLEX utilities which have been modified to save the current values to the RTC. In this way the TTYSET and ASN parameters will be set automatically when booting FLEX

FAST.CMD - Take control of the graphics terminal emulation from MON09 and passes it to the GDC's internal emulator. This has the same effect as building MON09 using the fastest version of 'GDCOUT.TXT'.

PDRW.CMD - Enables writing to the PROMdisk.

PDRO.CMD - Disables writing to the PROMdisk, this is the default.

FMTPD.CMD - Format PROMdisk allows increasing the PROMdisk size to 1.4MB 'in situ'. Note that this command will erase the PROMdisk so should be used with care. If the PROMdisk becomes corrupted then the system can be restored using the 'RM' command in MON09 to mount a remote version of the PROMdisk for recovery.

FLEXLINK.TXT & MONLINK.TXT - These files contain all of the FLEX and MON09 equates RMB's and jump table entries for use in your own programs. To use them in a program include the LIB pseudo op :-

OPT NOL	SWITCH OFF LISTING
LIB FLEXLINK	LINK IN FLEXLINK AND MONLINK
OPT LIS	SWITCH ON LISTING
*	
ORG \$C100	ORIGIN IS FLEX TPA
*	
START JSR [CLEARG]	JUST CLEAR THE GRAPHICS SCREEN
JMP FWARM	AND RETURN TO FLEX
*	
END START	TRANSFER ADDRESS IS START

Note that the monitor subroutine call is done by an indirect JSR. The source of flexlink and monlink is presented in appendix 2.

TYIO.TXT & STY-MB2.TXT - These two files are the drivers to adapt the word processing program STYLOGRAPH to the MB2K2. To adapt the program follow the procedure laid out in the STYLOGRAPH manual.

DEMO.CMD - This is a graphics demo for the MB2 which runs unmodified on the MB2K2.

TEXT.CMD - This program sets the display to the text screen.

GRAPH.CMD - This program sets the display to the graphics screen.

CLEARG.CMD - This command clears the graphics screen.

RECORD.CMD - This program will accept bytes from serial port 1 and store them into memory. The program assumes that the graphics display code of appendix 4 is being used.

INTERP.CMD - This program will decode the graphics display code in memory (starting from 0x0000), and display the commands and parameters on the text output device.

PLAY.CMD - This program will display the graphics images generated by the graphics display code in memory.

GRAPHICS.MAC - This is the graphics display code macro set. (see appendix 4 for more details)

The remaining utilities on the DSK are all modified versions of the utilities supplied as part of Michael Evenson's FLEXNet package for the Windows OS. There is no support for MacOS or Linux in this release but this is expected to be added in the future.

All of the utilities have been re-named to RXXX for consistency even though they support multiple mounted drives. Because the MB2K2 design has FLEXNet compatible drivers in ROM, the utilities do not need to check and link to drivers installed by the FNETDRV command, (which is no longer needed), instead the RMOUNT command has the network checks that were previously part of FNETDRV. The following descriptions are from the FLEXNet manual with additions for the MB2K2.

#### RCREATE - Remote Create

The RCREATE command will prompt the user for the location, name, and other parameters to create a new DSK file. After all parameters are entered, the user will be asked for a confirmation (yes/no) and if the answer is positive the file will be created. No parameters are required in the command line.

Example:  
+++RCREATE  
File path ? C:\folder3  
File name ? newname  
Disk number (in decimal) ? 123  
Number of tracks (in decimal) ? 35  
Sectors per track (in decimal) ? 10  
OK to proceed ? Y  
  
File successfully created  
+++

#### NOTES:

- The file path is the directory where the new file will be created. If none is specified, the file will be created in the current directory.
- The file name ("newname") will be used for both the name of the DSK file, as known by Windows, and for the volume name which is stored in the SIR (track 0, sector 3) of the DSK file.
- The disk number, 123 in this example, is stored as the volume number in the SIR.
- If non-numeric values are entered for the disk number, the number of tracks or the number of sectors per track, the question will be repeated.

- RCREATE does not check for the "validity" of the track/sector format entered by the user. The file will be created, as long as the values given are numeric.
- In the above example, the disk image will be created with 35 tracks (including track 0) of 10 sectors, for a total of 340 data sectors.
- Note that RCREATING a disk does not automatically RMOUNT it or change the current directory. You must use RCD to change directories if needed, and RMOUNT to mount the new disk.

#### RDELETE - Remote Delete

RDELETE will prompt the user for the file path and the name of the file to be deleted. If no file path is given, the current directory will be assumed. RDELETE also adds a .DSK extension to the filename. RDELETE will then display the full path and name of the file, and will prompt the user for a response (Yes/No) before deleting the file. If the file cannot be found, an error message will be displayed.

Syntax: RDELETE <filename> [cr]

#### RLIST - Remote List

RLIST displays a list of all the directories which are contained in the current directory. It is provided as an aid to the user when "navigating" in the Windows directory tree structure. No parameters are needed. RLIST displays the listing in the same fashion as RDIR, i.e. 20 lines at a time, then prompting the user for more.

Syntax: RLIST [cr]

### 6.2 - OS-9 and FLEX utilities

#### RCD - Remote Change Directory

This command will change the current directory, which is the default directory which the other utilities will use. For example, if no file path is provided in the RCREATE command, the new file will be created in the current directory. If RCD is typed without parameters, the the current file path will be shown.

Syntax: RCD <filepath>

Example: RCD C:\folder3

#### RDIR - Remote Directory

RDIR performs a DIR command under DOS, and returns an exact copy of the listing generated on the MS-DOS screen:

- The current directory is used
- Only files with the extension .DSK will be listed.
- Command line parameters are allowed, and are passed to the Windows command.

- RDIR displays 20 lines at a time, then prompts the user before displaying the next 20 lines. Typing a space will display the next lines, typing [esc] will stop the listing and return to the FLEX prompt.

Examples

+++RDIR [cr] Lists all DSK files in the current directory

+++RDIR A2\* [cr] Lists all DSK files which start with A2.

RESYNC - RE-SYNChronize

If something should happen and you restart the host computer, it will be looking for the Sync information from the FLEX/OS-9 system. RESYNC will re-establish the communication link and you can proceed. The command is simply RESYNC. If all is working properly you should not have to do anything at the PC end of the link.

Syntax: RESYNC [cr]

RMOUNT - Remote Mount

RMOUNT will "mount" a DSK file to the given drive number, in other words it selects a DSK file, opens it and sets it as the drive. After a file has been RMOUNTed, it can be read or written to by FLEX/OS-9 as it were a standard drive. RMOUNT assumes that the .DSK file is in the current Windows directory otherwise, the user may give the complete path and file name to RMOUNT a file which is in another directory. RMOUNT does not require a file extension to be typed; however, if one is entered, it must be .DSK (lowercase letters OK) or an error message will be generated. RMOUNT will check that the remote computer has FLEXNet running and will connect if needed.

NOTE: There is no need to "unmount" a file before RMOUNTing another one. However, a file which is "mounted" is open under Windows, and may be corrupted if the host computer is powered down while the file is open.

Examples:

+++RMOUNT <drive> <filename.dsk> [cr]

+++RMOUNT <drive> <filename> [cr]

Mount a file which is in the current directory. FLEXNet will automatically add the .DSK extension to the file name.

+++RMOUNT <drive> c:\folder\filename [cr]

Mount a file which is in any directory. In this case the file will be mounted without changing the current directory.

Note that for OS-9 <drive> is one of the /H0 through /H3 device paths. If <drive> is not specified then /H0 is assumed.

For OS-9, RMOUNT is a memory resident module loaded at boot time and so may be used to connect to a remote drive even if there is no valid PROMdisk image.

**REXIT - Remote Exit**

This command will close all files open on the host computer and exit to Windows.

**6.3 - OS-9 only utilities****blinky - simple multitasking test program**

blinky will simply flash the green '6809' LED approximately once per second. It's only function is to test that interrupts and multitasking is running. Append a '&' to the file name when launching from the Shell to make it a background task.

Syntax: blinky& [cr]

gotoxy - MB2K2 specific terminal emulator control code data file for the 'Frank Hogg Dyna' applications such as DynaStar.

H2 & H3 - are device descriptor for the last two FLEXLink drives (H0 and H0 are memory resident at boot time).

## Section 7 - Programming guide

The subroutines in MON09 may be called from other programs by means of indirect JSRs via a table located at \$F000. This table retains the same structure as MON09 for the MB2 for backwards compatibility and is included in the monlink.txt header file. The header files are listed in appendix 2 and can be found on the MB2K2\_SRC DSK in this package.

To use these routines in your program, insert a LIB flexlink directive at the beginning, and the use an indirect jump to subroutine whenever a routine is used. ie

```
opt nol
lib flexlink
opt lis
.
.
.
ldx #100
ldy #354
jsr [LINE]
.
.
```

### 7.1 - MB2 MON09 general routines

#### STATUS

- Status routine.
- Entry: no parameters.
- Exit: (Z)=0 if character ready.

#### INCH1

- Input character with no echo and input.
- Entry: no parameters.
- Exit: (A) = character.

#### INCH

- Input character with echo INCH
- Entry: no parameters
- Exit: (A) = character.

#### OUTCH

- Output char.
- Entry: (A) = character.
- Exit: no change.

#### READ

- Read sector routine.
- Entry: (X) = address where sector is to be placed.
- (A) = Track number.
- (B) = Sector number.
- Exit: (B) = Error code (z)=1 if no error.

**WRITE**

- Write track routine.
- Entry: (X) = Address of area of memory from which the data will be taken.
- (A) = Track number.
- (B) = Sector number.
- Exit: (B) = Error condition, (Z)=1 if no error.

**VERIFY**

- Verify sector routine.
- Entry: no parameters.
- Exit: (B) = Error condition (Z)=1 if no error.

**RST**

- Restore drive to track 00.
- Entry: (X) = FCB address (3,X contains drive number).
- Exit: (B) = Error condition, (Z)=1 if no error.

**DRV**

- Select current drive.
- Entry: (X) = FCB address (3,X contains drive number).
- Exit: (B) = Error condition, (Z)=0 and (C)=1 if error.
- (B) = \$0F if non existent drive.

**CHKRDY**

- Check for drive ready.
- Entry: (X) = FCB address (3,X contains drive number)>
- Exit: (B) = Error condition, (Z)=0 AND (C)=1 if drive is not ready.

**QUICK**

- Quick drive ready check.
- Entry: (X) = FCB address (3,X contains drive number).
- Exit: (B) = Error condition, (Z)=0 AND (C)=1 if drive not ready.

**DINIT**

- Init (cold start).
- Entry: no parameters.
- Exit: no change.

**WARM**

- Warm start.
- Entry: no parameters.
- Exit: no change.

**SEEK**

- Seek track.
- Entry: (A) = Track number.
- (B) = Sector number.
- Exit: (B) = Error condition, (Z)=1 if no error.

**PCRLF**

- Print a CR followed by a LF.
- Entry: no parameters.
- Exit: (A) destroyed.

**PDATA1**

- Print character string .
- Entry: (X) = Pointer to character string.
- Exit: (X) = Pointer to end of string token Hex(04).
- (A) Destroyed.

**PSTRNG**

- Print character string preceded by a CR,LF.
- Entry: (X) = Pointer to character string.
- Exit: (X) = Pointer to end of string token Hex(04).
- (A) = Destroyed.

**PRINTA**

- Print the A reg.
- Entry: (A) = Data to be printed.

**PRINTX**

- Print the X reg.
- Entry: (X) = Data to be printed.

**DELAY**

- Delay routine.
- Entry: (X) = Delay time in milli seconds.
- Exit: no change.

**BADDR**

- Build a four hex digit address.
- Entry: no parameters.
- Exit: (X) = Address.
- (A) = Destroyed.
- (B) = Destroyed.

**BYTE**

- Get a two digit hex byte.
- Entry: no parameters.
- Exit: (A) = Byte.

**OUTHL**

- Print left hex digit.
- Entry: (A) = Byte containing digit.
- Exit: (A) = Byte containing shifted digit.

**OUTHR**

- Output right hex digit.
- Entry: (A) = Byte containing digit.
- Exit: (A) = ASCII coded digit.

**INHEX**

- Input a valid hex character (If not hex then backspace).
- Entry: no parameters.
- Exit: (A) = Valid hex char.

**OUT2H****OUT2HA****OUT4HS****OUT2HS**

- Hex print routines.
- Entry: (X) = Pointer to a one or two byte hex number.
- Exit: (A) = Destroyed.

**OUTS**

- Output a space.
- Entry: no parameters.
- Exit (A) = Destroyed.

**RANDOM**

- Random number generator.
- Entry: no parameters.
- Exit: (A) = Random number from 0 to 255.

**GETRTC**

- Get a byte from the RTC.
- Entry : (B) = RTC address.
- Exit : (A) = Data.

**PUTRTC**

- Send a byte to the RTC.
- Entry : (B) = RTC address (A) = Data

**BLEEP**

- Beep for 100ms.

**7.2 - MB2K2 MON09 additional routines**

These routines are not in the original MB2 version.

**TOUPPER**

- convert to upper case chars in the range a-z
- Entry: (A) = ASCII char to be converted.
- Exit: (A) = converted char if in range, else no change.

**BCD2BIN**

- convert BCD coded value to binary
- Entry: (A) = value to be converted.
- Exit: (A) = converted value.

**BIN2BCD**

- convert binary value to BCD
- Entry: (A) = value to be converted.
- Exit: (A) = converted value.

**7.3 - MB2/MB2K2 MON09 graphics routines****GCOM**

- Send GDC command.
- Entry: (A) = GDC command
- Exit: No change.

**GPRM**

- Send GDC parameter.
- Entry: (A) = GDC parameter
- Exit: No change.

**GPRMI**

- Get a parameter from GDC.
- Entry: No parameters.
- Exit: (A) = Parameter byte

**MASK**

- Set mask.
- Entry: (X) = Mask value
- Exit: No change.

**SETPEN**

- Define line profile and 'pen' type.
- Entry: (A) = Pen type (0=replace 1=complement  
                  2=reset 3=set)
- (X) = Line profile
- Exit: No change.

**SETPAT**

- Set up graphics pattern in parameter ram.
- Entry: (X) = Pointer to eight byte pattern
- Exit: No change.

**FIGSF**

- Start figure drawing using parameter set in ram.
- Entry: (B) = Number of parameter bytes.

**FIGSG**

- Start graphics drawing using parameter set in ram.
- Entry: (B) = Number of parameter bytes.
- Exit: No change

**SETPAR**

- Set up display partitions in GDC.
- Entry: (X) = Start address of partition 1
- (D) = Start address of partition 2
- (Y) = Number of lines in partition 1
- (U) = Number of lines in partition 2
- Exit: No change.

**SYNC**

- Wait until vertical blanking period.
- Entry: No parameters.
- Exit: No change.

**SETCRG**

- Set graphics cursor.
- Entry: (X) = x coord (0<=x<=767)
- (Y) = y coord (0<=y<=575)
- Exit: No change.

**GETCRG**

- Read graphics cursor.
- Entry: No parameters.
- Exit: (X) = x coord of cursor
- (Y) = y coord of cursor

**OFF**

- Switch off display.
- Entry: No parameters.
- Exit: No change.

**ON**

- Switch on display.
- Entry: No parameters.
- Exit: No change.

**GRAPH**

- Set display to graphics.
- Entry: No parameters.
- Exit: No change.

**MODE**

- Set GDC mode.
- Entry: (A) = New mode byte
- (B) = Read flag
- Exit: If (B) <> 0 then (A) = New mode byte
- If (B) = 0 then (A) = OLD mode byte

**ZOOM**

- Set graphics zoom.
- Entry: (A) = New zoom byte
- (B) = Read flag
- Exit: If (B) <> 0 then (A) = New zoom byte
- If (B) = 0 then (A) = OLD zoom byte

**FILL**

- Area fill.
- Entry: (A) = Initial drawing direction
- (X) = Number of pixels in the initial direction
- (Y) = Number of pixels in the perpendicular direction
- Exit: No change.

**CLEARG**

- Clear graphics screen.
- Entry: No parameters.
- Exit: No change.

**CLEARX**

- Clear GDC ram from current cursor.
- Entry: (A) = Drawing mode (0=replace 1=complement  
2=reset 3=set)
- (X) = Number of words to be cleared
- Exit: No change

**GDCINIT**

- Init display.
- Entry: No parameters.
- Exit: No change.

**POINT**

- Plot a point at the current cursor position.
- Entry: No parameters.
- Exit: No change.

**LINE**

- Plot a line from the current cursor position.
- Entry: (X) = x coord
- (Y) = ● Entry: coord
- Exit: No change.

**RECT**

- Plot a rectangle.
- Entry: (A) = Initial drawing direction
- (X) = Length of side in the initial direction
- (Y) = Length of side in the perpendicular direction
- Exit: No change.

**CIRCLE**

- Plot a circle at the current cursor location.
- Entry: (A) = radius of circle (0<A<127)
- Exit: No change.

**SETCRT**

- Set text cursor.
- Entry: (X) = Cursor word address
- Exit: No change.

**GETCRT**

- Get text cursor.
- Entry: No parameters.
- Exit: (X) = Cursor word address

**TEXT**

- Set display to text.
- Entry: No parameters.
- Exit: No change.

**CLEAR**

- Clear text screen.
- Entry: No parameters.
- Exit: No change.

**GDCOUT**

- Put ascii character to screen.
- Entry: (A) = Character  
(control codes are given in appendix 1)

## Appendix 1 - Terminal emulator control codes

DECIMAL	HEX	KEY	FUNCTION
0	00	^@	NULL
1	01	^A	-
2	02	^B	-
3	03	^C	-
4	04	^D	EOT
5	05	^E	-
6	06	^F	-
7	07	^G	BELL
8	08	^H	BACKSPACE (CURSOR LEFT)
9	09	^I	CURSOR RIGHT
10	0A	^J	LINE FEED (CURSOR DOWN)
11	0B	^K	CURSOR UP
12	0C	^L	CLEAR SCREEN
13	0D	^M	RETURN
14	0E	^N	MOVE CURSOR (SEE NOTE)
15	0F	^O	HOME
16	10	^P	SCREEN ON
17	11	^Q	SCREEN OFF
18	12	^R	CURSOR ON
19	13	^S	CURSOR OFF
20	14	^T	SET CURSOR TYPE 1
21	15	^U	SET CURSOR TYPE 2
22	16	^V	INVERT ON
23	17	^W	INVERT OFF
24	18	^X	ERASE TO END OF LINE
25	19	^Y	ERASE TO END OF SCREEN
26	1A	^Z	ERASE LINE
27	1B	-	ESCAPE
28	1C	-	-
29	1D	-	-
30	1E	-	-
31	1F	-	-

NOTE: Move cursor has two parameters. The control code should be followed by two bytes, row and column. The home position is 0,0. The value 0x20 should be added to each value. ie to move the cursor to row 4 col 7, send the byte sequence 0x0E,0x24,0x27.



