

MILES GORDON TECHNOLOGY plc

SAM COUPE TECHNICAL MANUAL

version 3.0

(C) 1990

The purpose of this manual is to introduce hardware and software developers to the internal and external workings of the SAM Coupe computer. To this end it is a technical document assuming a certain amount of technical knowledge.

It is MGT's policy that the SAM Coupe and associated MGT products should be fully documented to help third party software and hardware developers take full advantage of all the Coupe's advanced features. If you are developing a product for the Coupe and require further clarification or explanation MGT technical staff will be pleased to assist.

All production machines contain ROM 1.0. This manual details information for ROM 1.0 and ROM 1.2. In the period April/May 1990 all Coupe owners will be issued with an enhanced ROM, issue 2.0, free of charge. The ROM 1.2 referred to in this manual is a pre-production version of ROM 2.0.

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With special Thanks to
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While every effort has been made to ensure that the contents of this manual are correct in every particular, it must be appreciated that MGT cannot guarantee that it is definitive since we have a policy of continual product enhancement.

Published by Miles Gordon Technology plc
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TECHNICAL SUPPORT FOR PROFESSIONAL DEVELOPERS

More and more hardware and software developers are working on SAM Coupe products.

HGT is keen to support the efforts of developers. To this end we have created the MGT SAM Coupe Developers Group. For a fee of £50.00 we offer members of the Developers Group the following benefits:

Unlimited telephone support from our Software Engineers.

Unlimited telephone support from our Hardware Engineers.

Free and first-off-the-press updates to the Technical Manual.

Free copies of supplementary information provided by developers, (where permission to distribute such information has been given).

Hardware port address allocation for hardware developers. This will avoid the possibility of two devices Using the same port address(es).

SAM Compatible: if a product, hardware or software, works with the Coupe we can issue 'SAM Compatible' stickers for the product case or packaging.

Developers Group registration number to ensure priority service.

If you require further information, or wish to join the Developers Group, please either write to, or phone, our Technical Department whose staff will be pleased to help you.

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STOP PRESS

THE SAM COUPE HARDWARE

The SAM Coupe is a modern micro-computer using a Z80B microprocessor running at 6MHz. It has 256K RAM as standard, with an expansion socket to allow the memory to be doubled to 512K with a small expansion board.

The machine's main controller is a VLSI VGT-200 gate array (ASIC), customised to carry out the main tasks of processor/video contention, paging and management of all memory, video memory mapping, colour palette table allocation, and all input/output port control. There are four modes of video operation with a hardware capacity to show 16 colours from a palette of 128 on each screen line.

The sound for the machine is generated by a Philips SAA1099, with a capability in stereo of six channels over eight octaves with 256 tones per octave, two white noise generators, six amplitude controllers and two envelope wave shapers.

GENERAL SPECIFICATIONS

CPU	Z80B microprocessor running at 6MHz
Special	Customised VLSI 10,000-gate ASIC chip
ROM	32K x 8 ROM, 150ns, containing SAM BASIC, disk bootstrap, BIOS
RAM	256K upgradeable to 512K (256K x 4 100ns DRAM)
Sound	Philips SM 1099 Synthesizer: 6 channels, 8 octaves, stereo with amplitude and envelope control, plus choice of wave form.
Graphics	Motorola MC 1377P video Chip. ASIC serves as graphics processor, offering four modes: Mode 1 32 x 24 character cells per screen, each cell capable of 2 colours; 16 colours selectable from 12e; Spectrum-attribute compatible. Mode 2 As mode 1, but with 32 x 192 cells, each cell capable of 2 colours: 16 colours selectable from 128. Mode 3 80 column text display - 512 x 192 pixel screen; each pixel selectable for colour; 4 colours per line selectable from 128. Mode 4 256 x 192 pixel graphics screen; each pixel selectable for colour; 16 colours selectable per line from 128.

In all modes, colours may be redefined at line interrupt, allowing all 128 colours to be displayed on-screen.

UHF (TV channel 36), through power supply unit. Colour composite video, digital and linear RGB, all through SCART.

Atari-standard joystick (dual capability with splitter cable).

Mouse - Coupe standard.

Light-pen, Light-gun - Coupe standard. Audio output socket.

Domestic cassette recorder.

MIDI In, MIDI Out (MIDI Through, via software switch). Network - screened microphone cable with 7 pin DIN connectors.

RS232 and parallel printer via external }4GT interface connected at expansion port.

64-pin Euroconnector for further peripherals.

Disk Drives 1 or 2 removable and internally mounted 3.5" ultra-slim Citizen drives, 1 Mb unformatted, 780K formatted.

Keyboard 72 full travel keys, membrane type, including 10 function keys (software defined).

Power Consumption 11.2 Watts.

Shock	- Operating 3 G
	- Non-operating 60 0

Vibration	- Operating	5 - 500Hz / 0.5 G
	- Non-operating	5 - 500Hz / 2 G

Environmental: Ambient Temperature	Operating 5 - 45 C
	Storage -20 - 50 C

Relative Humidity	Operating 20 - 80%
	Wet Bulb Maximum 29,4 C, No Condensation

Reliability:	MTBF: 10,000 POH; MTTR: 30 Mins;
	Component Life: >5 years

Weight	2.26Kg (4.97 lb)
--------	------------------

Power Supply	Primary Input voltage	240v AC 50Hz
	Secondary Output voltage	5v DC 2A Maximum Rating
		12v DC 200mA Maximum Rating

INTERFACES -

All connections to the Coupe except the removable internal disk drives, and the RAM expansion socket are made via the rear panel. please refer to the Input/Output Port map where reference is made to bits and registers.

- MIDI IN -

Standard 7 pin DIN type connector. This serial input, working at 31.25 Kbaud is fed via an opto-isolator to a serial/parallel converter, which interrupts the CPU when a data byte has been assembled in the MIDI-IN register (253 dec). This INPUT can also be read by bit 7 of the Video Memory Page Register VMPP (252 dec). This connector is also used by the network.

PIN	SIGNAL
1	NET - LOOP
2	N.C.
3	NET + LOOP
4	MIDI + IN
5	MIDI - IN
6	NET - LOOP
7	NET + LOOP

- MIDI OUT -

Standard 7 pin DIN type connector. By writing a data byte to the MIDI-OUT register (253 dec), the MIDI outputs a 7.5 mA current at 31.25 Kbaud. when transmitting, bit 1 of the PEN register (TXFMST of register 248 dec), is set. This OUTPUT can also be driven by bit 7 of the VMPP (252 dec). An internal through connection is made from MIDI IN to OUT by setting bit 6 THROM - through MIDI) of the BORDER register (254 dec). This connector is also used by the network, An interrupt is given on completion of the transmission of MIDI data.

PIN	SIGNAL
1	NET - LOOP
2	GND
3	NET + LOOP
4	MIDI + OUT
5	MIDI - OUT
6	NET - LOOP
7	NET + LOOP

- BREAK (NMI) BUTTON -

When pressed, this button forces the CPU to address (0066H) where it is vectored to any assignable address in the memory map. A versatile function for programmers to assign a vector, to enable its use as an ESC, BREAK or CRASH key. When the Disk Operating System Spectrum Emulator is loaded this button is used to activate the snapshot facility.

- JOYSTICK -

Standard 9 pin 'D' type plug. The joystick interface has standard ATARI connections except that it has an extra strobe line for a second joystick together with a line carrying 5 volts. MGT will allow for dual joystick control with the second joystick having a special plug-socket connector. The joystick is read by the Key-board port (254 dec) and overlays numeric keys 1 to 5 for second joystick and 6 to 0 for the first joystick.

PIN	SIGNAL
1	UP
2	DOWN
3	LEFT
4	RIGHT
5	0 VOLTS
6	FIRE
7	+5 VOLTS
8	STROBEL 1
9	STROBEL 2

- MOUSE PORT -

Proprietary 5 pin DIN type connector. The MGT mouse interrupts the CPU to request a read of its X and Y signal lines. The software driver is integral to the ROM and overlays the cursor control keys. The mouse input can be read by Keyboard port (254 dec) with address lines A8 to A15 set high. (RDMSEL}.

PIN	SIGNAL
1	DOWN
2	UP
3	CTRL
4	LEFT
5	RIGHT
6	MSE INT.
7	RDMSEL
8	+5 VOLTS
SCREEN	GROUND.

- RESET BUTTON -

When pressed this button causes the CPU to clear and restart at memory location (0000H). It also resets the following:

1. Floppy Disk Controller (Disk 1 and 2)
2. Memory page registers
3. MIDI receive and transmit registers
4. Border register

It does not reset the colour look up table, the sound chip registers or the LINE INTERRUPT register (249 dec) value. The ROM normally initialises LINE INT as part of its initialisation.

- CASSETTE JACK -

Standard 3.5mm mono jack socket. This is a bi-directional line. when outputting it should be connected to the MIC socket of a standard cassette tape recorder; when inputting it should be connected to the EAR socket of the recorder. It makes no difference to the Coupe if EAR and MIC are connected together, but only some tape recorders allow this, because of positive feedback.

- LIGHT PEN & AUDIO PORT -

Standard 5-pin, 180 degree, DIN type connector. This connector has a dual function of light-pen/gun input as well as stereo sound output capable at driving a HI-FI system on the AUX input.

PIN	SIGNAL
1	+5 VOLTS
2	AUDIO LEFT OUTPUT
3	0 VOLTS
4	SPEN INPUT
5	AUDIO RIGHT OUTPUT

- POWER INPUT -

Regulated DC input of 12 Volts at 200 milliamps and 5 Volts at 2 Amps. A fully loaded machine will have a power consumption of approximately 15 watts.

PIN	SIGNAL
1	+5 VOLTS
2	o VOLTS (SIGNAL GROUND)
3	o VOLTS (DIGITAL GROUND)
4	COMPOSITE VIDEO
5	+12 VOLTS
6	SOUND OUTPUT (MONO)

- EUROCONNECTOR (EXPANSION CONNECTOR) -

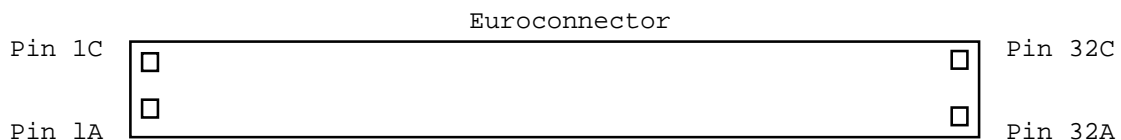
The Coupe's Euroconnector is a standard 64 pin type with rows A-C fitted. It has all the typical hardware signals found on other computer expansion ports. In addition, we include many extra hardware signals on the connector. This allows the hardware designer a hitherto unknown flexibility and control of a microcomputer from an external device.

SIGNALS

(NB row A is at the bottom of the Euroconnector, row C at the top).

PIN	SIGNAL	PIN	SIGNAL
1A	DBDIR	1C	IORQL
2A	RDL	2C	MREQ
3A	WRL	3C	HALT
4A	BUSAKL	4C	NMIL
5A	WAITL	5C	INTL
6A	BUSREOL	6C	CD1
7A	RESETL	7C	CD0
8A	CM1L	8C	CD7
9A	REFRESHL	9C	CD2
10A	0 VOLTS	10C	+5 VOLTS
11A	A0	11C	CD6
12A	A1	12C	CD5
13A	A2	13C	CD3
14A	A3	14C	CD4
15A	A4	15C	CPU CLK
16A	A5	16C	A15
17A	A6	17C	A14
18A	A7	18C	A13
19A	A8	19C	A12
20A	A9	20C	A11
21A	A10	21C	DISK 2L
22A	MSEINTL	22C	ROMCSL
23A	XMEML	23C	EARMIC
24A	8 MHz	24C	DISK 1L
25A	RED 1	25C	PRINTL
26A	GREEN 1	26C	BLUE 1
27A	C SYNC	27C	ROMCSRL
28A	SPEN	28C	AUDIO RIGHT OUTPUT
29A	BLUE 0	29C	AUDIO LEFT OUTPUT
30A	RED 0	30C	COMP VIDEO
31A	BRIGHT	31C	GREEN 0
32A	+5 VOLTS	32C	0 VOLTS

when looking at the back of the Coupe's expansion connector, the pins are numbered as follows:



For details of Z80B timing signals refer to any standard Z80 text. Please note that we will be releasing the SAM Coupe Multi Expansion (SME) in the near future. (This product has been referred to as the Card Cage in some of our literature). Some of the signals described here must be included in any designs to ensure their correct operation when used with the SME.