## Appendix 2 - Flexlink and Monlink sources

### 2.1 - Monlink

```

* Monitor definitions and equates for the MB2K2.
E000 PROM EQU $E000    Eeprom start address.
DE00 RAM EQU $DE00    Scratch ram + stack space.
FF00 IO EQU $FF00    I/O base address.
DE6F SSTACK EQU (RAM+127-16) Top of system stack.
DF80 SCRAT EQU (RAM+384) Start of scratch space.
*
* User callable subroutines. Use indirect JSR's to call.
F000 RESET EQU $F000    Cold start.
F002 CONTRL EQU $F002   Warm start.
F004 INCH1 EQU $F004   Input char without an echo .
F006 INCH EQU $F006   Input char .
F008 STATUS EQU $F008   Check for char.
F00A OUTCH EQU $F00A   Output char.
F00C PDATA1 EQU $F00C   Print string terminated by hex(04).
F00E PCRLF EQU $F00E   Print a cr followed by a lf.
F010 PSTRNG EQU $F010   PCRLF followed by PDATA1.
F012 INIT EQU $F012   Init active device.
F014 DELAY EQU $F014   Delay for (XREG) m/S.
F016 BADDR EQU $F016   Get a four digit hex address into X.
F018 BYTE EQU $F018   Get a two hex digit number into A.
F01A INHEX EQU $F01A   Get a one digit hex char into A.
F01C OUT2H EQU $F01C   Output two hex chars pointed to by X.
F01E OUT2HS EQU $F01E   OUT2H plus a space.
F020 OUT4HS EQU $F020   Output four hex chars etc.
F022 OUTHR EQU $F022   Output right hex digit in A.
F024 OUTHL EQU $F024   Output left hex digit in A.
F026 OUTS EQU $F026   Output a space.
F028 RANDOM EQU $F028   Returns a random number in the range 0-255.
F02A PRINTA EQU $F02A   Print the contents of A.
F02C PRINTX EQU $F02C   Print the contents of X.
F02E READ EQU $F02E   Read sector.
F030 WRITE EQU $F030   Write sector.
F032 VERIFY EQU $F032   Verify sector.
F034 RST EQU $F034   Restore to track 00.
F036 DRV EQU $F036   Select drive.
F038 CHKRDY EQU $F038   Check for drive ready.
F03A QUICK EQU $F03A   Quick check for drive ready.
F03C DINIT EQU $F03C   Drive cold start.
F03E WARM EQU $F03E   Drive warm start.
F040 SEEK EQU $F040   Seek to track.
F042 GETTIM EQU $F042   Get time string from RTC.
F044 PUTTIM EQU $F044   Put time string to RTC.
F046 GETRTC EQU $F046   Get a byte from the RTC.
F048 PUTRTC EQU $F048   Put a byte to the RTC.
F04A BEEP EQU $F04A   Sound a 100ms tone.
F04C GCOM EQU $F04C   Send command to GDC.
F04E GPRM EQU $F04E   Send parameter to GDC.
F050 GPRMI EQU $F050   Get parameter from GDC.
F052 MASK EQU $F052   Load mask register.
F054 SETPEN EQU $F054   Define drawing mode.
F056 SETPAT EQU $F056   Define graphics pattern.
F058 FIGSF EQU $F058   Start figure drawing.
F05A FIGSG EQU $F05A   Start graphics drawing.
F05C SETPAR EQU $F05C   Define display partitions.
F05E SETCRG EQU $F05E   Set graphics cursor.
F060 GETCRG EQU $F060   Get graphics cursor.
F062 SETCRT EQU $F062   Set text cursor.
F064 GETCRT EQU $F064   Get text cursor.
F066 OFF EQU $F066   Turn display off.
F068 ON EQU $F068   Turn display on.
F06A GRAPH EQU $F06A   Set display to graphics.
F06C TEXT EQU $F06C   Set display to text
F06E MODE EQU $F06E   Set GDC mode.

```

F070	ZOOM	EQU	\$F070	Set zoom factors.
F072	FILL	EQU	\$F072	Area fill routine.
F074	CLEARX	EQU	\$F074	Clear X words of display memory.
F076	CLEARG	EQU	\$F076	Clear graphics display.
F078	CLEART	EQU	\$F078	Clear text display.
F07A	GDCINIT	EQU	\$F07A	Initialise GDC.
F07C	GDCOUT	EQU	\$F07C	Output a character.
F07E	INKEY	EQU	\$F07E	Get a character from the keyboard.
F080	POINT	EQU	\$F080	Plot a point.
F082	LINE	EQU	\$F082	Plot a line.
F084	RECT	EQU	\$F084	Plot a rectangle.
F086	CIRCLE	EQU	\$F086	Plot a circle.
F088	ARC	EQU	\$F088	Plot an arc
F08A	CLINK	EQU	\$F08A	Link text parameters.
F08C	SYNC	EQU	\$F08C	Sync to vertical blanking.
*				
	* the following routines were not in the MB2 ROM.			
F08E	TOUPP	EQU	\$F08E	convert ASCII char to upper case
F090	BCD2B	EQU	\$F090	convert BCD value to binary
F092	BIN2B	EQU	\$F092	convert binary value to BCD
*				
F0A0	SCHAR	EQU	\$F0A0	FLEXNet driver send char
F0A2	RCHAR	EQU	\$F0A2	FLEXNet driver receive char
*				
*				
DE80		ORG	(RAM+128)	
DE80	BUFFER	RMB	256	Floppy interface sector buffer.
DF80	STACK	RMB	2	User system stack.
DF82	NMIV	RMB	2	NMI interrupt vector.
DF84	IRQV	RMB	2	IRQ interrupt vector.
DF86	FIRQV	RMB	2	FIRQ interrupt vector.
DF88	SWI2V	RMB	2	SWI2 interrupt vector.
DF8A	SWI3V	RMB	2	SWI3 interrupt vector.
DF8C	IPORT	RMB	1	Active input port.
DF8D	OPORT	RMB	1	Active output port.
DF8E	DRIVE	RMB	1	Format drive value.
DF8F	TRACK	RMB	1	Format track value.
DF90	SECTOR	RMB	1	Format sector value.
DF91	TEMP	RMB	1	
DF92	XTEMP	RMB	2	
DF94	YTEMP	RMB	2	
DF96	TTO	RMB	2	
DF98	RNDM	RMB	4	Random number storage.
DF9C	WARMs	RMB	1	Warm start flag.
DF9D	DDSTAB	RMB	4	Disc driver type table.
DFA1	REAVEC	RMB	2	Disc driver jump table.
DFA3	WRIVEC	RMB	2	
DFA5	VERVEC	RMB	2	
DFA7	RSTVEC	RMB	2	
DFA9	DRVVEC	RMB	2	
DFAB	CHKVEC	RMB	2	
DFAD	QUIVEC	RMB	2	
DFAF	INIVEC	RMB	2	
DFB1	WARVEC	RMB	2	
DFB3	SEEVEC	RMB	2	
DFB5	RTCFAIL	RMB	1	RTC fail flag.
DFB6	CURDRV	RMB	1	Active floppy drive.
DFB7	XCOORD	RMB	2	Cursor X value.
DFB9	YCOORD	RMB	2	Cursor Y Value.
DFBB	PART1	RMB	4	Display partition one.
DFBF	PART2	RMB	4	Display partition two.
DFC3	GPARAM	RMB	8	Parameter ram contents.
DFCB	GMODE	RMB	1	GDC mode register contents.
DFCC	GZOOM	RMB	1	Display + write zoom values.
DFCD	GFIGS	RMB	1	Figs 1st parameter value.
DFCE	DC	RMB	2	
DFD0	D	RMB	2	
DFD2	D2	RMB	2	
DFD4	D1	RMB	2	

DFD6	DM	RMB	2	
DFD8	CONST	RMB	1	
DFD9	ROW	RMB	1	
DFDA	COL	RMB	1	
DFDB	MAXCOL	RMB	1	
DFDC	MAXROW	RMB	1	
DFDD	CCOL	RMB	1	
DFDE	CROW	RMB	1	
DFDF	BCOL	RMB	1	
DFE0	BROW	RMB	1	
DFE1	ATTRI	RMB	1	
DFE2	CSPACE	RMB	1	
DFE3	CHARTAB	RMB	2	
DFE5	CURSOR	RMB	2	Text cursor position.
DFE7	OFFSET	RMB	2	
DFE9	CZOOM	RMB	1	
DFEA	CTYPE	RMB	1	
DFEB	ESCFLG	RMB	1	
DFEC	TS1	RMB	2	
DFEE	TS2	RMB	2	
DFF0	TL1	RMB	2	
DFF2	TL2	RMB	2	
DFF4	DEN	RMB	1	
DFF5	DEN1	RMB	1	
DFF6	STEP	RMB	1	
DFF7	STEP0	RMB	1	
DFF8	SPEED	RMB	1	
DFF9	FLASH	RMB	1	
DFFA	CFLAG	RMB	1	
	*			
	* the following were not in the MB2 ROM.			
DFFB	CHKSUM	RMB	2	FLEXNet driver checksum
DFFD	BRKPNT	RMB	1	saved instruction byte from breakpoint
DFFE	PDWPRT	RMB	1	promdisk write protect flag (0 = protected)
	*			
	* Hardware device equates.			
FF00	KEYREG	EQU	\$FF00	Keyboard register.
FF01	PIACA	EQU	\$FF01	Pia side a control register.
FF02	SYSREG	EQU	\$FF02	System control register.
FF03	PIACB	EQU	\$FF03	Pia side b control register.
	*			
FF08	ACIAD1	EQU	\$FF08	Acia port 0 data register.
FF09	ACIAC1	EQU	\$FF09	Acia port 0 control register.
FF04	ACIAD2	EQU	\$FF04	Acia port 1 data register.
FF05	ACIAC2	EQU	\$FF05	Acia port 1 control register.
FF0C	BAUD1	EQU	\$FF0C	Acia port 0 baud rate register.
FF0D	BAUD2	EQU	\$FF0D	Acia port 1 baud rate register.
	*			
FF10	COMREG	EQU	\$FF10	Fdc command register.
FF11	TRKREG	EQU	\$FF11	Fdc track register.
FF12	SECREG	EQU	\$FF12	Fdc sector register.
FF13	DATREG	EQU	\$FF13	Fdc data register.
	*			
FF14	GDCPRM	EQU	\$FF14	Gdc command register.
FF15	GDCCOM	EQU	\$FF15	Gdc parameter register.
	*			
FF18	RTCADD	EQU	\$FF18	Rtc address register.
FF19	RTCDAT	EQU	\$FF19	Rtc data register.
	*			
	* ramdisk controller registers			
FF20	RCOMRG	EQU	\$FF20	
FF21	RTRKRG	EQU	\$FF21	
FF22	RSECRG	EQU	\$FF22	
FF23	RDATRG	EQU	\$FF23	
	*			
	* promdisk controller registers			
FF30	ECOMRG	EQU	\$FF30	
FF31	ETRKRG	EQU	\$FF31	
FF32	ESECRG	EQU	\$FF32	

```

FF33 EDATRG EQU    $FF33
*
* disk controller commands
0000 RSCMD  EQU    $00
0010 SECMD  EQU    $10
0084 RECMD  EQU    $84
00A4 WRCMD  EQU    $A4
*
* Floppy disk controller status bits
0058 RSMASK EQU    $58
0010 SEMASK EQU    $10
001C REMASK EQU    $1C
005C WRMASK EQU    $5C
0018 VEMASK EQU    $18
0002 DRQ    EQU    $2
0001 BUSY   EQU    $1

```

## 2.2 - FLEXlink

```

*
*****
* This file contains the subroutine and      *
* storage location equates for FLEX. To      *
* use this file insert the following lines   *
* of code in your program :-                 *
*          OPT NOL                         *
*          LIB FLEXLINK                     *
*          OPT LIS                         *
* For details of the routines and           *
* parameters see the FLEX programmers guide *
*****
*
* Storage locations.
C080 LINBUF EQU    $C080    Line buffer start.
CC00 TTYBS  EQU    $CC00    TTYSET backspace character.
CC0B SYSDRV EQU    $CC0B    System drive number.
CC0C WRKDRV EQU    $CC0C    Working drive number.
CC0E MONTH  EQU    $CC0E    FLEX system date.
CC0F DAY    EQU    $CC0F
CC10 YEAR   EQU    $CC10
CC2B MEMEND EQU    $CC2B    Memory end pointer.
*
* User callable routines.
CD00 FCOLD   EQU    $CD00    Cold start.
CD03 FWARM   EQU    $CD03    Warm start.
CD06 RENTER  EQU    $CD06    Main loop entry point.
CD4B DOCMND EQU    $CD4B    Call dos as a subroutine.
CD4E STAT    EQU    $CD4E    Check terminal status.
CD09 FINCH   EQU    $CD09    Input character.
CD0C INCH2   EQU    $CD0C    Input character switched.
CD0F FOUTCH  EQU    $CD0F    Output character.
CD12 OUTCH2  EQU    $CD12    Output character switched.
CD15 GETCHR  EQU    $CD15    Get a char (main routine).
CD18 PUTCHR  EQU    $CD18    Put a char (main routine).
CD1B INBUFF  EQU    $CD1B    Input into line buffer.
CD1E FPSTRNG EQU    $CD1E    Print a char string.
CD21 CLASS   EQU    $CD21    Classify a char.
CD24 FPCRLF  EQU    $CD24    Print a crlf.
CD27 NXTCH   EQU    $CD27    Get next buffer char.
CD2A RSTIO   EQU    $CD2A    Restore i/o vectors.
CD2D GETFIL  EQU    $CD2D    Get file spec.
CD30 LOAD    EQU    $CD30    File loader.
CD33 SETEXT  EQU    $CD33    Set file extension.
CD39 OUTDEC  EQU    $CD39    Output decimal number.
CD3C OUTHEX  EQU    $CD3C    Output hexadecimal number.
CD45 OUTADR  EQU    $CD45    Output hex address.
CD3F RPTERR  EQU    $CD3F    Report error.

```

```

CD42 GETHEX EQU $CD42 Get hexadecimal number.
CD48 INDEC EQU $CD48 Input decimal number.
*
* Monitor definitions and equates for the MB2K2.
E000 PROM EQU $E000 Eprom start address.
DE00 RAM EQU $DE00 Scratch ram + stack space.
FF00 IO EQU $FF00 I/O base address.
DE6F SSTACK EQU (RAM+127-16) Top of system stack.
DF80 SCRAT EQU (RAM+384) Start of scratch space.
*
* User callable subroutines. Use indirect JSR's to call.
F000 RESET EQU $F000 Cold start.
F002 CONTRL EQU $F002 Warm start.
F004 INCH1 EQU $F004 Input char without an echo .
F006 INCH EQU $F006 Input char .
F008 STATUS EQU $F008 Check for char.
F00A OUTCH EQU $F00A Output char.
F00C PDATA1 EQU $F00C Print string terminated by hex(04).
F00E PCRLF EQU $F00E Print a cr followed by a lf.
F010 PSTRNG EQU $F010 PCRLF followed by PDATA1.
F012 INIT EQU $F012 Init active device.
F014 DELAY EQU $F014 Delay for (XREG) m/S.
F016 BADDR EQU $F016 Get a four digit hex address into X.
F018 BYTE EQU $F018 Get a two hex digit number into A.
F01A INHEX EQU $F01A Get a one digit hex char into A.
F01C OUT2H EQU $F01C Output two hex chars pointed to by X.
F01E OUT2HS EQU $F01E OUT2H plus a space.
F020 OUT4HS EQU $F020 Output four hex chars etc.
F022 OUTHR EQU $F022 Output right hex digit in A.
F024 OUTHL EQU $F024 Output left hex digit in A.
F026 OUTS EQU $F026 Output a space.
F028 RANDOM EQU $F028 Returns a random number in the range 0-255.
F02A PRINTA EQU $F02A Print the contents of A.
F02C PRINTX EQU $F02C Print the contents of X.
F02E READ EQU $F02E Read sector.
F030 WRITE EQU $F030 Write sector.
F032 VERIFY EQU $F032 Verify sector.
F034 RST EQU $F034 Restore to track 00.
F036 DRV EQU $F036 Select drive.
F038 CHKRDY EQU $F038 Check for drive ready.
F03A QUICK EQU $F03A Quick check for drive ready.
F03C DINIT EQU $F03C Drive cold start.
F03E WARM EQU $F03E Drive warm start.
F040 SEEK EQU $F040 Seek to track.
F042 GETTIM EQU $F042 Get time string from RTC.
F044 PUTTIM EQU $F044 Put time string to RTC.
F046 GETRTC EQU $F046 Get a byte from the RTC.
F048 PUTRTC EQU $F048 Put a byte to the RTC.
F04A BEEP EQU $F04A Sound a 100ms tone.
F04C GCOM EQU $F04C Send command to GDC.
F04E GPRM EQU $F04E Send parameter to GDC.
F050 GPRMI EQU $F050 Get parameter from GDC.
F052 MASK EQU $F052 Load mask register.
F054 SETPEN EQU $F054 Define drawing mode.
F056 SETPAT EQU $F056 Define graphics pattern.
F058 FIGSF EQU $F058 Start figure drawing.
F05A FIGSG EQU $F05A Start graphics drawing.
F05C SETPAR EQU $F05C Define display partitions.
F05E SETCRG EQU $F05E Set graphics cursor.
F060 GETCRG EQU $F060 Get graphics cursor.
F062 SETCRT EQU $F062 Set text cursor.
F064 GETCRT EQU $F064 Get text cursor.
F066 OFF EQU $F066 Turn display off.
F068 ON EQU $F068 Turn display on.
F06A GRAPH EQU $F06A Set display to graphics.
F06C TEXT EQU $F06C Set display to text
F06E MODE EQU $F06E Set GDC mode.
F070 ZOOM EQU $F070 Set zoom factors.
F072 FILL EQU $F072 Area fill routine.