DBDIR (1A)	<p>This signal is not used by the computer but <u>must</u> be driven by all external devices to allow their use with the SME. The SME has buffers present to prevent undue loading of the machine. However, it is the responsibility of the hardware designer to ensure that the data bus transceiver has its direction bit set according to the operation (read or write) being performed. The operation should be as follows:</p> <ol style="list-style-type: none">1. Processor sends out an address.2. External device decodes address.3. External device drives the DBDIR line, from an open collector output, LOW for a processor READ. It is configured as a WIRED-OR internally to the computer.4. Normal handshaking is continued with the Z80B for data transfer.
RDL (2A)	Read signal from the processor.
WRL (3A)	Write signal from the processor.
BUSAKL (4A)	Bus acknowledge signal from the processor.
WAITL (5A)	Wait signal to processor.
BUSREQ (6A)	Bus request signal to external device.
RESETL (7A)	This is a system reset generated by a 10 Kilohm resistor charging a 47 microfarad capacitor. This gives a pulse of approximately 330ms duration. It is suggested that if a sharp reset edge is required, this signal is passed through a schmitt inverter.
CM1L (6A)	Op-code fetch signal from the processor
REFRESHL (9A)	Refresh signal from the processor.
0 V (10A)	Zero Volt: not to be used as a supply rail.
A0 (11A)	Address lines A0 to A10 from the processor are on pins 11A to 21A.
MSEINTL (22A)	Mouse interrupt signal also present on the mouse port. The signal is pulled low by an external device to notify the processor that the mouse co-ordinates have changed.

XMEML (23A)	External memory signal which will be driven low when the processor requires to switch out the internal memory and access the external memory. Please note that only memory above address 8000H in each block of 64K will be switched out. It is the responsibility of the peripheral designer to ensure that the DIEM signal is included in the address decoding circuitry of the design, to avoid contention between the internal RAM and the external device.
8MHZ (24A)	8 MegaHertz clock signal.
RED1 (25A)	Each colour is generated by three colour driver signals, the intensity of which is determined by three bits each. RED1 is the MSB (Most significant Bit) of the red colour signal at the current pixel position.
GREEN1 (26A)	GREEN1 is the MSB of the green colour signal (see pin 25A for a full description).
CSYNC (27A)	Composite Sync for video circuitry as on the SCART connector.
SPEN (28A)	Light pen signal (active high) which is normally low. When the light pen is touched to the screen and the raster passes the point of the pen, a positive going edge is received on this signal from the light pen socket. This causes the two registers LPEN and HPEN to contain the current x and y co-ordinates of the light pen, respectively.
BLUE0 (29A)	BLUE0 is the second bit of the blue colour signal (see pin 25A for a full description).
RED0 (30A)	RED0 is the second bit of the red colour signal (see pin 25A for a full description).
BRIGHT (31A)	BRIGHT is the LSB (Least significant Bit) of all colour signals (see pin 25A for a full description).
+5V (32A)	+5 volt supply rail, up to 250 mA available.
IORQL (1C)	Input/output Request becomes active when the address bus contains a current port address from the processor.
MREQ (2C)	Memory Request becomes active when the address bus contains a current memory address from the processor.

HALTL (3C)	Halt indicates from the processor that it has executed a HALT instruction and is waiting for an interrupt.
NMIL (4C)	Non Maskable Interrupt causes the processor to execute a jump, from which it may be vectored anywhere by the user. It is used as a BREAK button by BASIC, and a SNAPSHOT button by the DOS. It is pulled up by a 10 Kilohm resistor internally, and should therefore be driven low by an open collector circuit.
INTL (5C)	Maskable Interrupt is used to interrupt the processor from its current task if the interrupts are currently enabled.
CD1 (6C)	Data lines D1,D0,D7 and D2 are on pins 6C to 9C.
+5V (10C)	+5 Volt reference only.
CD6 (11C)	Data lines D6,D5,D3 and D4 are on pins 11C to 14C.
CPUCLK (15C)	The 6 MegaHertz clock signal to the processor.
A15 (16C)	Address lines A15 to A11 are on pins 16C to 20C.
DISK2L (21C)	DISK2 is the decoded base address for the eight ports of drive 2.
ROMCSL (22C)	ROM chip select is pulled high to disable the internal ROM (Used in conjunction with ROMCSR on pin 27C) ₄ It indicates when the ROM is being accessed.
EARMIC (23C)	EARMIC is connected to the logic level side of the cassette port circuitry.
DISKiL (24C)	DISK1 is the decoded base address for the eight ports of drive 1.
PRINTL (25C)	PRINT is the decoded address for either of the two possible printer addresses (246 and 248).
BLUE1 (26C)	BLUE1 is the MSB of the blue colour signal (see pin 25A for a full description).
ROMCSRL (27C)	ROMCSR is connected to the ROMCS (22C) pin via a 1 Kilohm resistor. If ROMCS is pulled high by an external circuit, then ROMCSR could be used as a chip select for an external ROM which would then take the place on the internal one.

AUDIORIGHT(28C) The right audio signal, as on the light pen socket, is brought out here.(50mV pp as per auxiliary standard input) It must be amplified before being applied to a speaker.

AUDIOLEFT(29C) The left audio signal is present on this pin. The same precautions and signal levels as for AUDIORIGHT apply.

CVID (30C) Composite Video, as sent to the modulator and SCART socket is present on this pin.

GREENO (31C} GREENO is the second bit of the green colour signal (see pin 25A for a full description).

0 V (32C) Zero Volt supply rail.

- SCART SOCKET -

SCART socket to handle all video and sound outputs. Please note that not all connections are standard.

PIN	SIGNAL	PIN	SIGNAL
1	AUDIO OUT RH	2	SPEN
3	AUDIO OUT LH	4	AUDIO EARTH
5	BLUE EARTH	6	BLUE TTL OUT
7	BLUE LIN. OUT	8	RED TTL OUT
9	GREEN EARTH	10	GREEN TTL OUT
11	GREEN LIN. OUT	12	+5V POWER IN
13	RED EARTH	14	CSYNC EARTH
15	RED LIN. OUT	16	CSYNC
17	C.VID EARTH	18	+12V POWER IN
19	C.VID OUT	20	BRIGHT TTL OUT
21	GND.		

- UHF OUTPUT -

UHF television standard video and mono sound are output on channel 36; the UHF output is in the power supply box.

- SLIMLINE SLOT-IN DISK DRIVES -

The disk drives used in the SAM Coupe are Citizen Slim Line OSDC type 3.5', 1 megabyte (formatted 780 kilobytes).

The Coupe can control up to two disk drives. Connections to the two drives are made via two 32-pin Euroconnectors, with rows A and B connected. Drive 1 is on the left of the machine and drive 2 on the right. A list of signals available at these sockets are shown below.

PIN	SIGNAL	PIN	SIGNAL
1A	0 VOLTS	1B	WR
2A	0 VOLTS	2B	AO
3A	0 VOLTS	3B	A1
4A	0 VOLTS	4B	D0
5A	0 VOLTS	5B	D1
6A	0 VOLTS	6B	D2
7A	0 VOLTS	7B	D3
8A	0 VOLTS	8B	D4
9A	0 VOLTS	9B	D5
10A	0 VOLTS	10B	D6
11A	5 VOLTS	11B	D7
12A	5 VOLTS	12B	8 MHz
13A	5 VOLTS	13B	RST
14A	5 VOLTS	14B	No connection
15A	5 VOLTS	15B	A2
16A	5 VOLTS	16B	DISK 1 OR DISK 2

- DISK DRIVE INTERFACE -

The SAM Coupe can be connected to one or two disk drives. These would normally be internal SAM disk drives. However, we have made provision for people to use an external disk drive, (Shugart 400 type 5.25" or 3.5"), if they add the SAM External Drive Interface (SDI). Both the internal drives and the SDI use the VL-1772-02 disk controller chip manufactured by VLSI.

NB All values are given in Decimal.

The SAM Coupe controls each disk drive via 8 I/O mapped ports, as listed below for both drives:

Disk 1 224 to 231 inclusive.
Disk 2 240 to 247 inclusive.

In each case, the address can be given by:

Disk1base (224) + offset (0 to 7)
Disk2base (240) + offset (0 to 7)

Both sets of offsets perform the same functions on their respective sides of the disk. The first four offsets (0-3) refer to the first side of the disk, and the second four offsets, (4-7) refer to the second side of the disk. Offsets 4-7 can be ignored for single sided disk drives.

The offset determines which register of the 1772 will be accessed as shown below:

OFFSET	READ	WRITE
0	Status(disk side 1)	Command (disk side 1)
1	Track 1	Track 1
2	Sector 1	Sector 1
3	Data 1	Data 1
4	status(disk side 2)	Command (disk side 2)
5	Track 2	Track 2
6	Sector 2	Sector 2
7	Data 2	Data 2

For example, to read the current contents of the data register on side 2 of Disk 1:

 IN A,(231)
where 231 = Disk1base (224) + offset (7)

For complete information on controlling the 1772 chip refer to the data sheets contained in Appendix H.

MEMORY

- INTRODUCTION -

The Coupe can take 512 Kbytes of RAM on board (with extra memory able to be added via the expansion connector using signal XMEML). The basic machine has 256Kb fitted, with an internal expansion connector for an additional 256Kb. The memory used is Dynamic Random Access Memory 256K x 4 bits - 100ns access time, 20 pin dual in-line plastic package.

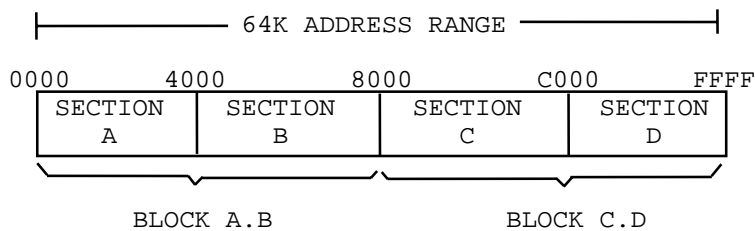
Because the Z80B CPU (central Processing Unit) is limited to a 64K addressing range, one of the functions of the ASIC (Application Specific Integrated Circuit) in the Coupe is to manage the addressing of this memory by splitting it into 32 pages of 16K.

The ASIC controls the paging via two 8-bit read/write registers.

LMPR (Low Memory Page Register)...I/O address 250dec
HMPR (High Memory Page Register)...I/O address 251dec

The lower 5 bits of each register represent pages 0 to 31. (of course on the basic machine with 256K of memory fitted, the paging is from 0 to 15).