```

F074	CLEARX	EQU	\$F074	Clear X words of display memory.
F076	CLEARG	EQU	\$F076	Clear graphics display.
F078	CLEART	EQU	\$F078	Clear text display.
F07A	GDCINIT	EQU	\$F07A	Initialise GDC.
F07C	GDCOUT	EQU	\$F07C	Output a character.
F07E	INKEY	EQU	\$F07E	Get a character from the keyboard.
F080	POINT	EQU	\$F080	Plot a point.
F082	LINE	EQU	\$F082	Plot a line.
F084	RECT	EQU	\$F084	Plot a rectangle.
F086	CIRCLE	EQU	\$F086	Plot a circle.
F088	ARC	EQU	\$F088	Plot an arc
F08A	CLINK	EQU	\$F08A	Link text parameters.
F08C	SYNC	EQU	\$F08C	Sync to vertical blanking.
*				
* the following routines were not in the MB2 ROM.				
F08E	TOUPP	EQU	\$F08E	convert ASCII char to upper case
F090	BCD2B	EQU	\$F090	convert BCD value to binary
F092	BIN2B	EQU	\$F092	convert binary value to BCD
*				
F0A0	SCHAR	EQU	\$F0A0	FLEXNet driver send char
F0A2	RCHAR	EQU	\$F0A2	FLEXNet driver receive char
*				

### Appendix 3 - PS/2 keyboard mapping

```
// Keyboard mapping for PS-2 keyboard and MB2K2.
// First dataset, shift = 0, shiftlock = 0
0x00 //Scancode = $00
,0x05 //Scancode = $01 F9 CEDRIC - delete char
,0x00 //Scancode = $02
,0x19 //Scancode = $03 F5 CEDRIC - cut
,0x0E //Scancode = $04 F3 CEDRIC - search and replace
,0x03 //Scancode = $05 F1 CEDRIC - search forward
,0x1A //Scancode = $06 F2 CEDRIC - search back
,0x08 //Scancode = $07 F12 CEDRIC - delete left (backspace)
,0x00 //Scancode = $08
,0x17 //Scancode = $09 F10 CEDRIC - delete word
,0x13 //Scancode = $0A F8 CEDRIC -
,0x10 //Scancode = $0B F6 CEDRIC - paste
,0x01 //Scancode = $0C F4 CEDRIC - global replace
,0x09 //Scancode = $0D Tab ` 
,'` //Scancode = $0E ` 
,0x00 //Scancode = $0F

,0x00 //Scancode = $10
,0x00 //Scancode = $11
,0x00 //Scancode = $12
,0x00 //Scancode = $13
,0x00 //Scancode = $14
,'q' //Scancode = $15 q
,'1' //Scancode = $16 1
,0x00 //Scancode = $17
,0x00 //Scancode = $18
,0x00 //Scancode = $19
,'z' //Scancode = $1A z
,'s' //Scancode = $1B s
,'a' //Scancode = $1C a
,'w' //Scancode = $1D w
,'2' //Scancode = $1E 2
,0x00 //Scancode = $1F

,0x00 //Scancode = $20
,'c' //Scancode = $21 c
,'x' //Scancode = $22 x
,'d' //Scancode = $23 d
,'e' //Scancode = $24 e
,'4' //Scancode = $25 4
,'3' //Scancode = $26 3
,0x00 //Scancode = $27
,0x00 //Scancode = $28
,' ' //Scancode = $29 Space
,'v' //Scancode = $2A v
,'f' //Scancode = $2B f
,'t' //Scancode = $2C t
,'r' //Scancode = $2D r
,'5' //Scancode = $2E 5
,0x00 //Scancode = $2F

,0x00 //Scancode = $30
,'n' //Scancode = $31 n
,'b' //Scancode = $32 b
,'h' //Scancode = $33 h
,'g' //Scancode = $34 g
,'y' //Scancode = $35 y
,'6' //Scancode = $36 6
,0x00 //Scancode = $37
,0x00 //Scancode = $38
,0x00 //Scancode = $39
,'m' //Scancode = $3A m
,'j' //Scancode = $3B j
,'u' //Scancode = $3C u
,'7' //Scancode = $3D 7
```

, '8' //Scancode = \$3E	8
,0x00 //Scancode = \$3F	
,0x00 //Scancode = \$40	
, ',' //Scancode = \$41	,
, 'k' //Scancode = \$42	k
, 'i' //Scancode = \$43	i
, 'o' //Scancode = \$44	o
, '0' //Scancode = \$45	0
, '9' //Scancode = \$46	9
,0x00 //Scancode = \$47	
,0x00 //Scancode = \$48	
, '.' //Scancode = \$49	.
, '/' //Scancode = \$4A	/
, 'l' //Scancode = \$4B	l
,0x3B //Scancode = \$4C	;
, 'p' //Scancode = \$4D	p
, '-' //Scancode = \$4E	-
,0x00 //Scancode = \$4F	
,0x00 //Scancode = \$50	
,0x00 //Scancode = \$51	
,0x27 //Scancode = \$52	'
,0x00 //Scancode = \$53	
, '[' //Scancode = \$54	[
, '=' //Scancode = \$55	=
,0x00 //Scancode = \$56	
,0x00 //Scancode = \$57	
,0x00 //Scancode = \$58	
,0x00 //Scancode = \$59	
,0x0D //Scancode = \$5A	Enter
, ']' //Scancode = \$5B	]
,0x00 //Scancode = \$5C	
,0x5C //Scancode = \$5D	backslash
,0x00 //Scancode = \$5E	
,0x00 //Scancode = \$5F	
,0x00 //Scancode = \$60	
,0x00 //Scancode = \$61	
,0x00 //Scancode = \$62	
,0x00 //Scancode = \$63	
,0x00 //Scancode = \$64	
,0x00 //Scancode = \$65	
,0x08 //Scancode = \$66	Backspace
,0x00 //Scancode = \$67	
,0x00 //Scancode = \$68	
,0x0A //Scancode = \$69	KP1 CEDRIC - move to line end
,0x00 //Scancode = \$6A	
,0x0C //Scancode = \$6B	KP4 CEDRIC - move cursor left
,0x09 //Scancode = \$6C	KP7 CEDRIC - (Tab)
,0x00 //Scancode = \$6D	
,0x00 //Scancode = \$6E	
,0x00 //Scancode = \$6F	
,0x00 //Scancode = \$70	KP0
, '.' //Scancode = \$71	KP.
,0x04 //Scancode = \$72	KP2 CEDRIC - move cursor down
,0x1C //Scancode = \$73	KP5 CEDRIC - point here
,0x12 //Scancode = \$74	KP6 CEDRIC - move cursor right
,0x15 //Scancode = \$75	KP8 CEDRIC - move cursor up
,0x1B //Scancode = \$76	Escape
,0x00 //Scancode = \$77	
,0x18 //Scancode = \$78	F11 CEDRIC - delete line
, '+' //Scancode = \$79	KP+
,0x06 //Scancode = \$7A	KP3 CEDRIC - move one line forward
, '-' //Scancode = \$7B	KP-
, '*' //Scancode = \$7C	KP*
,0x02 //Scancode = \$7D	KP9 CEDRIC - line back
,0x00 //Scancode = \$7E	

```

,0x00 //Scancode = $7F

// Second dataset, shift = 0, shiftlock = 1
,0x00 //Scancode = $00
,0x05 //Scancode = $01 F9 CEDRIC - delete char
,0x00 //Scancode = $02
,0x19 //Scancode = $03 F5 CEDRIC - cut
,0x0E //Scancode = $04 F3 CEDRIC - search and replace
,0x03 //Scancode = $05 F1 CEDRIC - search forward
,0x1A //Scancode = $06 F2 CEDRIC - search back
,0x08 //Scancode = $07 F12 CEDRIC - delete left (backspace)
,0x00 //Scancode = $08
,0x17 //Scancode = $09 F10 CEDRIC - delete word
,0x13 //Scancode = $0A F8 CEDRIC -
,0x10 //Scancode = $0B F6 CEDRIC - paste
,0x01 //Scancode = $0C F4 CEDRIC - global replace
,0x09 //Scancode = $0D Tab `

,'~' //Scancode = $0E
,0x00 //Scancode = $0F

,0x00 //Scancode = $10
,0x00 //Scancode = $11
,0x00 //Scancode = $12
,0x00 //Scancode = $13
,0x00 //Scancode = $14
,'Q' //Scancode = $15 Q
,'1' //Scancode = $16 1
,0x00 //Scancode = $17
,0x00 //Scancode = $18
,0x00 //Scancode = $19
,'Z' //Scancode = $1A Z
,'S' //Scancode = $1B S
,'A' //Scancode = $1C A
,'W' //Scancode = $1D W
,'2' //Scancode = $1E 2
,0x00 //Scancode = $1F

,0x00 //Scancode = $20
,'C' //Scancode = $21 C
,'X' //Scancode = $22 X
,'D' //Scancode = $23 D
,'E' //Scancode = $24 E
,'4' //Scancode = $25 4
,'3' //Scancode = $26 3
,0x00 //Scancode = $27
,0x00 //Scancode = $28
,' ' //Scancode = $29 Space
,'V' //Scancode = $2A V
,'F' //Scancode = $2B F
,'T' //Scancode = $2C T
,'R' //Scancode = $2D R
,'5' //Scancode = $2E 5
,0x00 //Scancode = $2F

,0x00 //Scancode = $30
,'N' //Scancode = $31 N
,'B' //Scancode = $32 B
,'H' //Scancode = $33 H
,'G' //Scancode = $34 G
,'Y' //Scancode = $35 Y
,'6' //Scancode = $36 6
,0x00 //Scancode = $37
,0x00 //Scancode = $38
,0x00 //Scancode = $39
,'M' //Scancode = $3A M
,'J' //Scancode = $3B J
,'U' //Scancode = $3C U
,'7' //Scancode = $3D 7
,'8' //Scancode = $3E 8

```

```

,0x00 //Scancode = $3F

,0x00 //Scancode = $40
,'.' //Scancode = $41
,'K' //Scancode = $42      K
,'I' //Scancode = $43      I
,'0' //Scancode = $44      0
,'0' //Scancode = $45      0
,'9' //Scancode = $46      9
,0x00 //Scancode = $47
,0x00 //Scancode = $48
,'.' //Scancode = $49      .
,'/' //Scancode = $4A      /
,'L' //Scancode = $4B      L
,0x3B //Scancode = $4C      ;
,'P' //Scancode = $4D      P
,'-' //Scancode = $4E      -
,0x00 //Scancode = $4F

,0x00 //Scancode = $50
,0x00 //Scancode = $51
,0x27 //Scancode = $52      '
,0x00 //Scancode = $53
,'[' //Scancode = $54      [
,'=' //Scancode = $55      =
,0x00 //Scancode = $56
,0x00 //Scancode = $57
,0x00 //Scancode = $58
,0x00 //Scancode = $59
,0x0D //Scancode = $5A      Enter
,']' //Scancode = $5B      ]
,0x00 //Scancode = $5C
,0x5C //Scancode = $5D      backslash
,0x00 //Scancode = $5E
,0x00 //Scancode = $5F

,0x00 //Scancode = $60
,0x00 //Scancode = $61
,0x00 //Scancode = $62
,0x00 //Scancode = $63
,0x00 //Scancode = $64
,0x00 //Scancode = $65
,0x08 //Scancode = $66      Backspace
,0x00 //Scancode = $67
,0x00 //Scancode = $68
,0x0A //Scancode = $69      KP1      CEDRIC - move to line end
,0x00 //Scancode = $6A
,0x0C //Scancode = $6B      KP4      CEDRIC - move cursor left
,0x09 //Scancode = $6C      KP7      CEDRIC - (Tab)
,0x00 //Scancode = $6D
,0x00 //Scancode = $6E
,0x00 //Scancode = $6F

,0x00 //Scancode = $70      KP0
,'.' //Scancode = $71      KP.
,0x04 //Scancode = $72      KP2      CEDRIC - move cursor down
,0x1C //Scancode = $73      KP5      CEDRIC - point here
,0x12 //Scancode = $74      KP6      CEDRIC - move cursor right
,0x15 //Scancode = $75      KP8      CEDRIC - move cursor up
,0x1B //Scancode = $76      Escape
,0x00 //Scancode = $77
,0x18 //Scancode = $78      F11      CEDRIC - delete line
,'+' //Scancode = $79      KP+
,0x06 //Scancode = $7A      KP3      CEDRIC - move one line forward
,'-' //Scancode = $7B      KP-
,'*' //Scancode = $7C      KP*
,0x02 //Scancode = $7D      KP9      CEDRIC - line back
,0x00 //Scancode = $7E
,0x00 //Scancode = $7F

```

```

//Third dataset, shift = 1, shiftlock = 0
,0x00 //Scancode = $00
,0x05 //Scancode = $01 F9 CEDRIC - delete char
,0x00 //Scancode = $02
,0x19 //Scancode = $03 F5 CEDRIC - cut
,0x0E //Scancode = $04 F3 CEDRIC - search and replace
,0x03 //Scancode = $05 F1 CEDRIC - search forward
,0x1A //Scancode = $06 F2 CEDRIC - search back
,0x08 //Scancode = $07 F12 CEDRIC - delete left (backspace)
,0x00 //Scancode = $08
,0x17 //Scancode = $09 F10 CEDRIC - delete word
,0x13 //Scancode = $0A F8 CEDRIC -
,0x10 //Scancode = $0B F6 CEDRIC - paste
,0x01 //Scancode = $0C F4 CEDRIC - global replace
,0x09 //Scancode = $0D Tab
,'~' //Scancode = $0E ~
,0x00 //Scancode = $0F

,0x00 //Scancode = $10
,0x00 //Scancode = $11
,0x00 //Scancode = $12
,0x00 //Scancode = $13
,0x00 //Scancode = $14
,'Q' //Scancode = $15 Q
,'!' //Scancode = $16 !
,0x00 //Scancode = $17
,0x00 //Scancode = $18
,0x00 //Scancode = $19
,'Z' //Scancode = $1A Z
,'S' //Scancode = $1B S
,'A' //Scancode = $1C A
,'W' //Scancode = $1D W
,'@' //Scancode = $1E @
,0x00 //Scancode = $1F

,0x00 //Scancode = $20
,'C' //Scancode = $21 C
,'X' //Scancode = $22 X
,'D' //Scancode = $23 D
,'E' //Scancode = $24 E
,'$' //Scancode = $25 $
,'#' //Scancode = $26 #
,0x00 //Scancode = $27
,0x00 //Scancode = $28
,' ' //Scancode = $29 Space
,'V' //Scancode = $2A V
,'F' //Scancode = $2B F
,'T' //Scancode = $2C T
,'R' //Scancode = $2D R
,'%' //Scancode = $2E %
,0x00 //Scancode = $2F

,0x00 //Scancode = $30
,'N' //Scancode = $31 N
,'B' //Scancode = $32 B
,'H' //Scancode = $33 H
,'G' //Scancode = $34 G
,'Y' //Scancode = $35 Y
,'^' //Scancode = $36 ^
,0x00 //Scancode = $37
,0x00 //Scancode = $38
,0x00 //Scancode = $39
,'M' //Scancode = $3A M
,'J' //Scancode = $3B J
,'U' //Scancode = $3C U
,'&' //Scancode = $3D &
,'*' //Scancode = $3E *
,0x00 //Scancode = $3F

```

```

,0x00 //Scancode = $40
,'<' //Scancode = $41 <
,'K' //Scancode = $42 K
,'I' //Scancode = $43 I
,'0' //Scancode = $44 0
,')' //Scancode = $45 )
,'(' //Scancode = $46 (
,0x00 //Scancode = $47
,0x00 //Scancode = $48
,'>' //Scancode = $49 >
,'?' //Scancode = $4A ?
,'L' //Scancode = $4B L
,:'.' //Scancode = $4C :
,'P' //Scancode = $4D P
,'-' //Scancode = $4E -
,0x00 //Scancode = $4F

,0x00 //Scancode = $50
,0x00 //Scancode = $51
,'''' //Scancode = $52 "
,0x00 //Scancode = $53
,'{' //Scancode = $54 {
,'+' //Scancode = $55 +
,0x00 //Scancode = $56
,0x00 //Scancode = $57
,0x00 //Scancode = $58
,0x00 //Scancode = $59
,0x0D //Scancode = $5A Enter
,'}' //Scancode = $5B }
,0x00 //Scancode = $5C
,'|' //Scancode = $5D |
,0x00 //Scancode = $5E
,0x00 //Scancode = $5F

,0x00 //Scancode = $60
,0x00 //Scancode = $61
,0x00 //Scancode = $62
,0x00 //Scancode = $63
,0x00 //Scancode = $64
,0x00 //Scancode = $65
,0x08 //Scancode = $66 Backspace
,0x00 //Scancode = $67
,0x00 //Scancode = $68
,0x0A //Scancode = $69 KP1 CEDRIC - move to line end
,0x00 //Scancode = $6A
,0x0C //Scancode = $6B KP4 CEDRIC - move cursor left
,0x09 //Scancode = $6C KP7 CEDRIC - (Tab)
,0x00 //Scancode = $6D
,0x00 //Scancode = $6E
,0x00 //Scancode = $6F

,0x00 //Scancode = $70 KP0
,'.' //Scancode = $71 KP.
,0x04 //Scancode = $72 KP2 CEDRIC - move cursor down
,0x1C //Scancode = $73 KP5 CEDRIC - point here
,0x12 //Scancode = $74 KP6 CEDRIC - move cursor right
,0x15 //Scancode = $75 KP8 CEDRIC - move cursor up
,0x1B //Scancode = $76 Escape
,0x00 //Scancode = $77
,0x18 //Scancode = $78 F11 CEDRIC - delete line
,'+' //Scancode = $79 KP+
,0x06 //Scancode = $7A KP3 CEDRIC - move one line forward
,'-' //Scancode = $7B KP-
,'*' //Scancode = $7C KP*
,0x02 //Scancode = $7D KP9 CEDRIC - line back
,0x00 //Scancode = $7E
,0x00 //Scancode = $7F

```

```

//Fourth dataset, shift = 1, shiftlock = 1
,0x00 //Scancode = $00
,0x05 //Scancode = $01 F9 CEDRIC - delete char
,0x00 //Scancode = $02
,0x19 //Scancode = $03 F5 CEDRIC - cut
,0x0E //Scancode = $04 F3 CEDRIC - search and replace
,0x03 //Scancode = $05 F1 CEDRIC - search forward
,0x1A //Scancode = $06 F2 CEDRIC - search back
,0x08 //Scancode = $07 F12 CEDRIC - delete left (backspace)
,0x00 //Scancode = $08
,0x17 //Scancode = $09 F10 CEDRIC - delete word
,0x13 //Scancode = $0A F8 CEDRIC -
,0x10 //Scancode = $0B F6 CEDRIC - paste
,0x01 //Scancode = $0C F4 CEDRIC - global replace
,0x09 //Scancode = $0D Tab ~
,'~' //Scancode = $0E
,0x00 //Scancode = $0F

,0x00 //Scancode = $10
,0x00 //Scancode = $11
,0x00 //Scancode = $12
,0x00 //Scancode = $13
,0x00 //Scancode = $14
,'q' //Scancode = $15 q
,'!' //Scancode = $16 !
,0x00 //Scancode = $17
,0x00 //Scancode = $18
,0x00 //Scancode = $19
,'z' //Scancode = $1A z
,'s' //Scancode = $1B s
,'a' //Scancode = $1C a
,'w' //Scancode = $1D w
,'@' //Scancode = $1E @
,0x00 //Scancode = $1F

,0x00 //Scancode = $20
,'c' //Scancode = $21 c
,'x' //Scancode = $22 x
,'d' //Scancode = $23 d
,'e' //Scancode = $24 e
,'$' //Scancode = $25 $
,'#' //Scancode = $26 #
,0x00 //Scancode = $27
,0x00 //Scancode = $28
,' ' //Scancode = $29 Space
,'v' //Scancode = $2A v
,'f' //Scancode = $2B f
,'t' //Scancode = $2C t
,'r' //Scancode = $2D r
,'%' //Scancode = $2E %
,0x00 //Scancode = $2F

,0x00 //Scancode = $30
,'n' //Scancode = $31 n
,'b' //Scancode = $32 b
,'h' //Scancode = $33 h
,'g' //Scancode = $34 g
,'y' //Scancode = $35 y
,'^' //Scancode = $36 ^
,0x00 //Scancode = $37
,0x00 //Scancode = $38
,0x00 //Scancode = $39
,'m' //Scancode = $3A m
,'j' //Scancode = $3B j
,'u' //Scancode = $3C u
,'&' //Scancode = $3D &
,'*' //Scancode = $3E *
,0x00 //Scancode = $3F

```

```

,0x00 //Scancode = $40
,'<' //Scancode = $41 <
,'k' //Scancode = $42 k
,'i' //Scancode = $43 i
,'0' //Scancode = $44 o
,')' //Scancode = $45 )
,'(' //Scancode = $46 (
,0x00 //Scancode = $47
,0x00 //Scancode = $48
,'>' //Scancode = $49 >
,'?' //Scancode = $4A ?
,'l' //Scancode = $4B l
,:'.' //Scancode = $4C :
,'p' //Scancode = $4D p
,'-' //Scancode = $4E -
,0x00 //Scancode = $4F

,0x00 //Scancode = $50
,0x00 //Scancode = $51
,'''' //Scancode = $52 "
,0x00 //Scancode = $53
,'{' //Scancode = $54 {
,'+' //Scancode = $55 +
,0x00 //Scancode = $56
,0x00 //Scancode = $57
,0x00 //Scancode = $58
,0x00 //Scancode = $59
,0x0D //Scancode = $5A Enter
,'}' //Scancode = $5B }
,0x00 //Scancode = $5C
,'!' //Scancode = $5D !
,0x00 //Scancode = $5E
,0x00 //Scancode = $5F

,0x00 //Scancode = $60
,0x00 //Scancode = $61
,0x00 //Scancode = $62
,0x00 //Scancode = $63
,0x00 //Scancode = $64
,0x00 //Scancode = $65
,0x08 //Scancode = $66 Backspace
,0x00 //Scancode = $67
,0x00 //Scancode = $68
,0x0A //Scancode = $69 KP1 CEDRIC - move to line end
,0x00 //Scancode = $6A
,0x0C //Scancode = $6B KP4 CEDRIC - move cursor left
,0x09 //Scancode = $6C KP7 CEDRIC - (Tab)
,0x00 //Scancode = $6D
,0x00 //Scancode = $6E
,0x00 //Scancode = $6F

,0x00 //Scancode = $70 KP0
,'.' //Scancode = $71 KP.
,0x04 //Scancode = $72 KP2 CEDRIC - move cursor down
,0x1C //Scancode = $73 KP5 CEDRIC - point here
,0x12 //Scancode = $74 KP6 CEDRIC - move cursor right
,0x15 //Scancode = $75 KP8 CEDRIC - move cursor up
,0x1B //Scancode = $76 Escape
,0x00 //Scancode = $77
,0x18 //Scancode = $78 F11 CEDRIC - delete line
,'+' //Scancode = $79 KP+
,0x06 //Scancode = $7A KP3 CEDRIC - move one line forward
,'-' //Scancode = $7B KP-
,'*' //Scancode = $7C KP*
,0x02 //Scancode = $7D KP9 CEDRIC - line back
,0x00 //Scancode = $7E
,0x00 //Scancode = $7F

};

}

```

## Appendix 4 - Graphics display codes

The graphics display code provides a simple way to generate pictures using the internal graphics drivers. Here is an example display list:-

```

OPT NOL
LIB GRAPHICS.MAC
OPT LIS
*
CLEAR_SCREEN
SET_PEN_TYPE 0,$FFFF
MOVE_CURSOR 100,100
PLOT_LINE 200,200
PLOT_TEXT 'HI THERE!'
END_DRAW
*
END

```

This list should be assembled with ASMB in the normal manner, placed into memory using GET, and then the FLEX PLAY command should be used to draw the picture.