To illustrate the paging system used by the Coupe, it's best to envisage the 64K addressing range of the Z80 as 2 blocks 2 of sections of 16K, represented by the letters A.B and C.D:

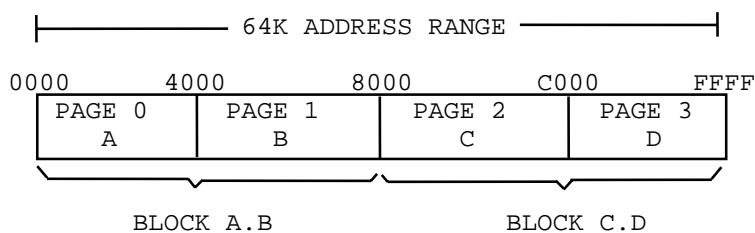


LMPR manages the block A.B, and the HMPR manages the block C.D

If we write 00H to the LMPR then page 0 of the memory is allocated to section A of the CPU address range. Section B is always automatically allocated one page above section A, in this case to page 1.

If we write 02H to the HMPR then page 2 of the memory is allocated to section C of the CPU address range. Section D is always automatically allocated one page above section C, in this case to page 3.

In our example the CPU address map would look like this:



SCREEN MODES

- INTRODUCTION -

There are four screen modes used in the Coupe, each using varying amounts of memory and each having different attributes for use by the programmer.

The hardware pointers which display the contents of the memory are controlled by the VMPR, Video Memory Page Register (252 dec).

By using the lower 5 bits of this register we can access up to 32 pages of video screen memory. It must be noted that modes 3 and 4 use 24 kilo-bytes, which go over the page boundary of 16 kilobytes. Where this happens, the video addressing hardware wraps into the next page within the same block. For example:

By entering page 12 to the VMPR, video wraps to page 13

The same applies to any page and the principal of even to odd always applies.

- MODE 1 -

32 cells x 24 lines in 2 colours from 16 out of a palette of 128 colours, giving 768 character cells (8 x 8) using 6 kilobytes of bit-mapped memory and 0.75 kilo-bytes of attribute memory. This mode emulates Spectrum memory mapping.

- MODE 2 -

32 cells x 192 lines in 2 colours from 16 out of a palette of 128 colours, giving 6144 character cells (8 x 1) using 6 kilobytes of bit-mapped memory and 6 kilobytes of attribute memory. This mode has contiguous memory addressing in two blocks.

- MODE 3 -

512 pixels x 192 lines in 4 colours out of a palette of 128 colours, giving 98304 dots using 24 kilo-bytes of memory. This mode, when used with a character set 6 pixels wide, will give 85 characters per line.

- MODE 4 -

256 pixels x 192 lines in 16 colours out of a palette of 128 colours, giving 49252 dots using 24 kilo-bytes of memory. This mode is ideal for graphic display, and when used in conjunction with LINE INTerrupt register can display the full 128 colours on screen.

- LOCATING THE CURRENT SCREEN -

The SAM Coupe provides a port called Video Memory Page Register (address 252). To locate the base address of the currently displayed screen use the following BASIC program:

```
10 LET A=IN 252 BAND 31          REM Input the current page
20 LET BASE=(A+1) * 16384        REM BASE now equals start
                                REM of screen area.
```

KEYBOARD

The Coupe has a full-travel 72 key keyboard. It is addressed as a 9 x 8 matrix, using two ports, KEYBOARD (254 dec) and STATUS (249 dec).

The 8 input lines are made up by the KEYBOARD port inputting the lower 5 bits represented by K1, K2, K3, K4 and K5, while the STATUS port inputs the upper 3 bits represented by K6, K7 and K8.

The 9 output scan lines are made up by the CPU address lines AD8, AD9, AD10, AD11, AD12, AD13, AD14, AD15 and the ASIC line RDMSEL.

An example of a typical keyboard scan:

```
LD    HL,SCAN                    ;set HL with buffer start
LD    B,11111110bin             ;set upper address lines

LOOP  LD    C,HIKEY              ;port address K6 - K8
      IN    A,(C)
      AND   11100000bin          ;strip unwanted bits
      LD    (HL),A              ;hold it

      LD    C, LOKEY             ;port address K1 - K5
      IN    A, (C)
      AND   00011111bin          ;strip unwanted bits
      OR    (HL)                ;make K1 - K8
      LD    (HL),A              ;save it

      INC   HL                  ;next location in buffer
      SCF                               ;set carry flag for
      RLC    B                  ;rotate next address line
      JR    C,LOOP              ;jump if not done

      IN    A,(C)                ;input RDMSEL line
      AND   00011111bin          ;strip unwanted bits
      LD    (HL),A              ;save it
      RET                       ;return to analyse scan
```

INPUT/OUTPUT PORTS

The SAM Coupe can address 64k of ports. Addresses 224 (EOH) to 255 (FFH) are allocated to the Coupe itself. Refer to the diagram provided for an overview of these ports and their contents.

- WRITE (OUTPUT) PORTS -

SOUND ports (address port 511 dec) and (data port 255 dec)

The sound chip, a Philips SAA1099, is controlled through these two port addresses. The sound chip is controlled in BASIC through using the SOUND a,d command. See the attached Philips application notes and the SAA1099 supplements included elsewhere for further information.

VMPR - Video Memory Page Register (252 dec)

This read/ write register mainly controls the page addressing for the screen display memory.

Bit 0 R/W	BCD 1	of video page control.
Bit 1 R/W	RCD 2	of video page control.
Bit 2 R/W	BCD 4	of video page control.
Bit 3 R/W	BCD 8	of video page control.
Bit 4 R/W	BCD 16	of video bank control, used to switch between the banks of 256 kilobytes.
Bit 5 R/W	MDE0	first bit of screen mode control.
Bit 6 R/W	MDE1	second bit of screen mode control.
Bit 7 -/W	TXMIDI	output bit to directly drive the MIDI OUT channel.
Bit 7 R/-	RXMIDI	input bit from MIDI IN channel.

HMPR - High Memory Page Register (251 dec)

This read/write register is used mainly for the control of paging memory in the CPU's addressing range.

Bit 0 R/W	BCD 1	of high memory page control.
Bit 1 R/W	BCD 2	of high memory page control.
Bit 2 R/W	BCD 3	of high memory page control.
Bit 3 R/W	BCD 4	of high memory page control.
Bit 4 R/W	BCD 16	of high memory page control.
Bit 5 R/W	MD3S0	BCD 4 of the colour look-up address available only in mode 3.
Bit 6 R/W	MD3S1	BCD 8 of the colour look-up address available only in mode 3.
Bit 7 R/W	MCNTRL	If this bit is set when the CPU addresses high memory, then the external signal XMEM goes low and the Coupe looks on its expansion connector for memory sections C and D (addresses 32768 to 65536).

(See section entitled CLUT IN MODE 4 & MODE 3 in the text ahead)

LMPR - Low Memory Page Register (250 dec)

This read/write register is used mainly for the control of paging low memory in the CPU's addressing range.

Bit 0	R/W	BCD 1	of low memory page control.
Bit 1	R/W	BCD 2	of low memory page control.
Bit 2	R/W	BCD 4	of low memory page control.
Bit 3	R/W	BCD 8	of low memory page control.
Bit 4	R/W	BCD 16	of low memory bank control.
Bit 5	R/W	RAM0	when bit set high, RAM replaces the first half of the ROM (ie ROM0) in section A of the CPU address map.
Bit 6	R/W	ROM1	when bit set high, the second half of the ROM (ie ROM1) replaces the RAM in section D of the CPU address map
Bit 7	R/W	WPRAM	Write Protection of the RAM in section A of the CPU address map is enabled when this bit is set high.

MIDI OUT port (253 dec)

By writing a data byte to this port, the hardware automatically transmits through the MIDI out channel at 31.25 kbaud, the standard for MIDI protocol. Bit 4 of the STATUS register (249 dec) is set high when this register is full.

BORDER port (254 dec)

This output port mainly controls the border colour of the screen by supplying a 4-bit address to the Colour Look Up Table (CLUT), to enable a colour to be displayed during border time.

Bit 0	BCD 1	of CLUT address for border colour.
Bit 1	BCD 2	of CLUT address for border colour.
Bit 2	BCD 4	of CLUT address for border colour.
Bit 3	MIC	output control bit, normally set high.
Bit 4	BEEP	output control bit, normally set low.
Bit 5	BCD 8	of CLUT address for border colour.
Bit 6	THROM	bit set high to allow through MIDI operation
Bit 7	SOFF	bit set high to disable screen display, only active in screen modes 3 and 4, also removes memory contention during off period.

LINE INTerrupt register (249 Dec)

This write-only register will cause an interrupt to the CPU at the end of the scan-line before the one matching its contents, (ie at the start of the right hand border). This works even for the first scan line. Line numbers are from 0 to 191. This function is always enabled, so to inhibit its operation a false line number from 192 to 255 can be entered. A useful function of this register can be to switch video modes or change colour lookup table values.

CLUT - Colour Look Up Table (base port 248 dec)

There are 16 write only 7 bit registers in the CLUT:

colour	0	addresses register 0	on port	248
colour	1	addresses register 1	on port	504
colour	2	addresses register 2	on port	760
colour	3	addresses register 3	on port	1016
colour	4	addresses register 4	on port	1272
colour	5	addresses register 5	on port	1528
colour	6	addresses register 6	on port	1784
colour	7	addresses register 7	on port	2040
colour	8	addresses register 8	on port	2296
colour	9	addresses register 9	on port	2552
colour	10	addresses register A	on port	2808
colour	11	addresses register B	on port	3064
colour	12	addresses register C	on port	3320
colour	13	addresses register D	on port	3576
colour	14	addresses register E	on port	3832
colour	15	addresses register F	on port	4088

Each register has 7 bits to represent 1 of 128 possible colours.

Bit 0 BLU0	least significant bit of blue.
Bit 1 RED0	least significant bit of red.
Bit 2 GRN0	least significant bit of green.
Bit 3 BRIGHT	half bit intensity on all colours.
Bit 4 BLU1	most significant bit of blue.
Bit 5 RED1	most significant bit of red.
Bit 6 GRN1	most significant bit of green.

The registers at switch on will be loaded from the ROM with a default set of values corresponding to:

register 0	black	(0)	register 8	black	(0)
register 1	blue	(16)	register 9	bright blue	(17)
register 2	red	(32)	register A	bright red	(34)
register 3	magenta	(48)	register B	bright magenta	(51)
register 4	green	(64)	register C	bright green	(68)
register 5	cyan	(80)	register D	bright cyan	(85)
register 6	yellow	(96)	register E	bright yellow	(102)
register 7	white	(120)	register F	bright white	(127)

The colour numbers are found by:

```
FOR c=0 TO 15 : PRINT PEEK (&55D8+c) : NEXT C
```

A typical routine for loading the CLUT from a memory table:

```
LD    HL, TABLE    ;load HL with top of table
LD    B, 16          ;load B with size of table
LD    C, 248         ;load C with port address

OTDR                ;execute a decrement B,
                    ;output to port (C) and
                    ;decrement HL until B=0
RET                 ;return to calling routine
```

CLUT IN MODE 4 & MODE 3

MODE 4

In screen mode 4, 4 bits are used to address the CLUT for the colour of a pixel. Within a byte, the most significant nibble refers to the first pixel and the least significant nibble refers to the second pixel.

MODE 3

The situation is similar in screen mode 3, however this time there are only 2 bits per pixel which address the CLUT. Out of an 8-bit data byte, the first two most significant bits are used as the address for the first pixel.

Normally, only 4 of the sixteen possible registers would be available. This is overcome by using an extra two bits from the high memory page register (HMPR-251 dec). Bit 5 of HMPR is used to access BCD 4 of the colour look up address and bit 6 of HMPR is used to access BCD 8 of the colour look-up address.

In this way, we can still access the 16 colours specified in the colour look-up table whilst having high resolution graphics.

- READ (INPUT) PORTS -

ATTRIBUTES register (255 dec)

This register enables the programmer to read the attributes of the currently displayed character cell in modes 1 and 2, and the third byte in every four displayed in modes 3 and 4.

KEYBOARD register (254 dec)

This read only register is mainly used for inputting the lower 5 bits of the keyboard matrix. It is also the input for the MOUSE when the address lines AD8 - AD15 are high.

Bit 0	K1	keyboard matrix line 1, Mouse Control.
Bit 1	K2	keyboard matrix line 2, Mouse Up.
Bit 2	K3	keyboard matrix line 3, Mouse Down/Button 2.
Bit 3	K4	keyboard matrix line 4, Mouse Left/Button 1.
Bit 4	K5	keyboard matrix line 5, Mouse Right/Button 3.
Bit 5	SPEN	light pen strobe/serial input bit.
Bit 6	EAR	serial input from EAR of cassette recorder.
Bit 7	SOFF	status bit show if external memory is set.

MIDI IN register (253 dec)

This read-only register generates an interrupt to the CPU when a data byte has been read from the MIDI serial input interface. The data must be read by the CPU before the next interrupt (typically 320 μ S).

STATUS register (249 dec)

This read-only register is mainly used for reading interrupt status. Although all five interrupts go to the CPU operating under mode 1 interrupt, there is no way of knowing which one is requesting, therefore a read of this register is necessary. Approximate interrupt times are 20 μ s long.

Bit 0	LINE	int	when low, signals the line interrupt register is requesting.
Bit 1	MOUSE	int	when low, signals the mouse requests the interrupt.
Bit 2	MIDIIN	int	when low, signals the MIDI channel has a data byte.
Bit 3	FRAME	int	when low, signals the frame scan has been completed (50 per/second).
Bit 4	MIDOUT	int	when low, indicates the NrDr out register has just completed data output.
Bit 5	K6		keyboard matrix line 6.
Bit 6	K7		keyboard matrix line 7.
Bit 7	K8		keyboard matrix line 8.

PEN registers (LPEN - 248 dec) (HPEN - 504 dec)

If the light pen is not connected, these read-only registers are continuously updating with the current position of the scan. The LPEN register is connected to the horizontal or X co-ordinate of the scan function and HPEN is connected to the vertical or Y coordinate of the scan function.

The first two bits of the LPEN register are:

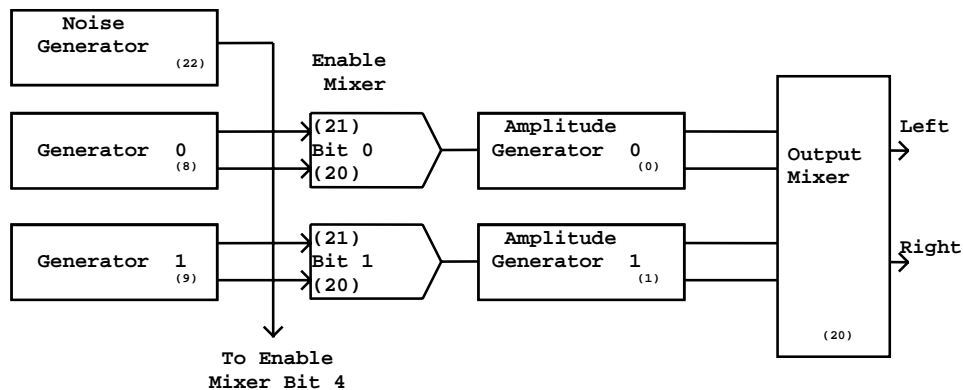
Bit 0 - Inputs BCD 1 of the current colour look up table address.

Bit 1 - TXFMST is the status bit for MIDI OUT. When this is high it shows that a byte is being transmitted.

PHILIPS SAA1099 SOUND CHIP

- INTRODUCTION -

The sound chip has six tone registers or oscillators and two noise generators. These can all be panned individually from left to right across the stereo field using one of the 256 possible positions, {ie. 16 volumes per channel, thus 16 x 16 combinations gives 256 positions}. The position in the stereo field, relating to that particular oscillator, is controlled by its amplitude register. The overall sound can be enabled or disabled using output mixer (28). To hear sound, this register should be '1', to kill the sound, it should be 0.

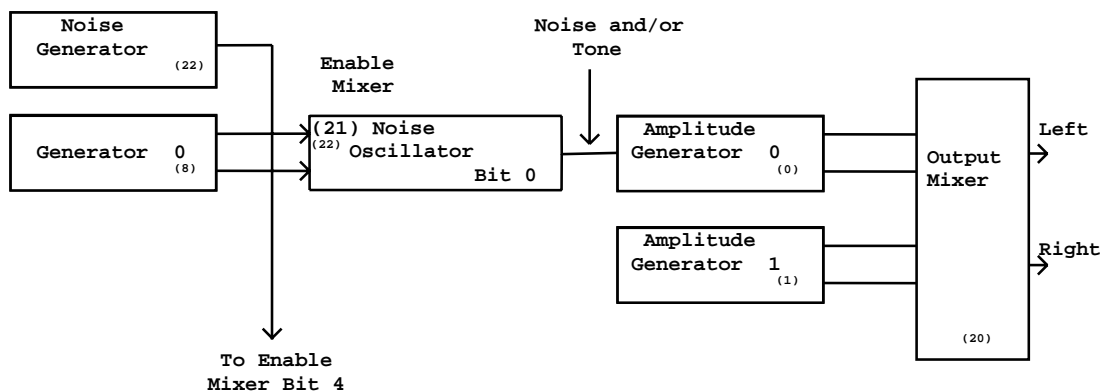


The six oscillators are split, three per noise generator. enables the two envelope registers to be used independently.

- NOISE & SOUND -

Mixer registers 20 and 21 mix the noise with each of the oscillators. Register 20 controls whether an oscillator's sound is passed or stopped, whilst register 21 controls the noise.

Example:



Using this mixer allows either noise or tone or both or nothing to be passed to a single amplitude register and so to a precise position in the stereo field.

- PITCH -

The pitch of each complete oscillator is controlled by two parameters. These are eight possible octaves per generator and 256 possible tones per octave. By carefully choosing octave and tone register data, a smooth transition is possible from the lowest frequency on this sound of 31Hz to the highest frequency of 7.81KHz.

- MUSIC -

Chromatic scales are possible using the table below. Please note also, that the tone numbers are also valid for the other octaves of the same note although tuning may be difficult towards the lower octaves.

- THE CHROMATIC SCALE

NB: All numbers given in decimal.

Note	Tone Number (decimal)	Octave Number	Required Frequency (Hz)	Actual Frequency (Hz)
Middle C	33	03	261.626	261.506
C#	60	03	277.183	277.162
D	85	03	293.665	293.427
D#	109	03	311.127	310.945
E	132	03	329.628	329.815
F	153	03	349.228	349.162
F#	173	03	369.994	369.822
G	192	03	391.995	391.850
G#	210	03	415.305	415.282
A	227	03	440.000	440.141
A#	243	03	466.164	466.418
B	5	04	493.883	494.071
C	33	04	523.251	523.013

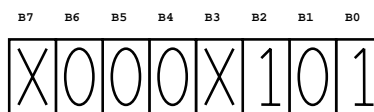
- OCTAVE REGISTERS -

Register 16 is an octave register altering the octave of tone registers 8 and 9. This is made possible by only using three bits per tone register to select the required octave.

Thus 2x2x2 gives us eight possible octaves as previously mentioned. So, to access the octave register for tone register 8, we must supply a number (0-7) to the lower 3 bits of register 16. If we needed to access the octave for tone register 9, we would then need to supply a number between 16 and 64 making sure that the first four bits D0-D3 contain zero, or the octave number for tone register 8 if in use.

Example:

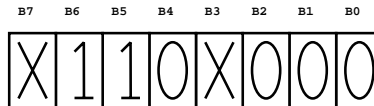
Required Octave 5
For Tone Register 8
only



X = Don't Care

Number output to Register 16 = 5

Required Octave 6
For Tone Register 9
only



Number output to Register 16 = 96

- AMPLITUDE REGISTERS -

Any data sent to a particular amplitude register can precisely control the position of a sound in the stereo field.

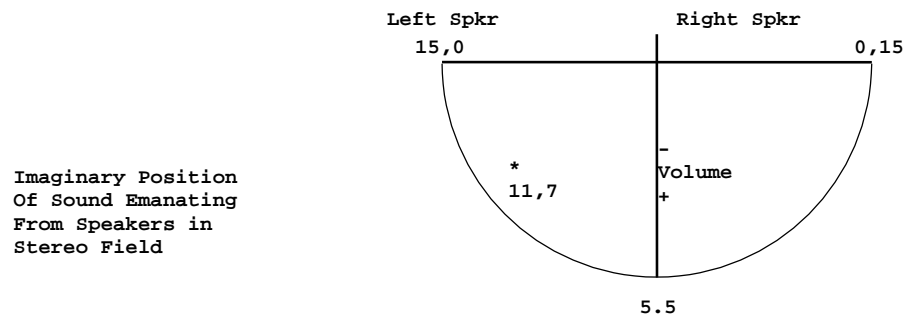
This is made possible by using the same technique as for the octave register. The only differences being that this time 4 bits are used to convey the volume of each channel, and the two 'halves' of the binary number refer to two channels (left and right) instead of two separate tone registers.

Volume 11 required
on left channel.
Volume 7 required
on right channel for
amplitude register 2



==== Right === ==== Left ====

This would place the sound towards the left side of the stereo field.



- NOISE GENERATORS -

We have two noise generators again controlled by one register. The operation is very similar to that of the octave registers, but this time only 2 bits are used per noise generator. This gives 4 possible noise clock frequencies. Three of these options are preset - namely 0=31.25KHz, 1=15.6KHz and 2=7.8KHz. The fourth option (External) is controlled by the frequency of Generator 0 in the case of Noise generator 0 or Generator 3 in the case of Noise Generator 1. Using these generators, we are able to vary the 'pitch' of the noise and/or tone. If only continuously controllable noise is required, the relative tone mixer bit is disabled, but the relative noise mixer bit enabled. This technique is called using a tone generator to "Modulate" the frequency of the noise.

- ENVELOPE REGISTERS -

The envelope controllers can be found on registers 24 and 25.

Bit 0-Controls whether the envelope that is set up is mirrored in the left or right channel. (This can be useful to generate a sense of movement without writing to the amplitude registers).

Bits 3,2,1-Set envelope shape. These three bits select an envelope shape from the table found in Fig 3. in the Philips sound chip data sheet.

Bit 4-Controls resolution of envelope if repeated very quickly. 16 levels of resolution controlling envelope modulation are available for repetition up to 977Hz and 8 levels for repetition rates above 977Hz.

Bit 5-This bit controls whether the envelope registers are controlled by generators 1 or 4. If this bit is reset(0), then the internal clock is used to control the shape of the envelope. If this bit is set(1), then the external clock is used(A0) to control the envelope.

Bit 6-is not used.

Bit 7-is used to enable or disable the operation of the envelope controller. Note that this bit should be set (1), the enable envelope control.

THE SAM COUPE SOFTWARE

MEMORY

Several memory arrangements are possible with the Coupe, with various advantages and disadvantages, and each of these sections is discussed in detail. The screen mode and the location of screen memory are perhaps the first factor to consider.