The graphics display codes are three byte 'opcodes' defined the macro set GRAPHICS.MAC. The available commands are :-

NULL

Do nothing.

CLEAR\_SCREEN

Clear the graphics screen.

MOVE\_CURSOR x-coord,y-coord

Moves the cursor to the given coords.

PLOT\_POINT x-coord,y-coord

Plots a point at the given coords.

PLOT\_LINE x-coord,y-coord

Plots a line from the present cursor position to the given coords.

PLOT\_RECTANGE sidex,sidey

Plots a rectangle (bottom rh corner is present coords), with given sides.

PLOT\_CIRCLE radius

Plots a circle (centre is present coords) with given radius where (0<radius<127).

PLOT\_TEXT 'text string'  
Plots the text string from the given coords.

SET\_PEN\_TYPE pen\_type,profile  
Sets the pen type and drawing profile.

SET\_TEXT\_ZOOM zoom\_factor  
Sets the text size (0<zoom\_factor<15)

END\_DRAW  
Ends the drawing process.

## Appendix 5 - Default display character set

```

// this array contains the CHARS1.CHR character set
char charSet[1086] = {
// character set attributes
    84, // screen chars/row
    24, // screen rows
    7, // char x pixels
    11, // char y rows
    9, // bounding box pixels
    12, // bounding box rows
    4, // initial attributes
    11 // char spacing (pixels)

// character set patterns
    , 0b00000000 //Character = ' '
    , 0b00000000
    ,
    , 0b00001000 //Character = '!'
    , 0b00001000
    , 0b00001000
    , 0b00001000
    , 0b00001000
    , 0b00000000
    , 0b00000000
    , 0b00000000
    , 0b00000000
    , 0b00000000
    ,
    , 0b00100100 //Character = """
    , 0b00100100
    , 0b00100100
    , 0b00000000
    ,
    , 0b00010100 //Character = '#'
    , 0b00010100
    , 0b00010100
    , 0b01111111
    , 0b00010100
    , 0b01111111
    , 0b00010100
    , 0b00010100
    , 0b00000000
    , 0b00000000
}

```

```
//  
, 0b00001000 //Character = '$'  
, 0b00111111  
, 0b01001000  
, 0b01001000  
, 0b00111110  
, 0b00001001  
, 0b00001001  
, 0b01111110  
, 0b00001000  
, 0b00000000  
, 0b00000000  
  
//  
, 0b00100000 //Character = '%'  
, 0b01010001  
, 0b00100010  
, 0b00000100  
, 0b00001000  
, 0b00010000  
, 0b00100010  
, 0b01000101  
, 0b00000010  
, 0b00000000  
, 0b00000000  
  
//  
, 0b00111000 //Character = '&'  
, 0b01000100  
, 0b01000100  
, 0b00101000  
, 0b00010000  
, 0b00101001  
, 0b01000110  
, 0b01000110  
, 0b00111001  
, 0b00000000  
, 0b00000000  
  
//  
, 0b00001100 //Character = '''  
, 0b00001100  
, 0b00001000  
, 0b00010000  
, 0b00000000  
, 0b00000000  
, 0b00000000  
, 0b00000000  
, 0b00000000  
  
//  
, 0b00000100 //Character = '('  
, 0b00001000  
, 0b00010000  
, 0b00010000  
, 0b00010000  
, 0b00010000  
, 0b00001000  
, 0b00000100  
, 0b00000000  
, 0b00000000
```

```
//  
, 0b00010000 //Character = ')'  
, 0b00001000  
, 0b00000100  
, 0b00000100  
, 0b00000100  
, 0b00000100  
, 0b00000100  
, 0b00001000  
, 0b000010000  
, 0b00000000  
//  
, 0b00000000 //Character = '//'  
, 0b00001000  
, 0b01001001  
, 0b00101010  
, 0b01111111  
, 0b00101010  
, 0b01001001  
, 0b00001000  
, 0b00000000  
, 0b00000000  
, 0b00000000  
//  
, 0b00000000 //Character = '+'  
, 0b00001000  
, 0b00001000  
, 0b00001000  
, 0b01111111  
, 0b00001000  
, 0b00001000  
, 0b00001000  
, 0b00000000  
, 0b00000000  
//  
, 0b00000000 //Character = ','  
, 0b00000000  
, 0b00000000  
, 0b00000000  
, 0b00000000  
, 0b00000000  
, 0b00011000  
, 0b00011000  
, 0b00010000  
, 0b00100000  
//  
, 0b00000000 //Character = '-'  
, 0b00000000  
, 0b00000000  
, 0b00000000  
, 0b00111110  
, 0b00000000  
, 0b00000000  
, 0b00000000  
, 0b00000000  
, 0b00000000
```

```
//  
, 0b00000000 //Character = 'fred'  
, 0b00000000  
, 0b00000000  
, 0b00000000  
, 0b00000000  
, 0b00000000  
, 0b00000000  
, 0b00011000  
, 0b00011000  
, 0b00000000  
, 0b00000000  
//  
, 0b00000000 //Character = '/'  
, 0b00000001  
, 0b00000010  
, 0b00000100  
, 0b00001000  
, 0b00010000  
, 0b01000000  
, 0b00000000  
, 0b00000000  
, 0b00000000  
//  
, 0b00111110 //Character = '0'  
, 0b01000001  
, 0b01000011  
, 0b01000101  
, 0b01001001  
, 0b01010001  
, 0b01100001  
, 0b01000001  
, 0b00111110  
, 0b00000000  
, 0b00000000  
//  
, 0b00001000 //Character = '1'  
, 0b00011000  
, 0b00101000  
, 0b00001000  
, 0b00001000  
, 0b00001000  
, 0b00001000  
, 0b00011110  
, 0b00000000  
, 0b00000000  
//  
, 0b00111110 //Character = '2'  
, 0b01000001  
, 0b00000001  
, 0b00000010  
, 0b00011100  
, 0b00100000  
, 0b01000000  
, 0b01111111  
, 0b00000000  
, 0b00000000
```

```
//  
    , 0b00111110 //Character = '3'  
    , 0b01000001  
    , 0b00000001  
    , 0b00000001  
    , 0b00011110  
    , 0b00000001  
    , 0b00000001  
    , 0b01000001  
    , 0b00111110  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b00000010 //Character = '4'  
    , 0b00000110  
    , 0b00001010  
    , 0b00010010  
    , 0b00100010  
    , 0b01000010  
    , 0b01111111  
    , 0b00000010  
    , 0b00000010  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b01111111 //Character = '5'  
    , 0b01000000  
    , 0b01000000  
    , 0b01111100  
    , 0b00000010  
    , 0b00000001  
    , 0b00000001  
    , 0b01000010  
    , 0b00111110  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b00011110 //Character = '6'  
    , 0b00100000  
    , 0b01000000  
    , 0b01111110  
    , 0b01000001  
    , 0b01000001  
    , 0b01000001  
    , 0b00111110  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b01111111 //Character = '7'  
    , 0b01000001  
    , 0b00000010  
    , 0b00000100  
    , 0b00001000  
    , 0b00010000  
    , 0b00010000  
    , 0b00000000  
    , 0b00000000
```

```
//  
, 0b00111110 //Character = '8'  
, 0b01000001  
, 0b01000001  
, 0b01000001  
, 0b00111110  
, 0b01000001  
, 0b01000001  
, 0b01000001  
, 0b00111110  
, 0b00000000  
, 0b00000000  
  
//  
, 0b00111110 //Character = '9'  
, 0b01000001  
, 0b01000001  
, 0b01000001  
, 0b00111111  
, 0b00000001  
, 0b00000001  
, 0b00000010  
, 0b00111100  
, 0b00000000  
, 0b00000000  
  
//  
, 0b00000000 //Character = ':'  
, 0b00000000  
, 0b00000000  
, 0b00011000  
, 0b00011000  
, 0b00000000  
, 0b00000000  
, 0b00011000  
, 0b00011000  
, 0b00000000  
, 0b00000000  
  
//  
, 0b00000000 //Character = ';'  
, 0b00000000  
, 0b00000000  
, 0b00011000  
, 0b00011000  
, 0b00000000  
, 0b00000000  
, 0b00011000  
, 0b00011000  
, 0b00000000  
, 0b00010000  
  
//  
, 0b00000100 //Character = '<'  
, 0b00001000  
, 0b00010000  
, 0b00100000  
, 0b00100000  
, 0b00010000  
, 0b00001000  
, 0b00000100  
, 0b00000000  
, 0b00000000
```

```
//  
, 0b000000000 //Character = '='  
, 0b000000000  
, 0b000000000  
, 0b00111110  
, 0b000000000  
, 0b00111110  
, 0b000000000  
, 0b000000000  
, 0b000000000  
, 0b000000000  
//  
, 0b00010000 //Character = '>'  
, 0b00001000  
, 0b00000100  
, 0b00000010  
, 0b00000001  
, 0b00000010  
, 0b00000100  
, 0b00001000  
, 0b00010000  
, 0b00000000  
//  
, 0b00011110 //Character = '?'  
, 0b00100001  
, 0b00100001  
, 0b00000001  
, 0b00000110  
, 0b000001000  
, 0b000001000  
, 0b00000000  
, 0b000001000  
, 0b000000000  
//  
, 0b00011110 //Character = '@'  
, 0b00100001  
, 0b01001101  
, 0b01010101  
, 0b01010101  
, 0b01011110  
, 0b01000000  
, 0b00100000  
, 0b00011110  
, 0b00000000  
, 0b000000000  
//  
, 0b00011100 //Character = 'A'  
, 0b00100010  
, 0b01000001  
, 0b01000001  
, 0b01111111  
, 0b01000001  
, 0b01000001  
, 0b00000000  
, 0b000000000
```

```
//  
    , 0b01111110 //Character = 'B'  
    , 0b00100001  
    , 0b00100001  
    , 0b00100001  
    , 0b00111110  
    , 0b00100001  
    , 0b00100001  
    , 0b00100001  
    , 0b01111110  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b00111110 //Character = 'C'  
    , 0b00100001  
    , 0b01000000  
    , 0b01000000  
    , 0b01000000  
    , 0b01000000  
    , 0b01000000  
    , 0b00100001  
    , 0b00011110  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b01111100 //Character = 'D'  
    , 0b01000010  
    , 0b01000001  
    , 0b01000001  
    , 0b01000001  
    , 0b01000001  
    , 0b01000001  
    , 0b01000010  
    , 0b01111100  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b01111111 //Character = 'E'  
    , 0b01000000  
    , 0b01000000  
    , 0b01000000  
    , 0b01111000  
    , 0b01000000  
    , 0b01000000  
    , 0b01000000  
    , 0b01111111  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b01111111 //Character = 'F'  
    , 0b01000000  
    , 0b01000000  
    , 0b01000000  
    , 0b01111000  
    , 0b01000000  
    , 0b01000000  
    , 0b01000000  
    , 0b00000000  
    , 0b00000000
```

```
//  
    , 0b00011110 //Character = 'G'  
    , 0b00100001  
    , 0b01000000  
    , 0b01000000  
    , 0b01000000  
    , 0b01001111  
    , 0b01000001  
    , 0b00100001  
    , 0b00011110  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b01000001 //Character = 'H'  
    , 0b01000001  
    , 0b01000001  
    , 0b01000001  
    , 0b01111111  
    , 0b01000001  
    , 0b01000001  
    , 0b01000001  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b00111110 //Character = 'I'  
    , 0b00001000  
    , 0b00111110  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b00011111 //Character = 'J'  
    , 0b00000100  
    , 0b00000100  
    , 0b00000100  
    , 0b00000100  
    , 0b00000100  
    , 0b01000100  
    , 0b00111000  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b01000001 //Character = 'K'  
    , 0b01000010  
    , 0b01000100  
    , 0b01001000  
    , 0b01010000  
    , 0b01101000  
    , 0b01000100  
    , 0b01000010  
    , 0b01000001  
    , 0b00000000  
    , 0b00000000
```

```
//  
, 0b01000000 //Character = 'L'  
, 0b01000000  
, 0b01111111  
, 0b00000000  
, 0b00000000  
  
//  
, 0b01000001 //Character = 'M'  
, 0b01100011  
, 0b01010101  
, 0b01001001  
, 0b01001001  
, 0b01000001  
, 0b01000001  
, 0b01000001  
, 0b01000001  
, 0b00000000  
, 0b00000000  
  
//  
, 0b01000001 //Character = 'N'  
, 0b01100001  
, 0b01010001  
, 0b01001001  
, 0b01000101  
, 0b01000011  
, 0b01000001  
, 0b01000001  
, 0b01000001  
, 0b00000000  
, 0b00000000  
  
//  
, 0b00011100 //Character = 'O'  
, 0b00100010  
, 0b01000001  
, 0b01000001  
, 0b01000001  
, 0b01000001  
, 0b00100010  
, 0b00011100  
, 0b00000000  
, 0b00000000  
  
//  
, 0b01111110 //Character = 'P'  
, 0b01000001  
, 0b01000001  
, 0b01000001  
, 0b01111110  
, 0b01000000  
, 0b01000000  
, 0b01000000  
, 0b00000000  
, 0b00000000
```

```
//  
, 0b00011100 //Character = 'Q'  
, 0b00100010  
, 0b01000001  
, 0b01000001  
, 0b01000001  
, 0b01001001  
, 0b01000101  
, 0b00100010  
, 0b00011101  
, 0b00000000  
, 0b00000000  
  
//  
, 0b01111110 //Character = 'R'  
, 0b01000001  
, 0b01000001  
, 0b01000001  
, 0b01111110  
, 0b01001000  
, 0b01000100  
, 0b01000010  
, 0b01000001  
, 0b00000000  
, 0b00000000  
  
//  
, 0b00111110 //Character = 'S'  
, 0b01000001  
, 0b01000000  
, 0b01000000  
, 0b00111110  
, 0b00000001  
, 0b00000001  
, 0b01000001  
, 0b00111110  
, 0b00000000  
, 0b00000000  
  
//  
, 0b01111111 //Character = 'T'  
, 0b00001000  
, 0b00000000  
, 0b00000000  
  
//  
, 0b01000001 //Character = 'U'  
, 0b01000001  
, 0b01000001  
, 0b01000001  
, 0b01000001  
, 0b01000001  
, 0b01000001  
, 0b00111110  
, 0b00000000  
, 0b00000000
```

```
//  
, 0b01000001 //Character = 'V'  
, 0b01000001  
, 0b01000001  
, 0b00100010  
, 0b00100010  
, 0b00010100  
, 0b00010100  
, 0b00001000  
, 0b00001000  
, 0b00000000  
, 0b00000000  
  
//  
, 0b01000001 //Character = 'W'  
, 0b01000001  
, 0b01000001  
, 0b01000001  
, 0b01001001  
, 0b01001001  
, 0b01010101  
, 0b01100011  
, 0b01000001  
, 0b00000000  
, 0b00000000  
  
//  
, 0b01000001 //Character = 'X'  
, 0b01000001  
, 0b00100010  
, 0b00010100  
, 0b00001000  
, 0b00001000  
, 0b00010100  
, 0b00100010  
, 0b01000001  
, 0b01000001  
, 0b00000000  
, 0b00000000  
  
//  
, 0b01000001 //Character = 'Y'  
, 0b01000001  
, 0b00100010  
, 0b00010100  
, 0b00001000  
, 0b00001000  
, 0b00001000  
, 0b00001000  
, 0b00001000  
, 0b00000000  
, 0b00000000  
  
//  
, 0b01111111 //Character = 'Z'  
, 0b00000001  
, 0b00000010  
, 0b00000100  
, 0b00001000  
, 0b00010000  
, 0b01000000  
, 0b01111111  
, 0b00000000  
, 0b00000000
```

```
//  
    , 0b00111110 //Character = '['  
    , 0b00100000  
    , 0b00111110  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b00000000 //Character = '\'  
    , 0b01000000  
    , 0b00100000  
    , 0b00010000  
    , 0b00001000  
    , 0b00000100  
    , 0b00000010  
    , 0b00000001  
    , 0b00000000  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b00111110 //Character = ']'  
    , 0b00000010  
    , 0b00111110  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b00001000 //Character = '^'  
    , 0b00011100  
    , 0b00101010  
    , 0b01001001  
    , 0b00001000  
    , 0b00001000  
    , 0b00001000  
    , 0b00001000  
    , 0b00001000  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b00000000 //Character = '_'  
    , 0b00000000  
    , 0b00000000  
    , 0b00000000  
    , 0b00000000  
    , 0b00000000  
    , 0b00000000  
    , 0b00111110  
    , 0b00000000  
    , 0b00000000
```

```
//  
    , 0b00011000 //Character = ``  
    , 0b00011000  
    , 0b00001000  
    , 0b00000100  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b00000000 //Character = 'a'  
    , 0b00000000  
    , 0b00000000  
    , 0b00111100  
    , 0b00000010  
    , 0b00111110  
    , 0b01000010  
    , 0b01000010  
    , 0b00111101  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b01000000 //Character = 'b'  
    , 0b01000000  
    , 0b01000000  
    , 0b01011100  
    , 0b01100010  
    , 0b01000010  
    , 0b01000010  
    , 0b01100010  
    , 0b01011100  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b00000000 //Character = 'c'  
    , 0b00000000  
    , 0b00000000  
    , 0b00111100  
    , 0b01000010  
    , 0b01000000  
    , 0b01000000  
    , 0b01000010  
    , 0b00111100  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b00000010 //Character = 'd'  
    , 0b00000010  
    , 0b00000010  
    , 0b00111010  
    , 0b01000110  
    , 0b01000010  
    , 0b01000110  
    , 0b00111010  
    , 0b00000000  
    , 0b00000000
```

```
//  
, 0b00000000 //Character = 'e'  
, 0b00000000  
, 0b00000000  
, 0b00111100  
, 0b01000010  
, 0b01111100  
, 0b01000000  
, 0b01000000  
, 0b00111100  
, 0b00000000  
, 0b00000000  
//  
, 0b00001100 //Character = 'f'  
, 0b00010010  
, 0b00010000  
, 0b00010000  
, 0b01111100  
, 0b00010000  
, 0b00010000  
, 0b00010000  
, 0b00010000  
, 0b00000000  
, 0b00000000  
//  
, 0b00000000 //Character = 'g'  
, 0b00000000  
, 0b00000000  
, 0b00111010  
, 0b01000110  
, 0b01000010  
, 0b01000010  
, 0b01000010  
, 0b00111010  
, 0b00000010  
, 0b01000010  
, 0b00111000  
//  
, 0b01000000 //Character = 'h'  
, 0b01000000  
, 0b01000000  
, 0b01011100  
, 0b01100010  
, 0b01000010  
, 0b01000010  
, 0b01000010  
, 0b01000010  
, 0b00000000  
, 0b00000000  
//  
, 0b00000000 //Character = 'i'  
, 0b00001000  
, 0b00000000  
, 0b000011000  
, 0b00001000  
, 0b00001000  
, 0b00001000  
, 0b00001000  
, 0b000011100  
, 0b00000000  
, 0b00000000
```

```
//  
    , 0b00000000 //Character = 'j'  
    , 0b00000010  
    , 0b00000000  
    , 0b00000110  
    , 0b00000010  
    , 0b00000010  
    , 0b00000010  
    , 0b00000010  
    , 0b00000010  
    , 0b00000010  
    , 0b00100010  
    , 0b00011100  
//  
    , 0b01000000 //Character = 'k'  
    , 0b01000000  
    , 0b01000000  
    , 0b01000100  
    , 0b01001000  
    , 0b01010000  
    , 0b01101000  
    , 0b01000100  
    , 0b01000010  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b00011000 //Character = 'l'  
    , 0b00001000  
    , 0b000011100  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b00000000 //Character = 'm'  
    , 0b00000000  
    , 0b00000000  
    , 0b01110110  
    , 0b01001001  
    , 0b01001001  
    , 0b01001001  
    , 0b01001001  
    , 0b01001001  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b00000000 //Character = 'n'  
    , 0b00000000  
    , 0b00000000  
    , 0b01011100  
    , 0b01100010  
    , 0b01000010  
    , 0b01000010  
    , 0b01000010  
    , 0b00000000  
    , 0b00000000
```

```
//  
, 0b00000000 //Character = 'o'  
, 0b00000000  
, 0b00000000  
, 0b00111110  
, 0b01000001  
, 0b01000001  
, 0b01000001  
, 0b01000001  
, 0b00111110  
, 0b00000000  
, 0b00000000  
  
//  
, 0b00000000 //Character = 'p'  
, 0b00000000  
, 0b00000000  
, 0b01011100  
, 0b01100010  
, 0b01000010  
, 0b01100010  
, 0b01011100  
, 0b01000000  
, 0b01000000  
, 0b01000000  
  
//  
, 0b00000000 //Character = 'q'  
, 0b00000000  
, 0b00000000  
, 0b00111010  
, 0b01000110  
, 0b01000010  
, 0b01000110  
, 0b00111010  
, 0b00000010  
, 0b00000010  
, 0b00000011  
  
//  
, 0b00000000 //Character = 'r'  
, 0b00000000  
, 0b00000000  
, 0b01011100  
, 0b01100010  
, 0b01000000  
, 0b01000000  
, 0b01000000  
, 0b01000000  
, 0b00000000  
  
//  
, 0b00000000 //Character = 's'  
, 0b00000000  
, 0b00000000  
, 0b00111100  
, 0b01000010  
, 0b00110000  
, 0b00001100  
, 0b01000010  
, 0b00111100  
, 0b00000000  
, 0b00000000
```

```
//  
, 0b00000000 //Character = 't'  
, 0b00010000  
, 0b00010000  
, 0b01111100  
, 0b00010000  
, 0b00010000  
, 0b00010000  
, 0b00010010  
, 0b00001100  
, 0b00000000  
, 0b00000000  
//  
, 0b00000000 //Character = 'u'  
, 0b00000000  
, 0b00000000  
, 0b01000010  
, 0b01000010  
, 0b01000010  
, 0b01000010  
, 0b01000010  
, 0b01000110  
, 0b00111010  
, 0b00000000  
, 0b00000000  
//  
, 0b00000000 //Character = 'v'  
, 0b00000000  
, 0b00000000  
, 0b01000001  
, 0b01000001  
, 0b01000001  
, 0b01000001  
, 0b00100010  
, 0b00010100  
, 0b00001000  
, 0b00000000  
, 0b00000000  
//  
, 0b00000000 //Character = 'w'  
, 0b00000000  
, 0b00000000  
, 0b01000001  
, 0b01001001  
, 0b01001001  
, 0b01001001  
, 0b01001001  
, 0b00110110  
, 0b00000000  
, 0b00000000  
//  
, 0b00000000 //Character = 'x'  
, 0b00000000  
, 0b00000000  
, 0b01000010  
, 0b00100100  
, 0b00011000  
, 0b00011000  
, 0b00100100  
, 0b01000010  
, 0b00000000  
, 0b00000000
```

```
//  
    , 0b00000000 //Character = 'y'  
    , 0b00000000  
    , 0b00000000  
    , 0b01000010  
    , 0b01000010  
    , 0b01000010  
    , 0b01000110  
    , 0b00111010  
    , 0b00000010  
    , 0b01000010  
    , 0b00111100  
//  
    , 0b00000000 //Character = 'z'  
    , 0b00000000  
    , 0b00000000  
    , 0b01111110  
    , 0b00000100  
    , 0b00001000  
    , 0b00010000  
    , 0b01111110  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b00001100 //Character = '{'  
    , 0b00010000  
    , 0b00010000  
    , 0b00010000  
    , 0b00010000  
    , 0b00010000  
    , 0b00010000  
    , 0b00001100  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b00001000 //Character = '|'  
    , 0b00001000  
    , 0b00001000  
    , 0b00000000  
    , 0b00001000  
    , 0b00001000  
    , 0b00001000  
    , 0b00000000  
    , 0b00000000  
    , 0b00000000  
//  
    , 0b00011000 //Character = '}'  
    , 0b00000100  
    , 0b00000100  
    , 0b00000100  
    , 0b00000100  
    , 0b00000100  
    , 0b00000100  
    , 0b00011000  
    , 0b00000000  
    , 0b00000000
```

```
//  
, 0b00110000 //Character = '~'  
, 0b01001001  
, 0b00000110  
, 0b00000000  
//  
, 0b00101010 //Character = 'del'  
, 0b01010101  
, 0b00101010  
, 0b01010101  
, 0b00101010  
, 0b01010101  
, 0b00101010  
, 0b01010101  
, 0b00101010  
, 0b00000000  
, 0b00000000  
//  
, 0b01111111 // Cursor type 1  
, 0b01111111  
, 0b00000000  
, 0b00000000  
//  
, 0b01100011 // Cursor type 2  
, 0b01000001  
, 0b01000001  
, 0b00000000  
, 0b00000000  
, 0b00000000  
, 0b01000001  
, 0b01000001  
, 0b01100011  
, 0b00000000  
, 0b00000000
```