- SAM COUPE MEMORY MAP -

0FFFFH	ROM1 OR PROGRAM, VARIABLES OR SCREEN	
0C000H	PROGRAM, VARIABLES OR SCREEN	
0B000H	START OF CHANNELS	CHANS
05CB6H	SYSTEM VARIABLES	SVARS
05A00H	KEYBOARD TABLE	
058E0H	DEF KEY BUFFER	KTAB DKLIN DKBU
05800H	LINE INTERRUPT COLOUR TABLE	
05600H	PALETTE TABLE	LINICOLS
055D8H	UDG PATTERNS CHR\$ (127 - 168)	PALTAB UDGS
05490E	CHARACTER PATTERNS CHR\$(32 - 127)	
05190H		CHARS

05120H	PAGE ALLOCATION OF 33 BYTES. (1 per 16K PAGE+FFH)	
05100H		ALLOCT
050FFH		
	GENERAL-PURPOSE BUFFER SPACE	
04F00H	MACHINE STACK	SP
	FLOATING POINT STKEND CALCULATOR STACK	
04D00H		STKBQT
04C00H	FARLDIR BUFFER	
04B50H		HDL
04B00H	TAPE HEADERS	
	BASIC STACK FOR GOSUB/DO/PROCED URES	HDR STKBQT BASSTK
		BSTKEND
	SPARE FOR HEAP OR BASIC STACK	
	SYSTEM HEAP. 2.7K AVAILABLE DOESN'T PAGE	HEAPEND
04000H		HEAPST
	ROM 0	
00000H		

- SCREEN MEMORY LOCATION -

A complete screen takes 6.75K in mode 1 and 12K in mode 2 (not including a 2K gap between pixel and attribute data). In these modes the memory containing the screen can be switched in at any 16K boundary. The paging system means that the other 16K RAM page in the same half of memory will page at the same time as the page containing the screen. Modes 3 and 4 require 24K and thus two 16K pages. You can either leave the screen memory permanently paged in or just page it in when you want to read it or write to it, providing your screen handling code is paged in at the same time! The ROM switches in the screen as it requires, in sections C and D of the memory map (8000H).

- THE STACK -

The ROM normally keeps the machine stack and system variables in section B at 4000H-5CD0H, so that they are not paged out when the screen, Basic program or variables area are paged in in the top half of memory.

ROM

ROM0 is normally switched into section A of the memory map. ROM1 is normally switched out until it is needed; when in use it is located in section D. Jump table routines in ROM0 that need ROM1 will page it in automatically, use it, and then restore its previous status.

- USE OF ROM SUBROUTINES -

The ROMs usually expect the stack to be in section B, and many routines require the system variables in the same area to be intact. However, if you wish to use this area for your own code, you can page out the system variables and use the ROM routines indirectly via JSVIN (see later). This routine will switch the system variables back in temporarily while the ROM routine of your choice is executed. The screen will be temporarily switched into section C and D if required, but your code can usually be located in the same area. Naturally, ROM0 must be enabled if you want to use the jump table, but you could page it out most of the time.

For example, you could load your machine code, disable interrupts, switch out ROM0, switch new RAM into section A/B, and use it for your program. You could provide some code to handle maskable and/or non-maskable interrupts, if desired. Before using a ROM routine, enable ROM0 from somewhere outside section A, and use JSVIN to call the routine you want. If you switch the page your code is currently executing in, remember that the next instruction will come from the new page!

- USING SCREEN MODES 3 AND 4 -

The arrangement of screen memory in modes 3 and 4 makes plotting a pixel very simple. A method similar to that used by the ROM for mode 4 (256*192, 16 colour) is shown below. On entry, L and H are the X and Y coordinates (0,0 at top left) and D has the colour to use in both its nibbles (e.g. D=77H for colour 7). H and L are returned unchanged (convenient, for example, during line drawing).

```
PLOT LH:      SCF
              RR  H
              RR  L
              LD  A,(HL)
              JR  C,PLOTODD ;jr if odd pixel

              XOR D
              AND 0FH
              XOR D          ;mix left nibble of D with right nibble
                          ;tread from screen
              LD  (HL),A
              ADD HL,HL      ;restore entry HL
              RET

PLOTODD:      XOR D
              AND 0F0H
              XOR D
              LD  (HL),A
              ADD HL,HL
              INC L          ;restore entry HL
              RET
```

The address of the next scan line can always be obtained by adding 128 to the current screen address.

The screen can be easily moved left or right by 1 pixel using the RLD and RRD instructions provided by the Z80. LDIR and LDDR can be used for 2, 4, 6 etc. pixel moves. The ROM subroutines support most possibilities.

- PALETTE SWITCHING -

The ROM interrupt routine sets up the palette registers (CLUT) at the start of every frame, using one of two tables of 16 bytes at PALTAB, and switching between them to give flashing colours. It is a good idea to keep these tables up-to-date with the current colours, even if you do not want to use the ROM routines, because the palette registers themselves cannot be read. Software entered via MNI would find an accurate PALTAB useful when doing screen dumps or palette alterations.

The ROM can also change a specified palette memory to a given value at a specific scan line, allowing many more than 16 colours to be displayed at once. If only a single change is made per scan line, it will occur during the scan flyback time and no flicker will occur in the display. In the Coupe's striped start-up screen all the stripes are actually palette colour 0 - but palette memory 0 is being altered.

If more than one palette change is programmed to occur at a given scan line, the later changes will occur as the picture is displayed, and this can cause flicker if the colour being altered is on-screen at that particular location. Up to 127 changes can be made per frame. If you wish to provide your own routine this can be added using the line interrupt vector address (LINIV), or by switching out the ROM.

- THE PAGING SYSTEM -

The paging system makes it possible to page in any address so that there are at least 16K bytes above it before FFFFH is passed. This means that when dealing with data structures less than 16K long, once the start of the data is paged in there is no need to take special precautions to ensure pointers do not "fall off" the end of memory. The ROM normally uses memory sections C and D as a "rotating window" onto memory and keeps system variables and the stack in section B. For example when the next Basic line is pointed to by adding a number to HL (adding current line length to current line start) code similar to that below checks to see if HL has moved out of section C into section D. If so, the page value is increased and HL is adjusted to point to the same actual byte, at an address 4000H lower, in section C. The whole line can then be dealt with fairly simply since no further checks of HL need be made until the next line is looked at.

```
        BIT 6,H
        JR Z,LAB1

        IN A,(HMPAGE)
        INC A
        OUT (HMPAGE)
        RES 6,H

LAB1: ETC.
```

Here there is no danger of the lower 5 bits of HMPAGE being incremented past 1FH to corrupt the upper bits, since the last line of program has a terminator. This will be the case with most other data structures you are likely to want to use.

- ROM RESOURCES -

The ROM should be used via the documented fixed locations or the jump table to avoid problems with new ROM issues. References are made to ROM 1.0 and ROM 1.2. All production machines contain ROM 1.0, however a free upgrade will allow users to change this to ROM 2.0, which is the production version of ROM 1.2. Production machines will be fitted with ROM 2.0 by mid 1990. The ROM version installed can be determined by: PRINT PEEK 15, and dividing the value displayed by 10.

FIXED ROUTINES NEAR THE START OF LOWER ROM

```
0000 MACHINE INITIALISATION
0004 POP HL          Call here to return your own address in HL.
0005 JP (HL)
```

The two instructions above provide the ability to (effectively) use CALL within relocatable code. For example.

```
HERE          CALL 0004H          ;get address of HERE in HL
              LD  DE,THERE-HERE
              ADD  HL,DE           ;add displacement to get
                                   ;address of THERE
              CALL 0005H          ;effectively, CALL THERE
              etc.

THERE         RET
```

The method above corrupts HL and DE, but it can be adapted to use the alternate register set or IX or IY if desired.

```
0006 JP (JY)
0008 ERROR HANDLER
000F ROM VERSION NUMBER
0010 Print char in 'A' register to current stream. The 'K'
      and 'S' channels respond to control codes for PEN,
      PAPER, OVER, INVERSE, FLASH, delete, left, right, up,
      down, AT, TAB and carriage return.

0013 Print BC bytes starting from DE, using current stream.
0016 JP (BC)
0018 Get current character from Basic line.
0020 Get next character front Basic line.
```

0028 Call floating point calculator. The example multiplies the top two numbers on the floating point calculator stack, then divides the result by 10 and swops top and third no.s.

```
RST 28H      ;a,b,c,d
DB MULT      ;a,b,c*d
DB STKTEN    ;a,b,c*d,10
DB DIVN      ;a,b,c*d/10
DB SWOP13    ;c*d/10,b,a
DB EXIT
```

The operation codes used are different from the Spectrum's, and more numerous; see the separate section on the floating-point calculator. Note: The vector address RST28V makes it possible to translate any operation code into another before the operation is performed.

```

002B      DJNZ 002B      Useful for uncontended timings.
002D      JP (IX)

0030      USER RST. Intended for debugging etc. JPs to the
          address in "RST30V".
0033      JP (DE)
0035      DJNZ 0035H      Useful for timing.
0037      RET
0038      MODE 1 INTERRUPTS
005C      OUT (HMPR),A
          JP (HL)
005F      LD A,B          Useful for timing.
          OR C
          DEC BC
          JR NZ,005F
          RET

0066      NON-MASKABLE INTERRUPTS

```

RAM contention means that ROM routines usually run slightly faster than identical RAM routines. If you are executing the Z80's block instructions on large blocks, and speed is important, it might be worthwhile to call the routines below:

```

008F      LDIR:  RET
0092      LDDR:  RET      (block moves run about 8% faster in ROM)
0095      CPIR:  RET
0098      CPDR:  RET
009B      OTIR:  RET
009E      OTDR:  RET

```

JUMP TABLE AT 0100H

Sometimes conditions for entry a few bytes past the start of a routine are given, as well as the usual entry conditions to the routine; where this is done, you can read the routine address from the jump table, add a displacement, and enter part-way through (for example using CALL HLJUMP). The documented entry conditions will remain constant.

When routines are described as "generating an error" this means that error handling (using RST 08H) will clear the machine stack back to the value held in ERRSP and then do a RET. Normally this leads to an error message being given in the lower screen window, but this can be avoided by PUSHing the address of your own error handler onto the stack, and altering ERRSP (possibly temporarily) to hold the current Stack Pointer. When you gain control, ERRNR will hold the error number (see the list in the Basic manual).

JSCRN (0100H)	Select screen held in the C register (1-16). Equivalent to Basic's SCREEN command. An error is generated if the screen is not open. This Jump Table entry is not available in version 1.0 of the ROM
JSVIN (0103H)	Call parameter word with system variables page switched in. HL', DE', BC' and F are corrupted, and interrupts are enabled, before the parameter address is called. All other registers are passed intact. On exit, all registers except AF' have the values left in them by the called routine. The original status of HMPR is restored. For example: <div style="margin-left: 40px;">CALL JSVIN DW JGETINT LD (STORE),HL etc.</div>
JHEAPROOM (0106H)	Reserve BC bytes in the system heap. This is always paged in; it is in the same page as the stack and the system variables, paged into memory area B. On entry, BC=bytes to reserve (if BC is positive) or bytes to release (if BC is negative). On exit, if the carry flag is set the call was successful, and DE points to the old HEAP END (the start of the reserved space), HL points to the new HEAP END (one byte past the end of the reserved memory), and BC is unchanged. If the carry flag is reset, not enough space was available, and HL holds the amount that the request exceeded the available space by.
JWKROOM (0109H)	Open BC bytes in workspace (a temporary work area, cleared before each Basic statement is dealt with). On exit, DE points to the reserved space, starting in section C of the memory map, paged in. HL points one byte past the end of the space, provided it is less than 16K long. A and BC are unchanged.
JMKRBIG (010CH)	Open A 16K pages and BC bytes at HL in section C of the memory map. BC must be 0-3FFFH. This routine can be used to open space before the Basic program, inside it, in the variables area, or the workspace. If there is not sufficient space, an error will be generated. On exit, HL points to the space and DE points to the end of the space (if the space <16K).

JCALLBAS (010FH) Call BASIC subroutine at line HL. When RETURN is used, or any error occurs (for example, STOP, variable not found, etc. - even "OK" counts, in this case), your machine code will be re-entered. On return, A holds an error code, or zero if there was no error (and the zero flag will be set if there was no error). When your machine code finally does a RET to return to Basic, the statement that called the code in the first place, such as CALL 54000 or PRINT USR 54000, will be completed, but then the program will carry on at the statement after the RETURN in the Basic subroutine, or after the point where an error occurred, because Basic's notion of its current line and statement have been altered during the subroutine execution.

To return to the statement after your CALL, or anywhere else in the program for that matter, read the values from SUBPPC and PPC before using any Basic subroutines, then INC the SUBPPC value and place it in NSPPC, and place the old PPC into NEWPPC. This will cause a GO TO of the specified line and statement when your machine code RETs.

JSETSTRM (0112H) Set the stream specified by the A register (FBH-10H).

FBH=channel 'B' (Always)	Printer binary output.
FCH=channel '\$' (Always)	Output to a string.
FDH=channel 'K' (Always)	Lower screen I/O.
FEH=channel 'S' (Always)	Upper screen I/O.
FFE=channel 'R' (Always)	Output to edit line.
00H=channel 'K' (Usually)	
01H=channel 'K' (Usually)	
02H=channel 'S' (Usually)	
03H=channel 'P' (Usually)	Printer text output.

JPOMSG (0115H) Output message number A from table at DE. Zero gives the first message. Each message should have bit 7 set on the last character. Characters 0-31 should not be included. The current output stream is used.

JEXPT1NUM (0118H) Syntax check/evaluate a numeric expression. During syntax checking an invisible 5-byte form of any literal numbers is inserted. During run time the result of the expression is left on the floating point calculator stack.

JEXPTSTR (0116H) Syntax check/evaluate a string expression. See JEXPT1NUM.

JEXPTEXPR (011EH) Syntax check/evaluate an expression. See JEXPT1NUM. These three routines can be useful in extending the Basic interpreter.

JGETINT (0121H) Unstack number from calculator stack into HL. BC holds a copy of HL, and A holds a copy of L. An error is generated if the rounded number is not in the range 0-65535.

JSTKFETCH (0124H) Unstack last value from calculator stack to AEDCB. If the value is a floating-point number, the 5 bytes are in CPC/Spectrum format. If the value is a whole number between 0 and 65535 (which may be negative) it may be in a special form where A=0 (showing special form), E=SGN (0=positive, FFH=negative) and D and C are less and more significant bytes. If the value is a string, A holds the page the string text starts in, DE holds the start address of the text start within the page (8000-BFFF), and BC holds the string length.

JSTKSTORE (0127H) Stack AEDCB registers on the calculator stack. On exit, HL holds the new STKEND, and AEDCB are unchanged. No other registers are altered.

JSBUFFET (012AH) Unstack the details of a string from the calculator stack and copy the text to a buffer in the system page in section B of the memory map. Paging is undisturbed on exit, no matter where the string is copied from. Generates an error if the string is more than 255 characters long, or the null string. On exit, DE points to the start of the buffer and BC holds the string length. The A register holds a copy of C.

JFARLDIR (012DH) Copies bytes from page A, offset HL to page C, offset DE. Copies (PAGCOUNT) 16K pages and (MODCOUNT) bytes (MODCOUNT=0000-3FFF), paging as needed. The paging state on entry is unimportant, and is unchanged on exit. Since the routine copies via a buffer, it is usually possible to write a faster, more specialised routine if the required paging can be arranged.

JFARLDDR (0130H) A LDDR version of FARLDIR.

JPUT Screen modes 3 and 4 only. Place a block of data on
(0133H) the screen at given coordinates.

On entry, C holds the x coordinate (bit 0 is not significant, since the data can only be aligned to byte accuracy). The x-range is 0-255, whatever the MODE.

The B register holds the y coordinate, with 0 at the top of the screen and 191 at the bottom.

The HL register points to the data to use; the first and second bytes of the data specify width in bytes and height in pixels, followed by 811 bytes for the top scan of the block, all bytes of the second scan, etc.

The A register determines the method of placing the data on the screen. 0=overwrite with INVERSE option, 1=XOR, 2=OR, 3=AND, 4=overwrite (with no INVERSE option - faster), 5=mask. The mask option requires a second block of data the same length as the first (excluding the first 2 bytes of the first block) pointed to by HL', with bits set for "unmasked" and reset for "masked".

This allows a complex shape, perhaps with holes in it, to be placed on a background without border effects. If the shape hangs off the bottom of the screen, it will be "trimmed" to fit. If the data overlaps the right border of the screen, it will wrap round to the left, but 1 scan lower.

Both HL and HL' (if used) must point to data that will be available for use; since JPUT will temporarily switch in the current screen (using CUSCRNP, or at least the contents of that address) at 8000H, the data must be located at 4000-7FFFH, or E000-FFFFH in the screen page. JPUT also needs to use the system variable CURP (or a byte at that address) as a temporary store, and it will read INVERT to determine INVERSE status, where this is an option. JPUT should run rather faster than Basic's PUT, since Basic has to move data from the variables area.

Unlike attribute colour systems, the colours to be used are implicit in the block data, although methods 0-3 allow an INVERSE option. The restriction that blocks must be put down at even pixel boundaries is to keep the speed high. If you wish to place blocks at 1-pixel intervals, it is possible to prepare two versions of the same graphic, with the data displaced by 1 pixel in one of them, in order to get the required effect.

In version 1.0 ROMs there is an error in JPUT, but you can get the same effect by using: PUSH AF: CALL 3A7BH: POP AF: CALL 2DACH instead of CALL 0133H. If the ROM version number (PEEK 15) is not 10, you must use 0133H.

JGRAB Screen modes 3 and 4 only. Store a block of screen
(0136H) data from given coordinates to a buffer.

On entry, C holds the x coordinate (bit 0 is not significant) and the x-range is 0-255 whatever the screen MODE. B holds the y coordinate, with 0 at the top of the screen and 191 at the bottom. E holds the block width in bytes, and D holds the length in pixels. On exit, DE points to the start of the block in the current screen page (specified by CUSCRNP); the first byte is always zero, the next byte is the width in bytes, the next byte is the length in pixels, and the following bytes store the block, scan line after scan line. BC holds the block length, including the a header bytes. Since the area is stored in the "spare" 8K following a MODE 3/4 screen, the length of the data must be a little under 8K, at the most. JGRAB requires temporary storage at the variable CURP (or storage at that address) and it will read CUSCRNP in order to temporarily switch the screen in. If the GRABed area hangs off the bottom of the screen, it will be trimmed as needed.

JPLOT Plot pixel at x coordinate in C and y coordinate in B,
(0139H) except when the MODE is 3 and FATPIX 0 is in force (THFATT will be zero); in which case use HL as the x coordinate (0-511) and plot a "thin" pixel. The y-axis has 0 at the top and 191 at the bottom in all cases. There is no control to prevent you plotting beyond the bottom of the screen.

JDRAW Draw a line from the current position C (or HL if "thin"
(013CH) pixels are in Use, according to THFATT) pixels horizontally and B pixels vertically. D=1 for down (or for no y movement) and FF for up, E=1 for right (or for no x movement) and FF for left. The colour and OVER and INVERSE state come from the temporary graphics variables. The screen used comes from CUSCRNP. An error is generated if the line is drawn over the screen edge.

JDRAWTO Draw a line from current position to point C,B (or point HL,
(013FH) B if "thin" pixels are in use). The y axis has zero at the top and 191 at the bottom. Colours etc. come from the temporary graphics variables.

JCIRCLE Draw circle at C,B radius A. If "thin" pixels are set, HL
(0142H) should hold an offset from the left-hand screen border (in pixels). This allows a circle to be placed anywhere on a mode 3 screen even though the x coordinate is limited to 1 byte. The y axis has zero at the top. Colours etc. come from the temporary graphics variables.

JFILL
(0145H) Modes 3 and 4 only. Uses the 16*16 pixel pattern at DE to fill an area starting at coordinates C,B. The y axis has zero at the top. If DE holds zero, a "solid" fill with the current PEN (from M23INKT) is performed. Otherwise DE can have any value (but values 0001-3FFFH will use the ROM as a pattern!). If A=0 then a preliminary transfer of the screen memory to a scratchpad area (6K long, immediately after the 24K screen memory) is made; you will need to make A=0 for at least the first fill you use. Later fills on the same screen over the same colour can make A non-zero for greater speed.

If you are using MODE 3 with "thin" pixels, HL should hold a byte offset from the left-hand screen edge for the point to start filling at. This allows any part of the screen to be filled, despite the x coordinate being limited to one byte.

The pattern data pointed to by DE has 8 bytes for the top row, 8 bytes for the next, etc. so 128 bytes are needed. Each nibble controls colour for 1 pixel in mode 4 or 2 pixels in mode 3.

JBLITZ
(0148H) Execute a string of graphic commands BC long at DE. DE can be anything from 4000H to FFFFH, and BC anything from 0 to FFFFH (JBLITZ will *page* if required). PLOT, DRAW, DRAW TO, CIRCLE, OVER, INK, CLS and PAUSE commands can be included in the string. They are handled at a higher level than JPLOT, JDRAW and JCIRCLE; the floating point calculator and special Basic variables can be used for offset and scaling. The use of numerous system variables makes having the system variables paged in hard to avoid. x coordinates and moves of 0-255 only are allowed; i.e. only half the screen is easily usable in MODE 3 with FATPIX 0 selected. The coordinate system used is the same as that used by Basic; e.g. bytes 01 00 00 would act like PLOT 0,0 in Basic and be modified if XOS or YOS were altered. To perform a RELATIVE DRAW:

00 or FF give the SGN of an x movement (00=positive, FF=negative), followed by the x movement, followed by the SON of the y movement and the y movement. If movements are negative, they are stored as 256-move.

PLOT:	01	followed by x,y
DRAW TO:	02	followed by x,y
CIRCLE:	03	followed by x,y,r
OVER:	04	followed by 0-3
PEN:	05	followed by 0-17
CLS:	0G	followed by 0-1
PAUSE:	07	followed by 0-255

The easiest way to prepare the data for JBLITZ is to use RECORD in Basic and then POKE the string where you need it.

JROLL
(014BH) Modes 3 and 4 only. Move part of screen left, right, up or down. The screen area must be an even number of pixels across. A horizontal move by 1 pixel or any even number of pixels is possible. A vertical move by any number of pixels is possible. Wrap-round is optional; it uses the area immediately after screen memory as a buffer. On entry, A is 00 if a SCROLL (no wrap) is wanted, or FFH for a ROLL (with wrap). B holds the pixels to move by, C is a direction code (1=left, 2=up, 3=right, 4=down), D holds length of block in pixels and E holds width of block in pixels (bit 0 is non-significant). HL holds the coordinates of the top left-hand corner of the block to be moved, L holding the x coordinate (range 0-255, whatever the MODE) and H holding the y coordinate with 0 at the top of the screen. JROLL checks the MODE system variable, copies the permanent graphics variables onto the temporary ones, and uses M23PAPT as the background colour for new screen generated by SCROLL. The routine uses CURP and TEMPBPB3 in the system variables, and up to 0181H bytes at 4D00H to store "unrolled" code loops.

JCLSBL
(014EH) Clear entire screen if A=0, else clear upper screen.

JCLSLOWER
(0151H) Clear lower screen. Also selects channel K (lower window input/output).

JPALET
(0154H) If A=FFH, put colours BC in PALTAB as main and flashing colours for palette colour E. (Make B=C for no flashing). Colours should be 0-127, palette entry 0-15. If A is non-zero, it is a y-coordinate to alter the palette at. PALTAB is not altered; instead an entry is made in the line interrupt colour table.

JOPSCR
(0157H) OPEN SCREEN number C in mode B. The pages required are located in the Page Allocation Table and reserved, and an entry is made in SCLIST. The screen number must be 2-16, and it must not be already open, or an error is generated.