};

## Appendix 6 - MB2K2 promdisk contents

The promdisk is part of the Xmos boot image and is loaded into flash at the same time as the firmware image via the Xmos tools.

By default the promdisk is read only but can be set to read/write with the 'PDRW' command and write protected again with 'PDRO'. Although the promdisk can be written to, there is no wear levelling and repeated writes (1,000's) will eventually 'wear out' the part of the flash image containing the FLEX SIR and other frequently written sectors.

### FLEX binaries

- |             |   |
|-------------|---|
| FLEX.COR    | - FLEX 3.01 binary used by the 'BF' command, replace to use different versions of FLEX. |
| ERRORS.SYS  |   |
| STARTUP.TXT | - Gets the time/date and sets TTYSET and ASN parameters from the battery backed RTC     |

### Standard FLEX utilities

- APPEND.CMD
- ASN.CMD
- BUILD.CMD
- CAT.CMD
- COPY.CMD
- DATE.CMD
- DELETE.CMD
- ECHO.CMD
- EXEC.CMD
- I.CMD
- JUMP.CMD
- LIST.CMD
- N.CMD
- O.CMD
- PROT.CMD
- RENAME.CMD
- SAVE.CMD
- SAVETXT.CMD
- TTYSET.CMD
- TOUCH.CMD
- VERIFY.CMD
- VERSION.CMD
- XOUT.CMD
- Y.CMD

**Additional FLEX utilities**

CMPMEM.CMD  
CONTIN.CMD  
COMPARE.CMD  
DATECOPY.CMD  
DIR.CMD  
DUMP.CMD  
FILES.CMD  
FIND.CMD  
FREE.CMD  
HECHO.CMD  
MAP.CMD  
MEMEND.CMD  
PDEL.CMD  
RUN.CMD  
SPLIT.CMD  
ZAP.CMD

**FLEX Diagnostic utilities**

EXAMINE.CMD  
FILETEST.CMD  
REBUILD.CMD  
UNDELETE.CMD  
VALIDATE.CMD

**Text editors**

E.CMD - This is the CEDRIC editor configured for the MB2K2's keyboard layout  
PS/2  
STYLO.CMD - Stylograph configured for the MB2K2  
STYHLP1.TXT  
STYHLP2.TXT  
STYHLP3.TXT  
STYHLP4.TXT  
STYHLP5.TXT  
STYHLP6.TXT

**TSC 6809 Assembler**

ASMB.CMD

**Dynamite 6809 Disassembler**

DISA.CMD  
DISLBL09.BIN

**TSC Debug Package**

DEBUG.CMD

Windrush PL/9 compiler

PL9.CMD  
 PL9\_TD.CMD  
 SETPL9.CMD  
 HEXGLOBL.DEF  
 TRUFALSE.DEF  
 PL9.ERR  
 BASTRING.LIB  
 BITIO.LIB  
 REALCON.LIB  
 REALIO.LIB  
 SCIPACK.LIB  
 SORT.LIB  
 STRSUBS.LIB  
 TERMSUBS.LIB  
 SETPL9.PL9

James McCosh C compiler

CC.CMD  
 CPREP.CMD  
 CPASS1.CMD  
 CPASS2.CMD  
 COPT.CMD  
 CASM.CMD  
 CLOAD.CMD  
 CLIB.LIB  
 CSTART.R  
 CTYPE.H  
 FLEX.H  
 SETJMP.H  
 STDIO.H  
 HELLO.C

MB2/MB2K2 specific utilities

MONLINK.TXT	- MON09 6809 assembly header file
FLEXLINK.TXT	- FLEX 6809 assembly header file
ALLOCATE.CMD	- allocate logical disk types to FLEX drive numbers
TIME.CMD	- Time and date from the battery backed RTC
SETTIME.CMD	- set the time and date in the battery backed RTC
GRAPH.CMD	- switch display to graphics
TEXT.CMD	- switch display to text
CLEAR.G.CMD	- clear graphics screen
PRETTY.CMD	- MB2 terminal emulator with higher resolution character set
FAST.CMD	- MB2K2 terminal emulator using uPD7220A command extensions
NORMAL.CMD	- revert to internal MON09 terminal emulator
SCOPY.CMD	- fast track based disk copy (only for disks with the same format)
PDRW.CMD	- enable writes to the promdisk
PDRO.CMD	- write protect the promdisk
GRAPHICS.MAC	- macro commands to define graphics vector list
PLAY.CMD	- playback pre-defined vector list
INTERP.CMD	- decode vector list to text

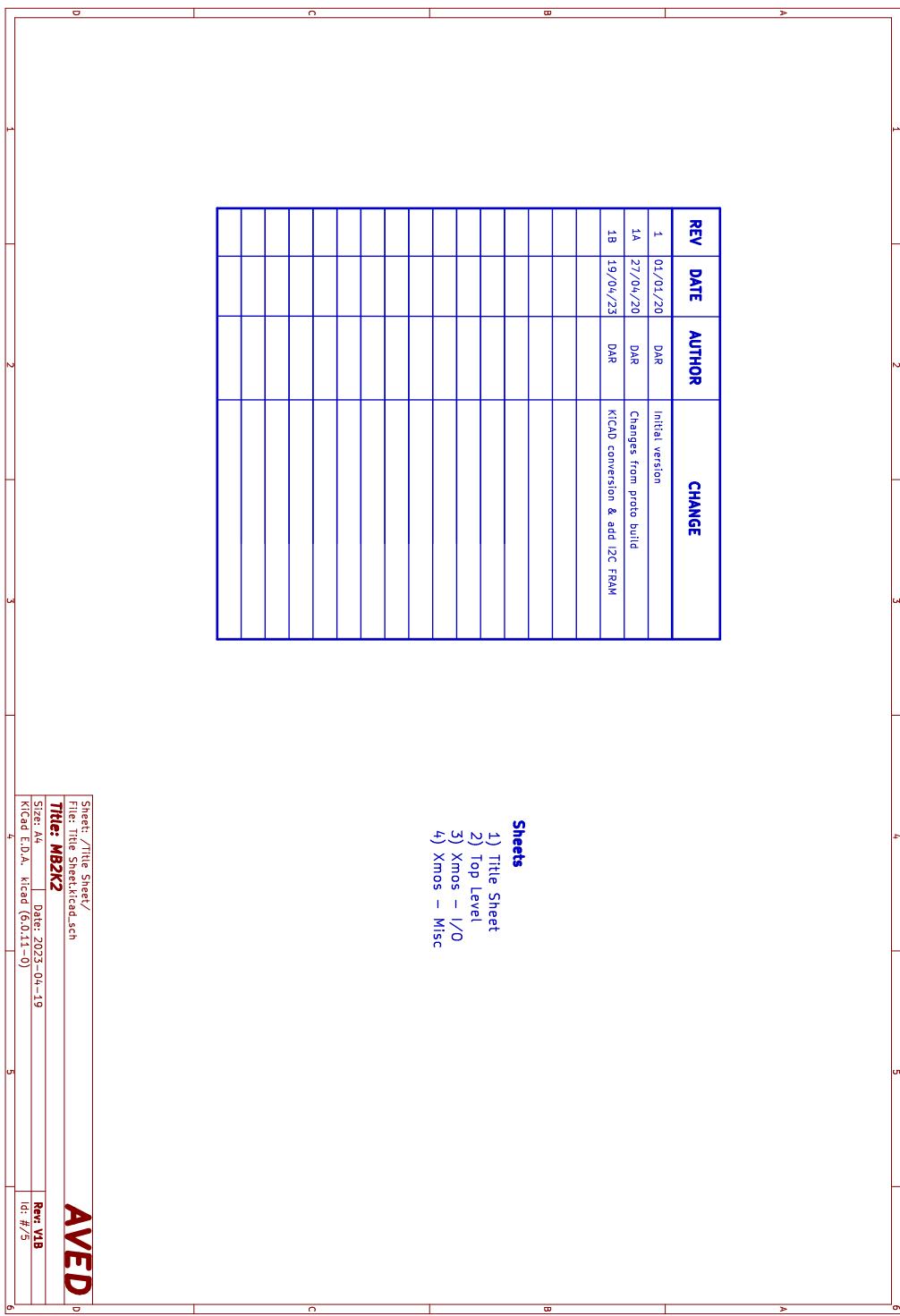
**FLEXNet utilities**

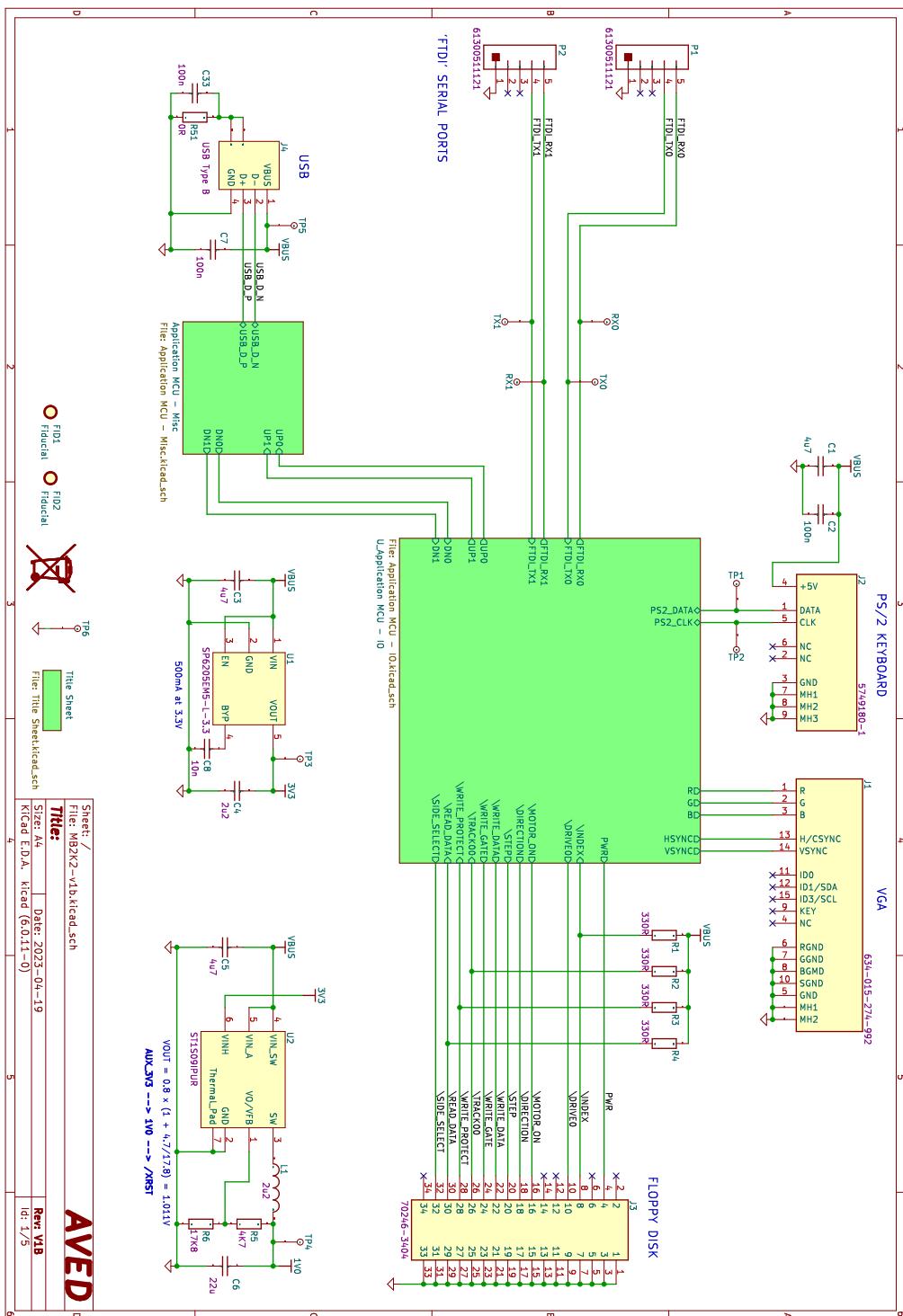
- |             |  |
|-------------|--|
| RMOUNT.CMD  | - mount remote disk image, or show currently mounted images<br>RMOUNT must be run before using any other FLEXNet command |
| RDRIVE.CMD  | - show current remote directory  |
| RLIST.CMD   | - folder list of remote directory  |
| RDIR.CMD    | - file list of the remote directory  |
| RCD.CMD     | - change directory in the remote system  |
| RCREATE.CMD | - create remote disk image   |
| RDELETE.CMD | - delete remote disk image   |
| RESYNC.CMD  | - resynchronise the serial link to the remote system   |
| REXIT.CMD   | - close remote volumes and shut down connection  |