JMODE
(015AH) Set screen MODE that is in the A register (0-3 gives MODES 1-4).

JTDUMP
(015DH) Do a text screen dump (if dump utility installed).

JGDUN?
(0160H) Do a graphic screen dump (if dump utility installed). The system variables documented in the Basic manual control the area dumped and its magnification.

JRECLAIM (0163H) Reclaim (close up) BC bytes at HL (8000H-BFFFFH). Can be used to close up memory before a Basic program, within it, or in the variables area or workspace. BC must be less than 16K; if you want to reclaim a bigger space, call one byte from the start of the routine, with A holding number of 16K pages to reclaim, in addition to the space specified in BC.

JKBFLUSH (0166H) Flush keyboard buffer.

JREADKEY (0169H) Read keyboard, flush butter (like INKEYS). Z/NC if no key pressed, else NZ/CY and A=key value (ASCII).

JWAITKEY (016CR) Read next key into A from keyboard buffer. Wait for a key to be pressed if needed.

JBEEP (016FH) Make a beep DE-1 cycles long at period HL*8 T states.

JSAVE (0172H) Save a block CDE bytes long starting at HL (switched into section C). C holds the number of 16K pages, and DE holds the length MOD 16K. Make A register first byte saved, (FFH for 'data block', 01 for SAM 'header', 00 for spectrum header). If SLDEVT (see system variables) holds "T", the SAVE will be to tape-if it holds "N" the SAVE will be to the Network. SLNUMT controls the save speed to tape (112 is standard speed).

JLOAD (0175H) If the carry flag is set, LOAD CDE bytes to HL (switched into section C of the memory map). If the carry flag is reset, do a VERIFY. The A register holds the type of data to deal with (FFH=data block, 01=SAM or Spectrum header, 00=spectrum header). If SLDEVT holds "T", tape will be used; if "N", the Network. Varying input tape speeds are handled automatically. The routine returns with carry set if the operation was successful; otherwise there has been an error.

JLDVD (0178H) If the carry flag is set, LOAD CDE bytes of data (not header) to HL. If the carry flag is reset, do a VERIFY. Use disk, tape or Net according to the contents of SLDEVT. An error is generated if the operation fails.

JEDGE2
(017BH) Waits for 2 signal transitions on EAR, returning in A and C the number of 47-T state units taken. On entry, B should hold the current EAR status in bit 6, bit 3 should be set, and the other bits should reflect what you want sent to the BORDER port when there is a signal transition. Bits 2-0 will be reversed on every transition. The D' register should hold a value that determines the length of a pause between finding one transition and looking for another (this avoids double counts when the tape signal has buzzy edges). For standard speed tapes, D' should be about 46H, JLOAD sets D' according to tape speed. Interrupts should be disabled for accurate results.

The routine returns Z if it had to wait too long (256 units), NC if ESC was pressed, and CY if okay. Entry 2 bytes from the start avoids the initial zeroing of the C register which is used as a counter; entry 6 bytes from the start waits for only 1 signal transition on EAR. On exit the B register holds a new value suitable for another call to the routine, and A and C both hold the counter value. Note: In version 1.0 ROMs this jump table entry incorrectly has bit 15 of the address set. You should read the address at 017CH, reset bit 15, and CALL that address.

JSTRS
(017EH) Create ASCII version of number on floating-point calculator stack in buffer at 5BA0H. On exit, DE holds 5BA0H and BC holds the number of characters in the buffer.

JSEND A
(0181H) Send the byte in the A register to the parallel printer. The system variable at 5A10H is read to obtain the port to use, and the routine loops until the printer is ready before sending the byte and then returning. If ESC is pressed, an error will be generated. Uses A and BC only.

JUMP TABLE ENTRIES INTRODUCED AFTER ROM 1.0

JNCHAR
(0184H) Call SCREEN\$ subroutine. Try to match the character at line D, column E on the screen with any character in the main character set (pointed to by CHARS) or any character in the set pointed to by UDG. On exit, the carry flag is set if the search was successful, in which case A holds a character code of 20H-7FH (32-127) if the character was found in the main set, or 80H-7FH (128-168) if the character was found in UDG set. If the carry flag was reset, A=0 and the search failed.

JGRCOMP
(0187H) Subroutine used by graphic dump utility.

JGTTOK Try to match potential spelled-out keyword pointed to by DE
 (018AH) in a list of keywords at HL+1. The list should be in upper
 case, with bit 7 set on the last letter of each keyword. The
 A register should hold the number of words in the list, plus
 1. On exit no match was found if the zero flag is set. If a
 the zero flag is reset, the A register holds the entry number
 in the list (1 or more), HL points to the start of the
 original word and DE points just past the end of it.

JCLSCR Close screen number held in the C register.
 (018DH)

- CHARACTER SET -

The character set from CHR\$ 32 to CHR\$ 130 is stored in compressed form in ROM1 and loaded into RAM in the system variables page when the machine is turned on. CHR\$ 131-168 are initially defined as blanks, although CHR\$ 128-143 are displayed as block graphics unless "BLOCKS 0" has been set. (The block graphic shapes are generated as needed - the character set itself does not contain them). Characters apart from block graphics occupy a 6*8 matrix, making them suitable for display at 6-pixel or 8-pixel intervals.

Character definitions occupy 8 bytes, from top row of pixels to bottom row. The left and right columns of pixels of this 8*8 block are not used when printing is at 6-pixel intervals. The character set base address is 5190H, and space is available for CHR\$ 32 to 168 in one continuous block. An additional system variable, HUDG, can be set up to point to definitions for CHR\$ 169-254, but standard designs for characters 128 to 168 are supplied (file 'font') which includes a full set of foreign characters which match the accented characters on most printers. Their use is recommended so that software can easily be converted for use abroad.

- VECTORS -

These allow important ROM routines to be intercepted by the user. They contain addresses which will be called if (and only if) the most significant byte is non-zero. This gives the option of RETURNing (perhaps you decide not to handle a particular case), or discarding the return address and turning the vector into effectively a JUMP.

Several programmers might want to use the same vector. If your programs simply overwrite vectors they are likely to be incompatible with future utilities from MGT and other software suppliers. We recommend that your programs save the old vector value. Unfortunately, an automatic linking mechanism that made this very easy had to be omitted from the ROM, but the solution is still fairly simple: for example, to add code to provide some action for the STEP token:

```

;Initialise CMDV but store any existing entry first.
INIT      LD  HL,(CMDV)
          LD  (STORE),HL
          LD  HL,MYPATCH
          LD  (CMDV),HL
          RET
MYPATCH   CP  STEPTOKEN
          JR  Z,MYP2      ;JR if we are interested
          LD  HL,(STORE)
          INC H
          DEC H
          RET Z          ;RET if no address was in CMDV at INIT

          JP  (HL)        ;let another routine have a go

MYP2      (Code to provide some action for STEP)
          RET

```

NB All examples are program fragments, not complete programs, and do not, for example, include the above code, which should be included in actual applications.

LIST OF VECTORS

DMPV Called if the DUMP keyword is used in run-time. CHAD points
(5ADAH) to 0DH or 3AH if just DUMP was used; otherwise DUMP CHR\$ was
 used.

SETIYV SETTY is called when DRAW, PLOT and CIRCLE "decide" what
(5ADCH) pixel setting routine to use, and itself calls SETIYV if its
 most significant byte is non-zero. SETIY points the IY
 register to a suitable routine, and the provision of a vector
 is intended to allow extra plotting modes, such as dotted
 lines, to be implemented without all the graphics commands
 being rewritten. On entry to SETIYV, A holds the current
 screen mode-1.

On return to PLOT, DRAW and CIRCLE the IY register should point to a pixel setting routine, and only A and HL should be altered otherwise. In mode 4, and mode 3 when "fat" pixels are selected, the value of A on exit is passed to D' by the graphics commands, and can be used to hold the PEN colour if desired.

If you alter SETIYV, as with all the vectors, your routine making just RET will cause the normal ROM routine to be executed. Thus your code might start with a check of the mode to see if it is one you want the ROM to deal with, and RET if so. Otherwise, POP the return address so that the ROM routine is never used, and set IY yourself. The next RET will be to DRAW, PLOT or CIRCLE.

The pixel setting routine that you supply the address of in IY should plot the pixel at L,H and return with only AF changed. The coordinate system used has 0,0 at the top left-hand corner of the screen. You may want to take note of the current OVER, INVERSE and PEN settings. (In which case you may find it speeds things up if, like the ROM, you set IY to a different routine for some options). The routine should end in JP (IX), not RET.

PRTOKV (5ADEH)	Print a token. A=token code to expand and print as ASCII.
MNIV (5AE0H)	Non-maskable interrupt. Normally holds the address of a routine that returns to Basic when the BREAK button is pressed. NMIV switches in the system page temporarily, and provides its own stack there, whatever the paging state when the interrupt was generated. On entry, the LMPR status when the NNI occurred is stored in NMILRP, the Stack Pointer when NMI occurred is stored in NMISP, and the AF and HL registers have already been PUSHed onto the stack in use when NMI occurred (which may be paged out).
FRAMIV (5AE2H)	Called by the frame interrupt 50 times a second. All main registers can be used.
LINIV (5AE4H)	Called by the line interrupt, which is generated when the value in the line interrupt register matches the scan about to occur. This vector can be used to alter the palette, change screen or screen mode, etc. in mid-screen. To synchronise such changes with the scan flyback, it is possible to wait for a change at the HPEN port to show that the scan number has just changed. (This will fail if a light-pen is connected, however). All main registers can be used.
COMSV (5AE6H)	Called by COMMS interrupt.
MIPV (5AE8H)	Called by MIDI input interrupt. On entry, the A register has just been read from the MIDI IN port.
MOPV (5AEA H)	Called by MIDI output interrupt.
EDITV (5AECH)	Called before the editor is used for editing a line or INPUT.
RSTOBV (5AEEH)	Called early in error handling, with A=error code. The alternate registers have been selected, CHAD and CHADP have been copied to XPTR and XPTRP, DE points to the error code that follows RST 08H, and an address 1 byte past that code is on the stack, underneath the return address to the error handling routine. No clearing of stacks has been done at this stage.

RST28V
(5AF0H) Called by floating point calculator with A=next code in the list that follows a RST 28H instruction. DE points to the end of the floating point calculator stack. On exit, the IX register should be unchanged, and DE should point to the end of the floating point calculator stack. (This may be different from the entry value, if items have been added, discarded or combined). See example below.

RST30V
(5AF2H) User RST. Jumped to (Not called like the other vectors) by RST 30H. (ROM0 uses RST 30H to provide a "CALL ROM1" facility, but this only applies to RST instructions used inside ROM0). All registers are passed intact.

CMDV
(5AF4H) Called with the A register holding the code of the character about to be syntax checked or executed (normally a command code). Can be used to add commands, or modify the action of the existing ones.

EVALUW
(5AF6H) Expression evaluator. Called with A=current character in expression; can be used to add new functions.

LPRTV
(5AF8H) Called as each character code above 127 is handled by the printer driver, when channel "P" is being used. (More complete control can be obtained by altering the "P" or "B" channel output address - see below).