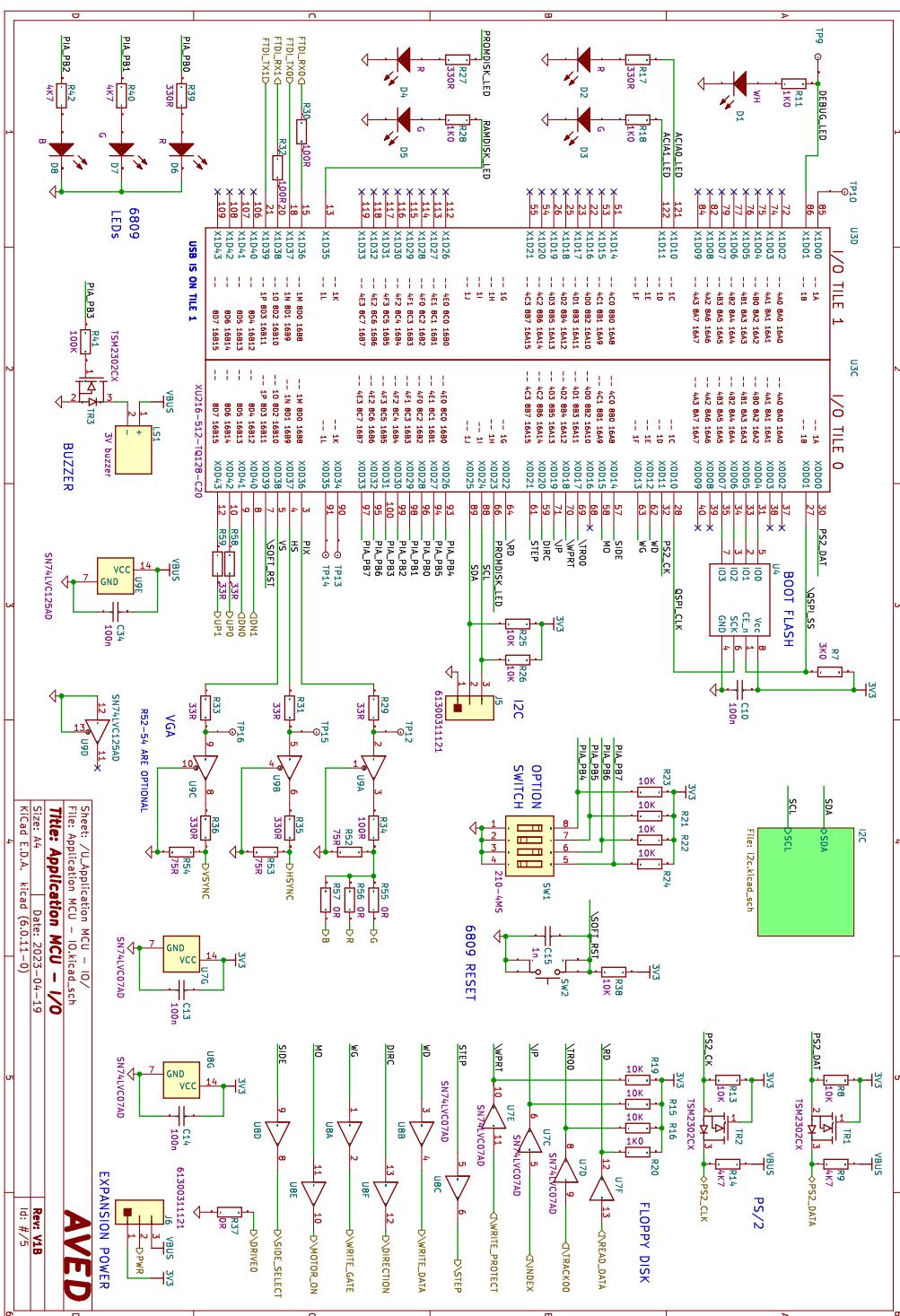
**Misc**

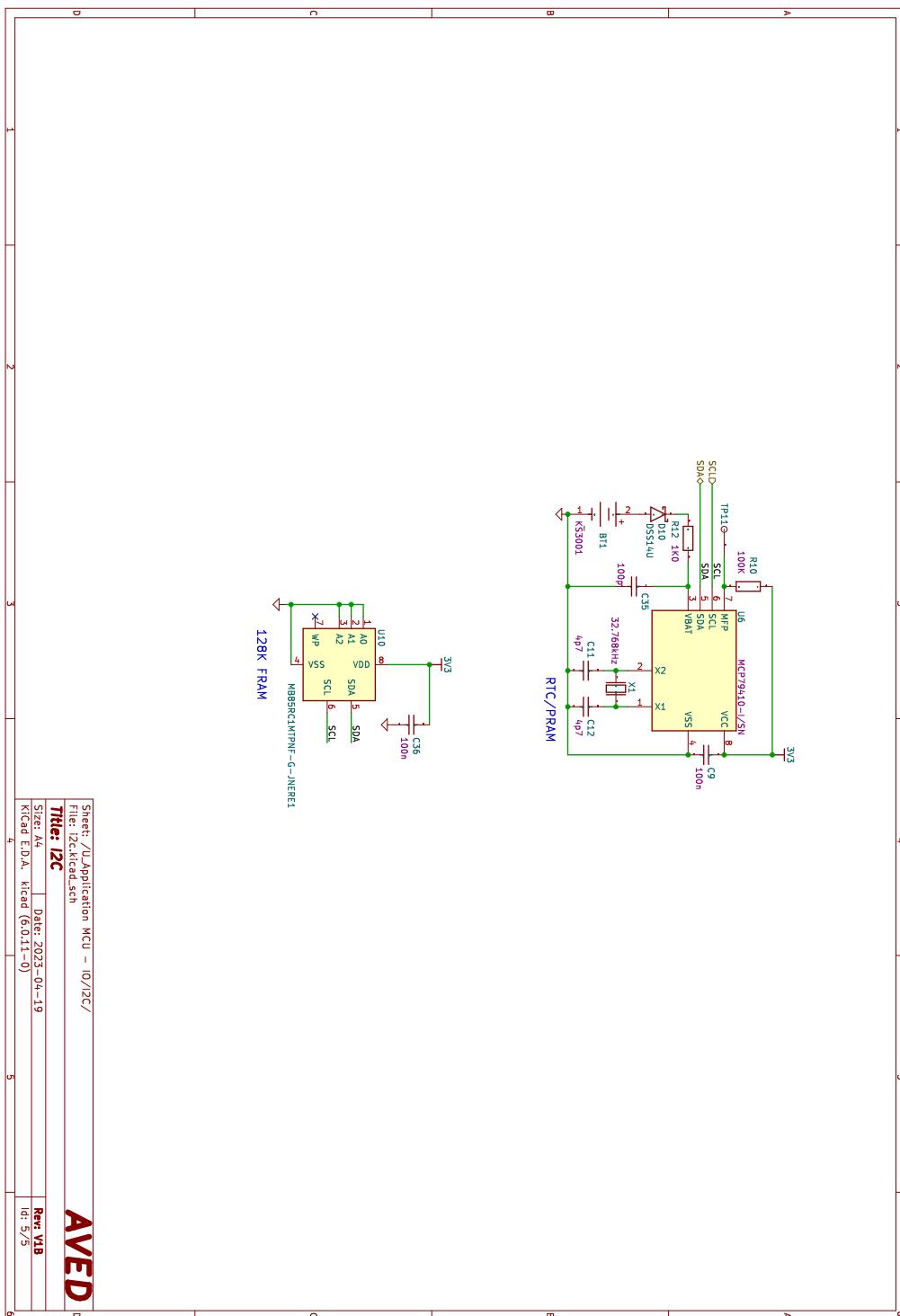
- |              |  |
|--------------|--|
| DEMO.CMD     | - the MB2 graphics line drawing demo                             |
| ADV.CMD      | - The classic Adventure game (overwrites FLEX due to large size) |
| ADVENTUR.SYS | - database for ADV.CMD   |
| STARTREK.CMD | - A version of the text based Trek game                          |
| STARTREK.TXT | - source code for the above                                      |

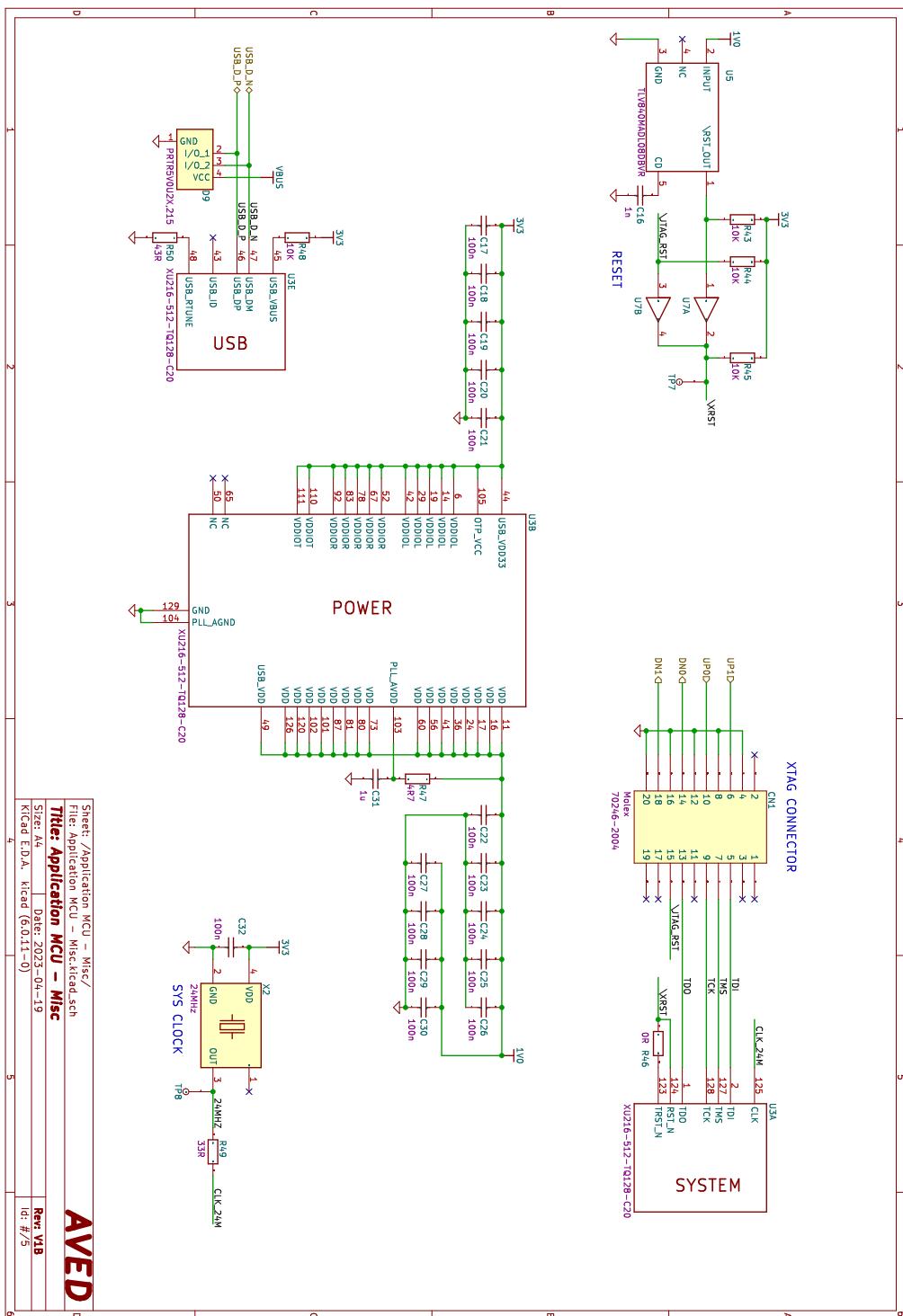
## Appendix 7 - Schematics



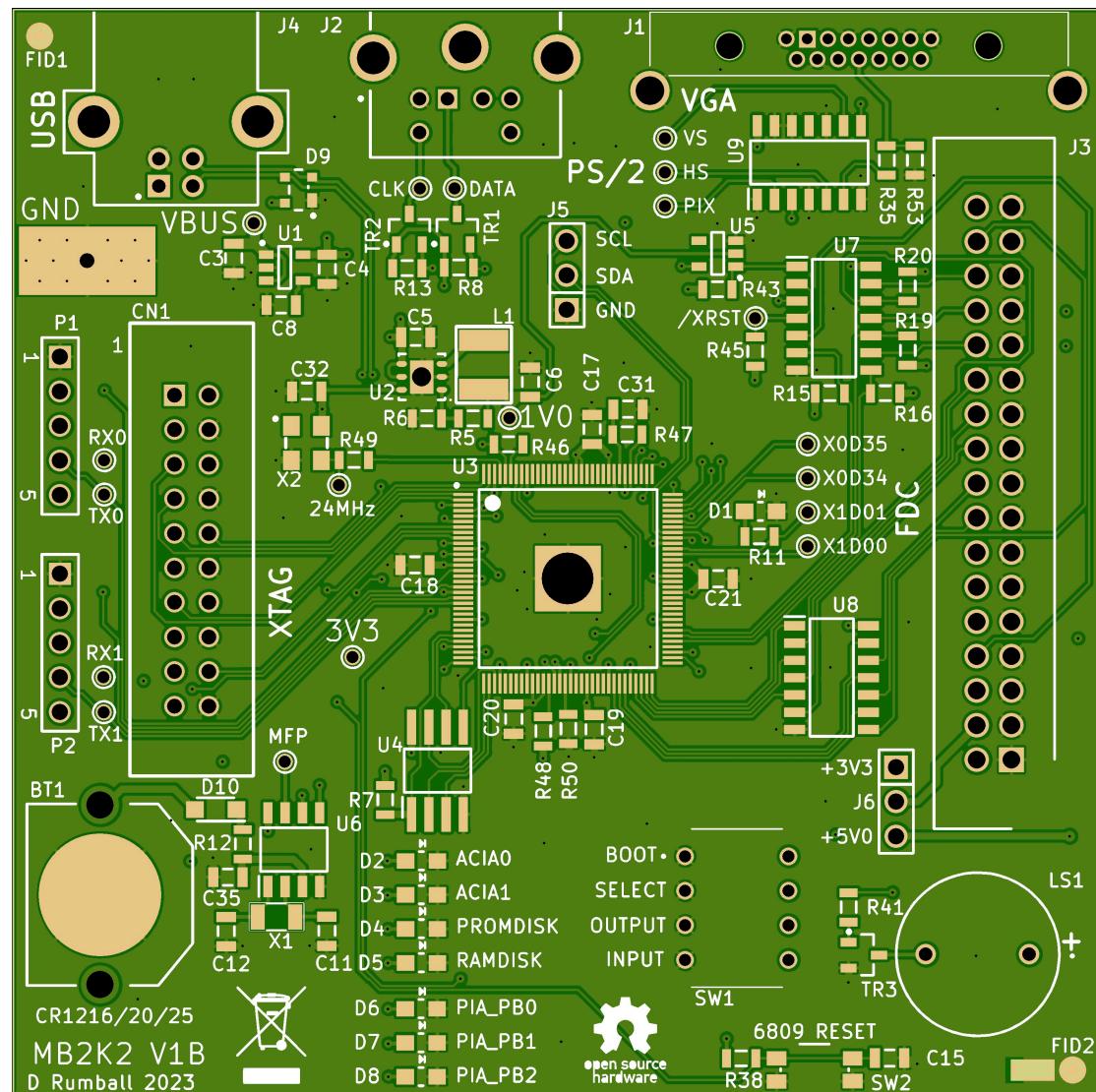




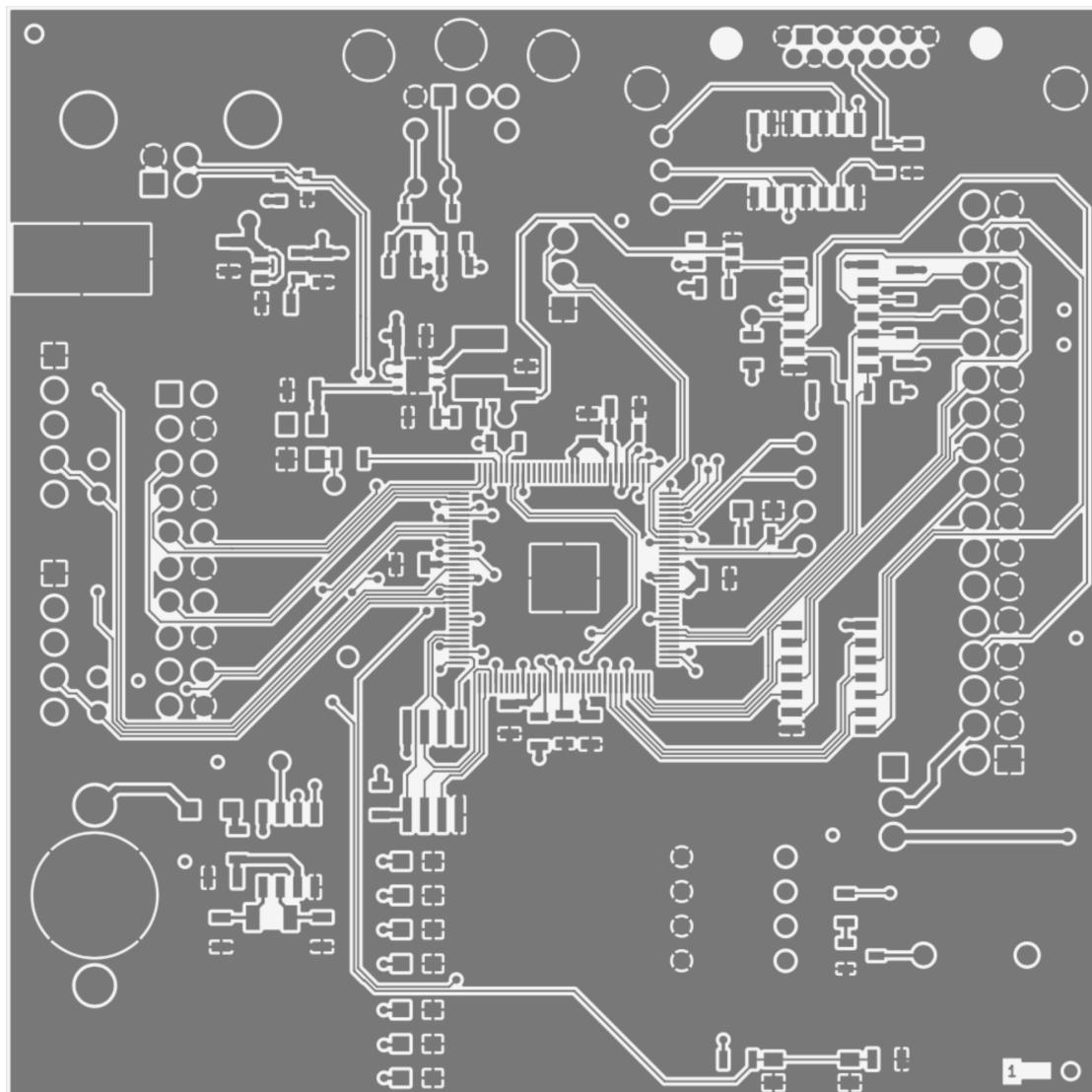




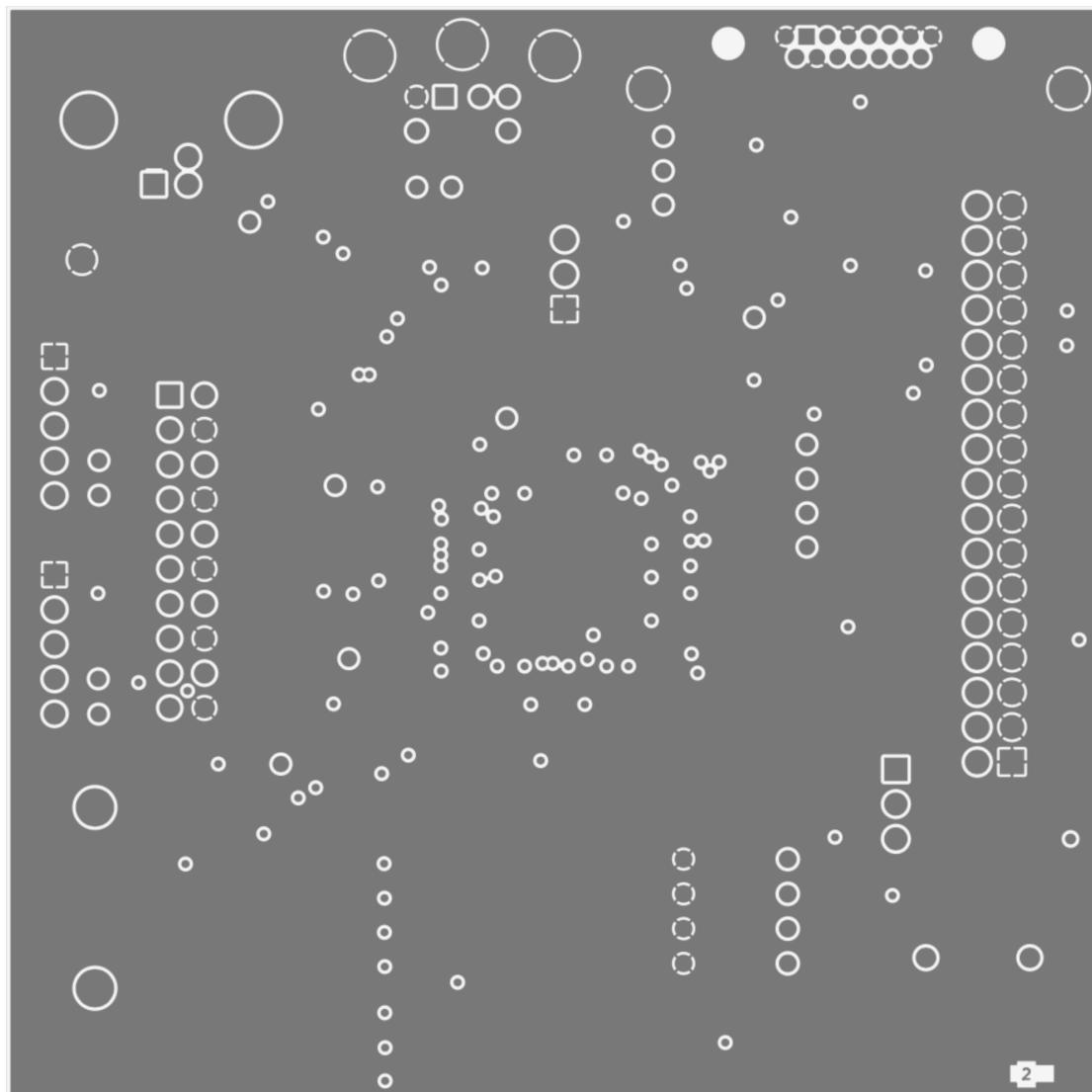
## Appendix 8 - PCB plots



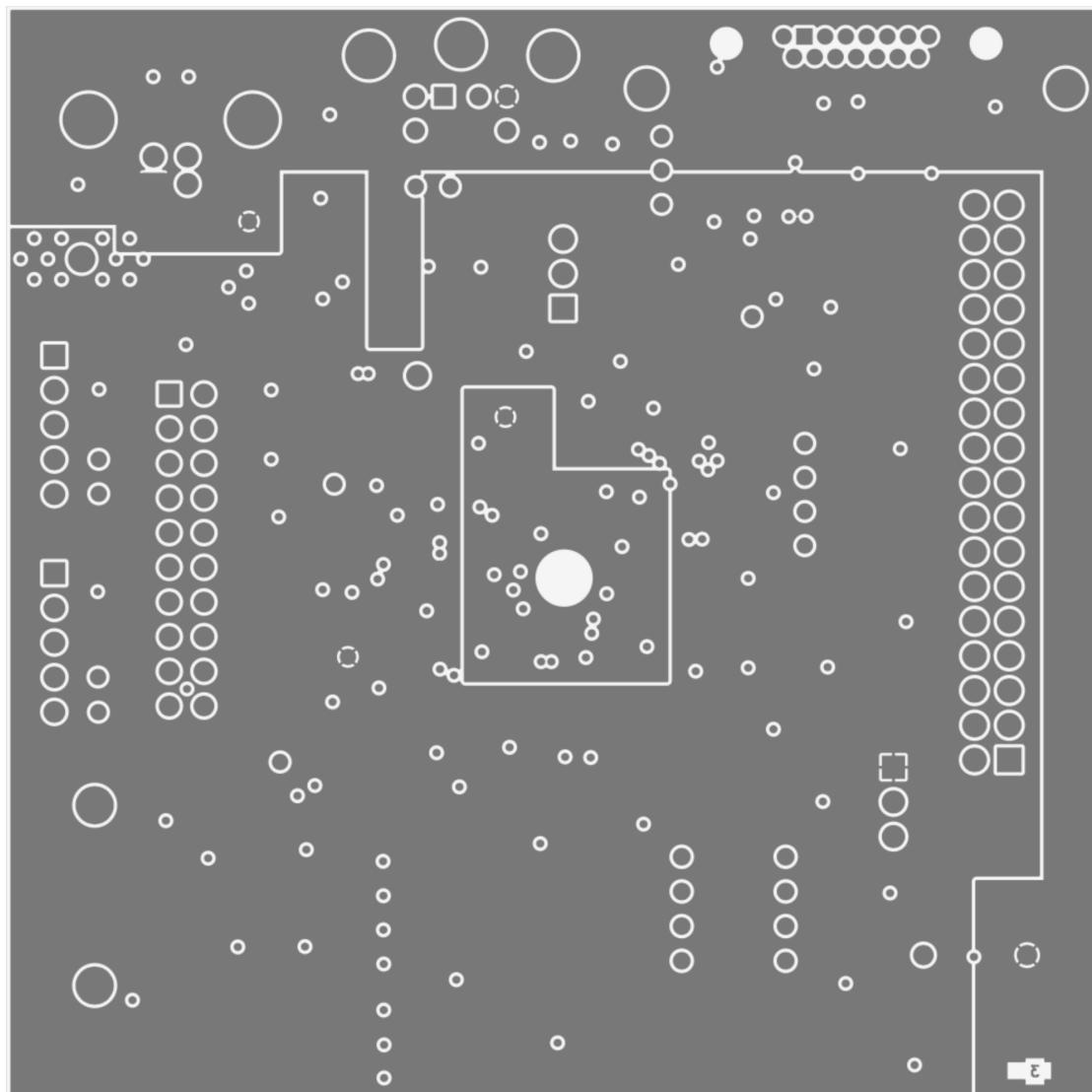
Top view



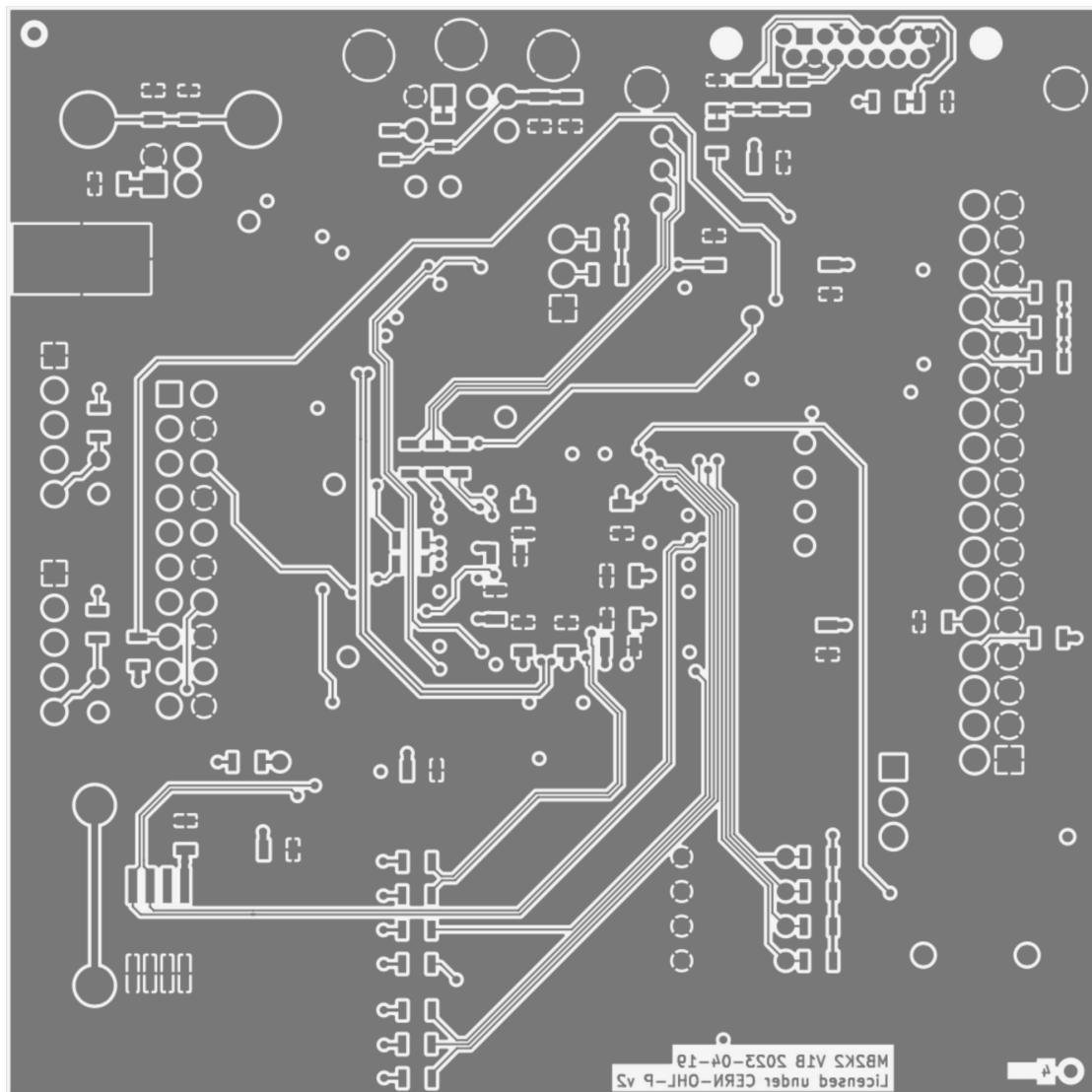
TOP layer



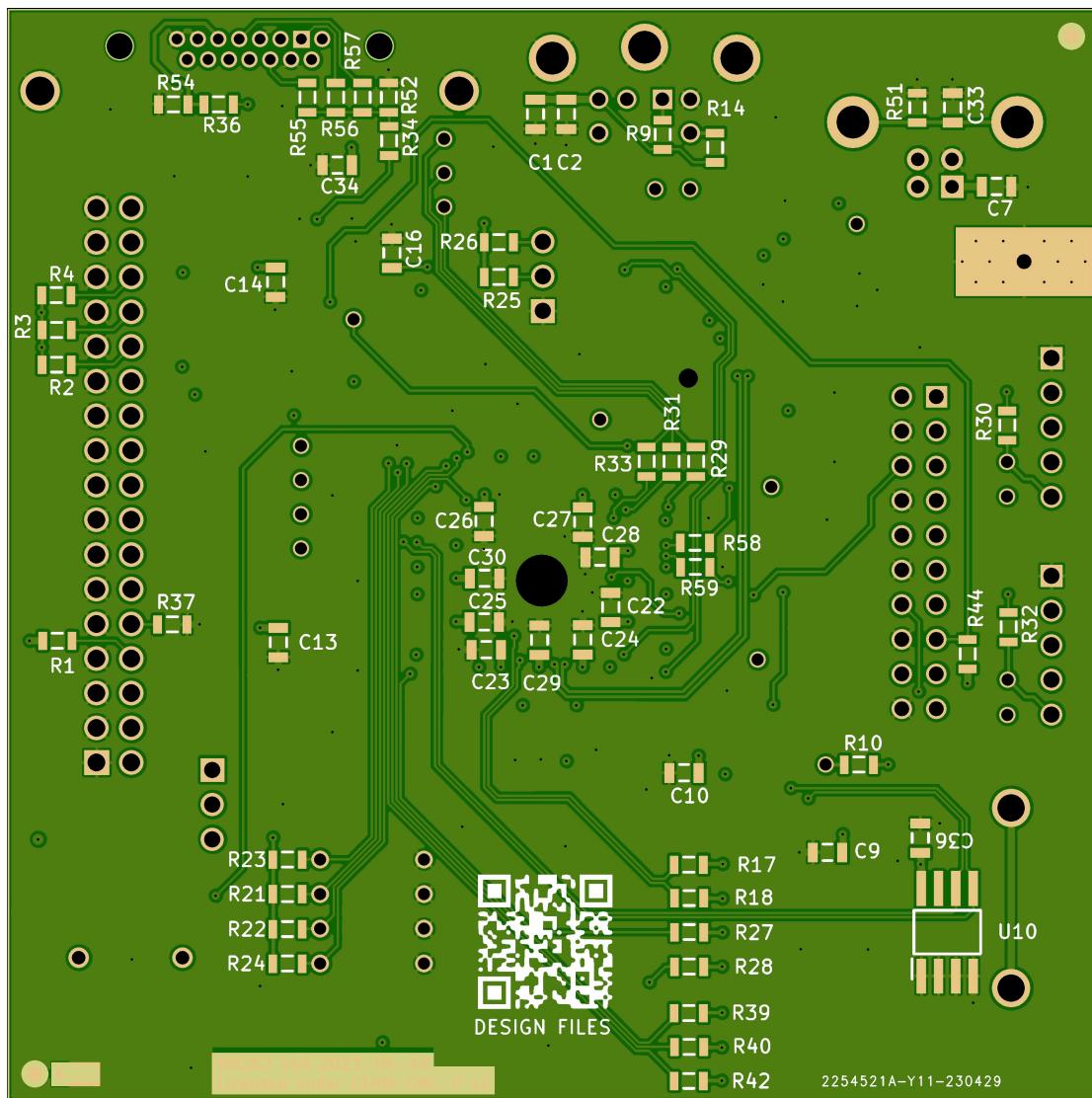
INNER1 layer (Gnd)



INNER2 layer (Power)

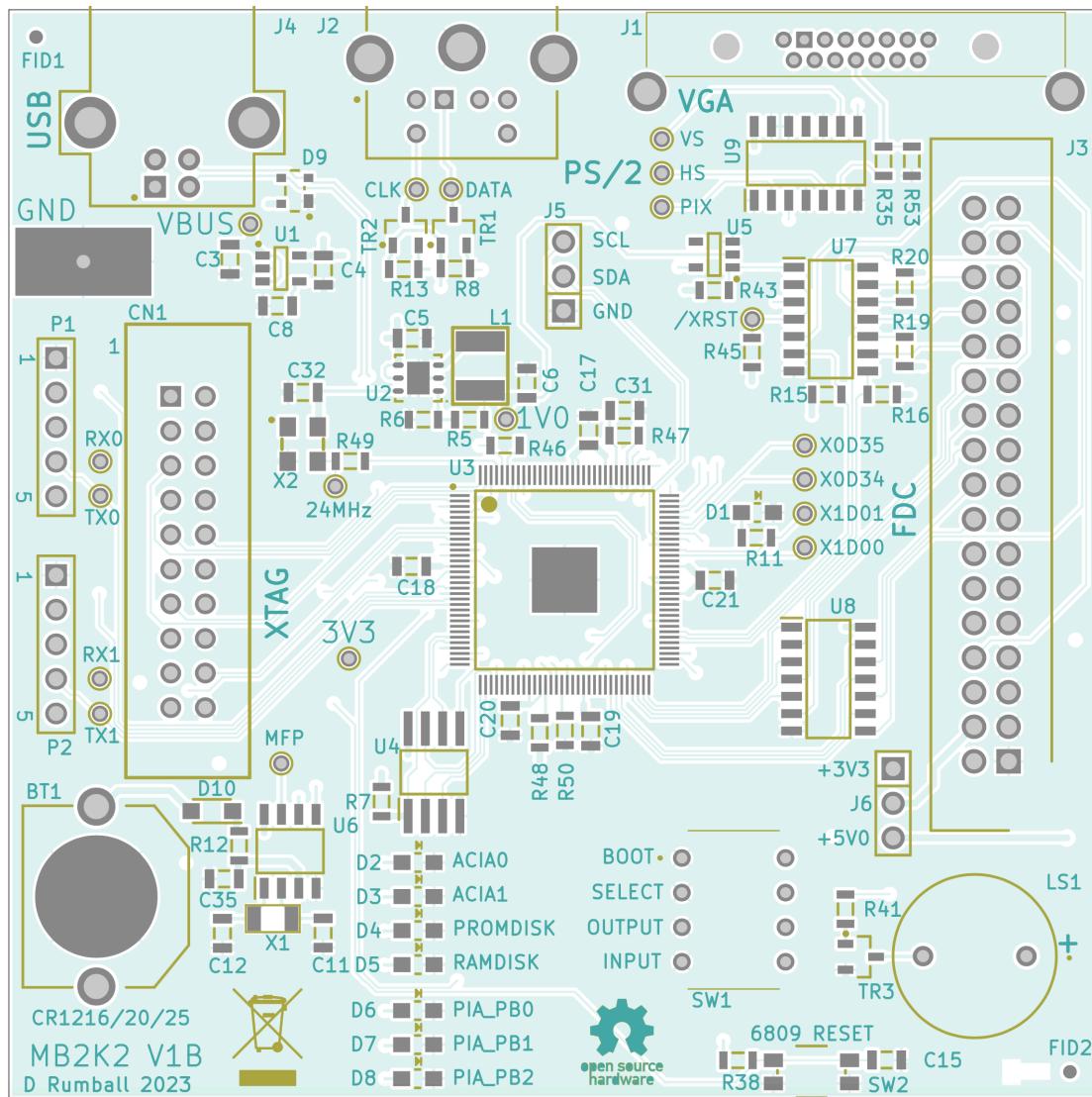


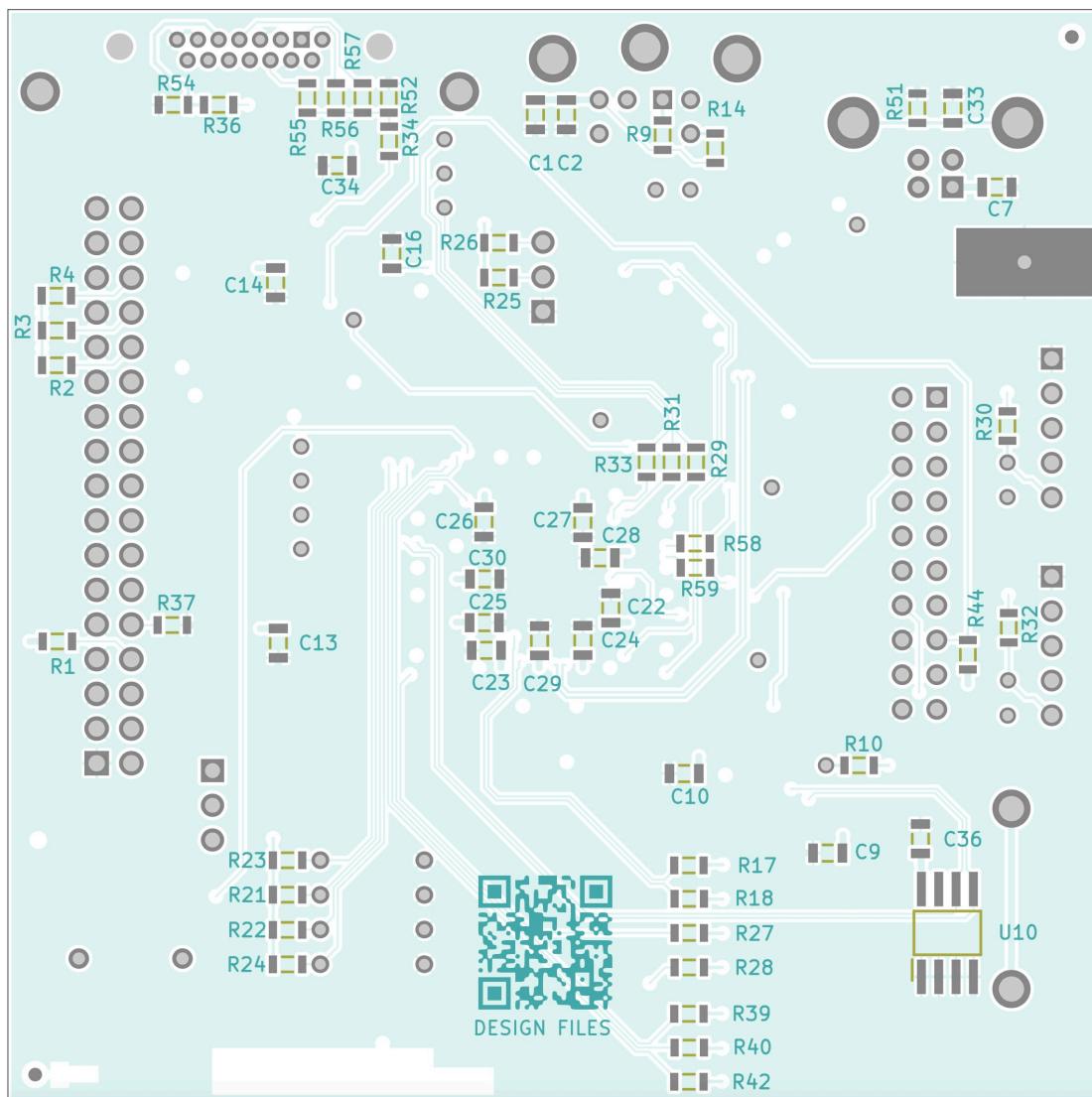
BOT layer



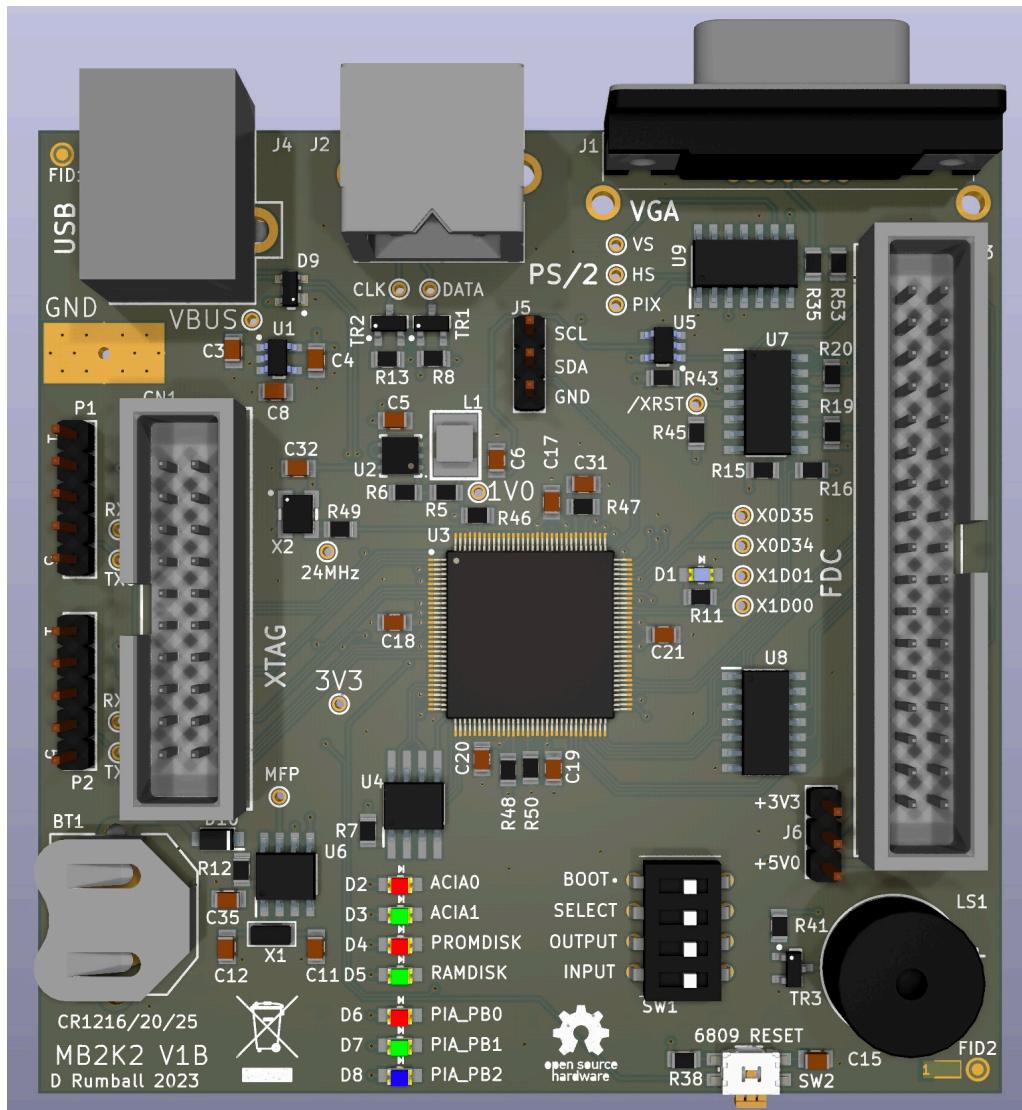
Bottom view

## Appendix 9 - Assembly drawings

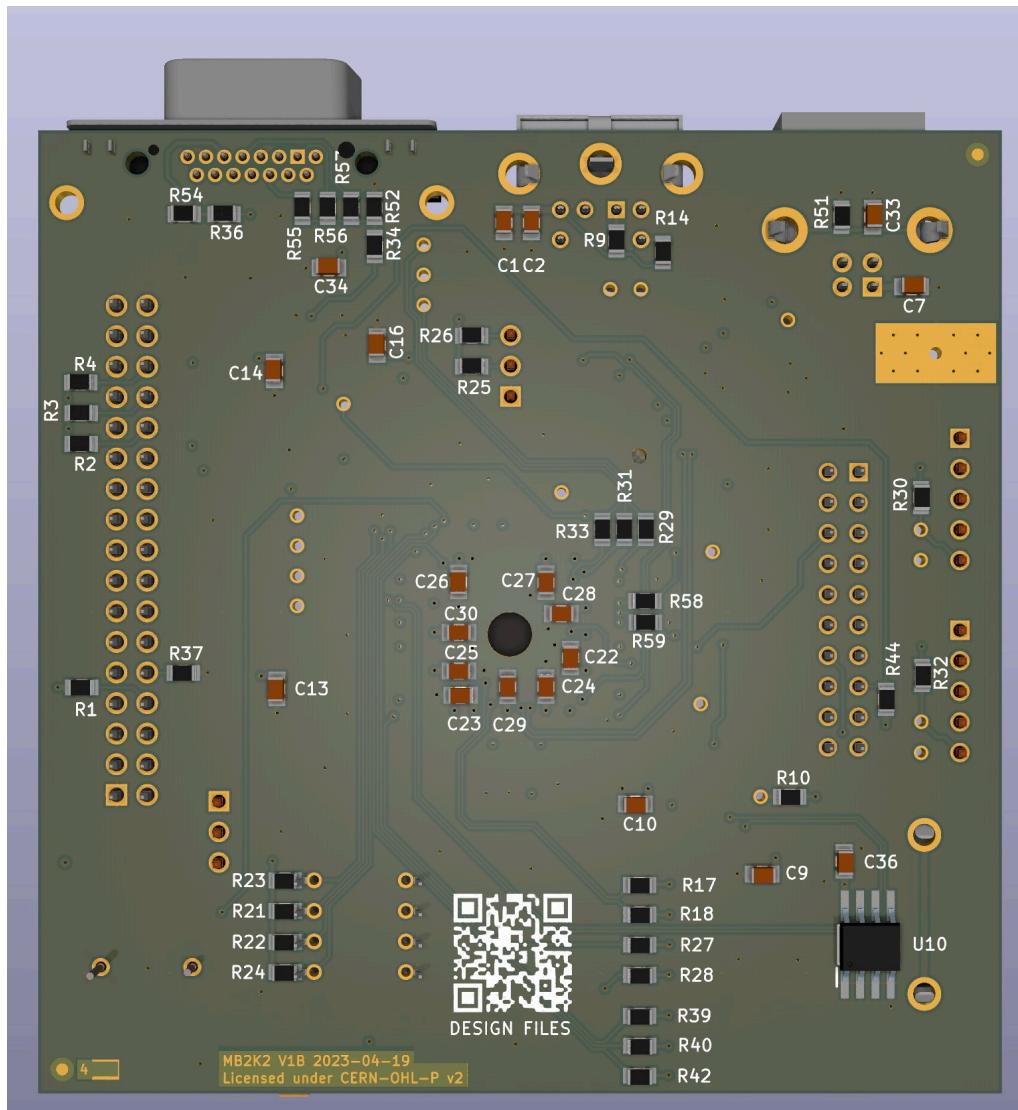




## Appendix 10 - 3D renderings



Top view



Bottom view

MB2K2-v1b BOM

Item	Oty	Reference(s)	Value	Footprint	Manufacturer	Manufacturer PN	Description
1	1	BT1	KS3001	CR1216 through hole	Keystone	3001	Battery Holder: THM, 1 Coin Cell, 12mm, PhosBronze/Tin-Nickel
2	3	C1, C3, C5	4u7	C0805	Generic		
3	24	C9, C7, C9, C10, C13, C14, C17, C18, C19, C20, C21, C22, C23, C24, C25, C26, C27, C28, C29, C30, C32, C33, C34, C36	100n	C0805	Generic		
4	1	C4	2u2	C0805	Generic		
5	1	C6	22u	C0805	Generic		
6	1	C8	10n	C0805	Generic		
7	2	C11, C12	4p7	C0805	Generic		
8	2	C15, C16	1n	C0805	Generic		
9	1	C31	1u	C0805	Generic		
10	1	C35	100p	C0805	Generic		
11	1	CN1	70246-2004	20 pin box HDR, 2 row, 2.54mm pitch	Molex	70246-2004	Conn Shrouded Header (4 Sides) HDR 20 POS 2.54mm Solder ST Thru-Hole
12	1	D1	WH	LED0805	Generic		
13	3	D2, D4, D6	R	LED0805	Generic		
14	3	D3, D5, D7	G	LED0805	Generic		
15	1	D8	B	LED0805	Generic		
16	1	D9	PRTRSV0U2X,215	SOT-113B	Nexperia	PRTRSV0U2X,215	Ultra low capacitance double rail-to-rail ESD protection diode
17	1	D10	DS114U	SOD-123F	Nexperia	PMEG4010EH,115	Diode Schottky 50V, 1A
18	1	J1	634-015-274-992	D-Sub, 15pin, 1.52mm pitch, RA	EDAC	634-015-274-992	D-Subminiature SKT 15 POS 1.52mm Solder RA Thru-Hole 15 Terminal
19	1	J2	5749180-1	Mini DIN Connector, 6pin	TE	5749180-1	DIN Connector, 6 Contact(s), Female, Board Mount, Solder Terminal
20	1	J3	70246-3404	34 pin box HDR, 2 row, 2.54mm pitch	Molex	70246-3404	Conn Shrouded Header (4 Sides) HDR 34 POS 2.54mm Solder ST Top Entry Thru-Hole
21	1	J4	USB Type B	USB Type B	Multicomp	USB-B-S-R4	USB Connector, 4 Contact(s), Female, Right Angle, Solder Terminal, Locking
22	2	J5, J6	61300311121	3 pin HDR, 2.54mm pitch	Wurth Elektronik	61300311121	THT Vertical Pin Header WR-PHD, Pitch 2.54 mm, Single Row, 3 pins
23	1	L1	2u2	Ind 3.8x3.8	Vishay Dale	IFSC1515AHER2R2M01	Inductor Power Shielded Wirewound 2.0uH 20% 100kHz 2.8A 0.045Ohm DCR 1515 T/R
24	1	LS1	3V buzzer	12mm dia, 9mm pitch	CMI	CMI-1295IC-0385T	Audio Buzzer Magnetic 2VDC 5VDC 30mA 3VDC 85dB 2300Hz to 2500Hz Through Hole
25	2	P1, P2	61300511121	5 pin HDR, 2.54mm pitch	Wurth Elektronik	61300511121	THT Vertical Pin Header WR-PHD, Pitch 2.54 mm, Single Row, 5 pins
26	9	R1, R2, R3, R4, R17, R27, R35, R36, R39	330f	R0805	Generic		
27	5	R5, R6, R14, R40, R42	4K7	R0805	Generic		
28	1	R6	17KB	R0805	Generic		
29	1	R7	3K0	R0805	Generic		
30	16	R8, R13, R15, R16, R19, R21, R22, R23, R24, R25, R26, R38, R43, R44, R45, R46	10K	R0805	Generic		
31	2	R10, R41	100K	R0805	Generic		
32	5	R11, R12, R18, R20, R28	1K0	R0805	Generic		
33	6	R30, R31, R33, R48, R58, R59	33R	R0805	Generic		
35	3	R30, R32, R34	100R	R0805	Generic		
36	6	R37, R46, R55, R56, R57	0R	R0805	Generic		
37	1	R47	4R7	R0805	Generic		
38	1	R50	43R	R0805	Generic		
38	1	SW1	210-4MS	8 pin DIP	CTS	210-4MS	Switch DIP ON OFF SPST 4 Raised Slide 0.1A 20VDC 2.54mm Thru-Hole
39	1	SW2	TL1014AF220QG	TL1014AF220QG	E-Switch	TL1014AF220QG	Switch Tactile N.O. SPST Rectangular Button Gull Wing 0.05A 12VDC 1.57N SMD
40	3	TR1, TR2, TR3	TSM2302CX	SOT23	Taiwan Semiconductors	TSM2302CX	Transistor MOSFET N-CH 20V 3.9A 3-Pin SOT-23 Plastic T/R
41	1	U1	SP6205EM5-L-3.3	SOT23_5	Exar	SP6205EM5-L-3-3/TR	SP6205 Series 3.3 V 500 mA SMT Low Noise CMOS LDO Regulator - SOT-23-5
42	1	U2	ST1509IPUR	DFN60_N	STMicroelectronics	ST1509IPUR	Switching Regulator, Current-mode, 1.5A, 1800kHz Switching Freq-Max
43	1	U3	XU216-512-TQ128-C20	TQFP128_XMOS	XMOS	XU216-512-TQ128-C20	XCore XU Microcontroller IC 32-Bit 16-Core 2000MIPS ROMless 128-TQFP (14x14)
44	1	U4	IS25LP032D-JNLE	SOIC-8N	ISSI	IS25LP032D-JNLE	NOR Flash Serial (SPI, Dual SPI, Quad SPI) 2.5V/3V/3.3V 32-bit 4M x 8 bits 8-Pin SOIC N
45	1	U5	TLV840MADL06DBVR	SOT23_5	TI	TLV840MADL06DBVR	Low-voltage supervisor with adjustable-reset time delay and manual reset 5-SOT-23 -40 to 125
46	1	U6	MCP79410-I-NSN	SOIC-8N	Microchip	MCP79410-I-NSN	Real Time Clock Serial 64byte Clock/Calendar/Alarm/Battery Backup Automotive 8-Pin SOIC N
47	2	U7, U8	SN74LVC07AD	SOIC-14N	Texas Instruments	SN74LVC07AD	Non Inverting Buffer, CMOS SOIC-14
48	1	U9	SN74LVC125AD	SOIC-14N	Texas Instruments	SN74LVC125AD	Buffer/Line Driver 4-CH Non-Inverting 3-ST CMOS SOIC-14
49	1	U10	MB85RC1MTPNF-G-JNRE1	SOIC-8	Fujitsu		1Mbit FRAM with I2C serial interface, 1.8V, 3V
50	1	X1	FC-135 32.7680KA-A	XTAL_3215	Epson Toyocom	FC-135 32.7680KA-A	Mini SMD Xtl KHz +/-20PPM, -40~85C 9PF
51	1	X2	ASE-24.000MHZ-LC-T	SMD 3.2mm x 2.5mm	Abracan LLC	ASE-24.000MHZ-LC-T	Oscillator 24MHz +/-50ppm 15pF CMOS 55% 2.5V 4-Pin SMD

## Appendix 11 - BOM