On entry to the routine the character code is in the register. For example to transform CHR \$ 130 to "A":

```

INIT:      LD  HL,PATCH
           LD  (5AF8H),HL
           RET

PATCH:    CP  130
           RET NZ

           POP BC                ;JUNK RETURN ADDRESS

           LD  A,65
           RST 10H                ;PRINT CHARACTER
           LD  HL,5A70H           ;PRINTER COLUMN VARIABLE
                                   ;(SVAR &70)
           INC (HL)                ;1 COLUMN RIGHT
           RET

```

Instead of using RST 10H to print the new character(s), you might prefer to use either CALL 0181H (send A to parallel printer) or probably better, call the following code to send the A register to channel "B":

```

CHBOP:      LD  HL,(5C4FH)      ;CHANNELS BASE ADDRESS
            LD  DE,25          ;(use 15 to point to "p"
                               ; channel)

            ADD HL,DE
            LD  E,(HL)
            INC HL
            LD  D,(HL)         ;DE=channel B output address
            EX  DE,HL
            JP  (HL)

```

Channel "B" handles all output without fiddling with it; channel "p". responds to control codes, adds auto-LF etc. and then sends its output to channel "B". something like ESC ;"R"; CHR\$ 0 should be sent via the **"B"** channel. Channel "B" normally outputs using 0181H, but if you use CHBOP rather than 0181H directly, it will be easier for others to divert printer output to another device, such as a serial interface. (By altering the output address in the channel).

MTOKV
(5AFAH) Called if a potential spelled-out keyword is not recognised by the ROM. On entry, DE points to the potential keyword. On exit, conditions should match those of jump table entry JGTTOK.

MOUSV
(5AFCH) Called every frame. when this vector is used, the ROM's own scan of the mouse is bypassed.

KURV
(5AFEH) Called before the editing cursor is printed (by calling the address in MNOP). ROM1 is on. Could be used to supply a "transparent" or other cursor.

Additional example: Suppose you have a lot of machine code graphics subroutines which require the screen to be switched in at 4000H. It would be nice to modify USR so that any use of the subroutines switched in the required page temporarily; the routine below does this, for machine code located in the top half of memory. INIT is called to alter the floating point calculator ~ vector to point to USRPATCH; whenever the calculator handles a USR, we intercept it, juggle the pages to put the screen at 4000H (taking care with the stack) and call the USR address, stacking BC back on the floating point calculator stack as the result of USR, and returning DE pointing to STKEND and IX unchanged. (All as expected by the calculator).

USRPATCH must be in the system page to guarantee it is resident when the vector is called; the best place is in the system Heap. PART2 must be in the top half of memory, but in any case it is a good idea to use a short routine in the Heap to call a large routine in another page, since this keeps the Heap train being filled up.


```

INIT      LD  HL,USRPTCH
          LD  (RST28V),HL
          RET

USRPTCH   CP  45H                      ;USR code
          RET NZ                      ;keep things simple and ignore
                                      ;anyone else who might want to use
                                      ;this vector

          POP BC                      ;junk RET address
          IN  A,(HMPR)
          PUSH AF                     ;save current HMPR status
          LD  A,1                     ;OK if PART2 in page 1 or 2
          OUT (HMPR),A                ;page in PART2

          IN  A,(LMPR)
          AND 0BFH
          OUT (LMPR),A                ;ROM1 off
          CALL PART2
          IN  A,(LMPR)
          OR  40H
          OUT (LMPR),A                ;ROM1 on again for RET to calculator
          POP AF
          OUT (HMPR),A                ;original HMPR status restored
          RET

PART2     LD  (STORE),SP              ;we will be switching out the stack,
                                      ;so save current SP
          LD  SP,TSTACK               ;put a new stack elsewhere (>=8000H)
          PUSH AF                     ;LMPR status
          PUSH IX                     ;calculator needs IX unchanged
          CALL JGETINT                ;get USR address in BC
          IN  A,(VPAGE)
          AND 1FH                     ;A=screen page
          DEC A
          OUT (LMPR),A                ;page it in at 4000H
          CALL BCJUMP                 ;CALL USR address
          POP IX
          POP AF
          OUT (LMPR),A                ;original LNPR status
          LD  SP,(STORE)              ;original SP
          XOR A
          LD  E,A
          LD  D,C
          LD  C,B
          CALL JSTKSTORE
          EX  DE,HL
          RET

STORE     DW  0

```

FLOATING POINT CALCULATOR COMMAND CODES

The floating-point calculator performs all the mathematical operations of the Coupe, and many of the string operations. Since it provides a simple way of programming quite complex tasks in a sort of sub-language, it can be very convenient. The calculator is called using RST 28H, followed by a series of command codes (which may have parameters). A special code terminates the list. The data that the calculator manipulates is placed on a special stack that we will refer to as the FPCS. All items are five bytes long. The jump table allows registers to be passed to and from this stack, and the B register is passed into and out of the calculator (see below).

Numbers are held in two forms; the integer form stores whole numbers between -65535 and +65535 as zero, SGN (0 for positive, FFH for negative), less significant and more significant bytes, and a final zero byte. E.g. 80H is stored as 00 00 80 00 00, 4001H as 00 00 01 40 00, -1 as 00 EFF FF FF 00 and -80H as 00 FF 80 FF 00. (Negative values are stored in negated form (65536 minus the number).)

If numbers are in integer form the calculator is often able to use specialised, faster forms of operations such as multiply, subtraction and addition. Numbers outside the -65535 to +65535 have to be held in a different form, as 2 to the power of a number called the exponent, multiplied by another number called a mantissa. The first byte is the exponent +80H, and the other four bytes are the mantissa. This is always between 0.5 and just less than 1, which means that the first bit is always 1, allowing it to be actually used as a SGN bit (0 for positive, 1 for negative).

This scheme allows values between about 1E38 and 1.7E-39 to be stored to an accuracy of 9 or 10 digits. It is important to note that some fractional numbers (such as 1/10) cannot be stored exactly in this binary form (just as, for example 1/3 cannot be represented exactly in decimal form). This means that if you subtract 0.1 from 1 ten times, the result is not exactly zero. This is not a fault - just a limitation of number systems in general, which you should be aware of.

Strings are held as 16K page of string text start, offset of string text start (8000H-BFFFFH, LSB/MSB) and string length (LSB/MSB).

In the list below, the action of many of the calculator codes is shown symbolically. Where a command code deals with two numbers (e.g. multiply) the last number on the FPCS is referred to as N2 and the number below that is referred to as N1. If the values dealt with are strings, \$2 and \$1 are used.

00H	MULT	$N1 * N2$
01H	ADDN	$N1 + N2$
02H	CONCAT	$\$1 + \2 Prepare the concatenated text of $\$1 + \2 in the Workspace, and stack the details of this temporary string.
03H	SUBN	$N1 - N2$
04H	POWER	$N1 ^ N2$
05H	DIVN	$N1 / N2$
06H	SWOP	Swap $V1, V2$
07H	DROP	Discard last value
08H	MOD	$N1 \text{ MOD } N2$
09H	IDIV	$N1 \text{ DIV } N2$
0AH	BOR	$N1 \text{ BOR } N2$
0BH	Reserved	
0CH	BAND	$N1 \text{ BAND } N2$
0DH	NUOR	$N1 \text{ OR } N2$
0EH	NUAND	$N1 \text{ AND } N2$
0FH	NOTE	$N1 <> N2$ Comparisons like $<>$ delete the two compared values from the FPCS and replace them with 1 or 0 (true or false).
10H	NLESE	$N1 \leq N2$
11h	NGRTE	$N1 \geq x2$
12H	NLESS	$N1 < N2$
13H	NEQUAL	$N1 = N2$
14H	NGRTR	$N1 > N2$
15H	SAND	$\$1 \text{ AND } N2$
16H	SNOTE	$\$1 <> \2
17H	SLESE	$\$1 \leq \2
18H	SGRTE	$\$1 \geq \2
19H	SLESS	$\$1 < \2
1AH	SEQUAL	$\$1 = \2
1BH	SGRTR	$\$1 > \2
1CH	SWOp13	Swap last value and value 2 below.
1DH	SWOp23	Swap second-to-last value and value below it.

The three command codes below, along with DECB, use a displacement byte to skip backwards or forwards in the list of commands (like GO TO in Basic, or JP in assembly language). The displacement is the distance between the displacement byte and where you want to jump to; if it is greater than 7FH it treated as a backwards jump, for example, FFH is backwards by 1.

1EH	JPTRUE	Jump by displacement given in next byte, if the last value is one. (The last value is discarded).
1FH	JFFALSE	Jump by displacement given in next byte, if the last value is zero. (The last value is discarded).
20H	JUMP	Jump by displacement given in next byte.

The calculator has a special store called BREG that initially holds whatever the Z80's B register did when the calculator was called. The four command codes below use BREG.

21H	LDBREG	Load BREG with next byte.
22H	DECB	Decrement BREG and jump by the displacement given in the next byte if BREG is non-zero.
23H	STKBREG	Put BREG on FPCS as a number between 0 and 255.
24H	USEB	Take the next calculator code from BREG.

25H DUP	Duplicate top FPCS entry.
26H ONELIT	Stack next byte on FPCS (as a number between 0 and 255).
27H FIVELIT	Stack next 5 bytes on FPCS (as any number).
28H SOMELIT	Stack number of bytes specified by next byte, using (next byte+1} as the first byte. (This allows many 5-byte values to be stacked at once).
29H LKADDRB	Use the next 2 bytes as an address; stack the byte found at that address on the FPCS.
2AH LKADDRW	Use the next 2 bytes as an address; stack the word (2 bytes) found at that address on the FPCS.
2BH REDARG	Fiddle with the argument of SIN.
2CH LESS0	Stack 1 (TRUE) or 0 (FALSE) according to whether the last value is <0. The last value is discarded.
2DH LESE0	Stack 1 or 0 according to whether the last value is <=0. The last value is discarded.
2EH GRTR0	Stack 1 or 0 according to whether the last value is >0. The last value is discarded.
2FH GRTE0	Stack 1 or 0 according to whether the last value is >=0. The last value is discarded.
30H TRUNC	Chop off the digits after the decimal point in the last value.
31H RESTACK	Transform the last value to full 5-byte form if it isn't already in that form.
32H POWR2	Calculate 2 to the power of the last value.
33H EXIT	Finish using floating point calculator.
34H EXIT2	Finish using floating point calculator, and do a RET.
35H Reserved	
36H Reserved	
37H Reserved	
38H Reserved	

The command codes below are used to provide most of Basic's functions:

39H SIN	4CH EOF
3AH COS	4DH PTR
3BH TAN	4EH Reserved
3CH ASN	4FH UDG
3DH ACS	50H NUMBER
3EH ATN	51H LEN
3FH LOGN	52H CODE
40H EXP	53H VAL\$
41H ABS	54H VAL
42H SQN	55H TRUNC\$
43H SOR	56H CHR\$
44H INT	57H STR\$
45H USR	58H BIN\$
46H IN	59H HEX\$
47H PEEK	5AH USR\$
48H DPEEK	5BH INKEY\$ #
49H DVAR	5CH NOT
4AH SVAR	5DH NEGATE
4BH BUTTON	

The calculator has six 5-byte memories for holding temporary results. The following codes store and recall the memories:

C8H STOD0	Copy the last value to calculator memory 0-5,
C9H STOD1	then delete it from the FPCS.
CAH STOD2	
CBH STOD3	
CCH STOD4	
CDH STOD5	

D0H ST00	As above, but do not delete the last value
D1H ST01	after copying it.
D2H ST02	
D3H ST03	
D4H ST04	
D5H ST05	

DBH RCL0	Stack the value in calculator memory 0-5 on.
D9H RCL1	the FPCS
DAH RCL2	
DBH RCL3	
DCH RCL4	
DDH RCL5	

The codes below provide a compact method of stacking comanonly used constants on the FPCS:

E0H STKHALF	Stack 0.5
E1H STKZERO	Stack zero
E2H STX1SK	Stack 16384
EGH STKFONE	Stack 5-byte form of 1.
E9H STKONE	Stack integer form of 1.
ECH STKTEN	Stack 10.
FOE STKRALFPI	Stack $\pi/2$

TAPE SYSTEM

There are five types of tape files; Basic program, Machine Code, Numeric array, String array and SCREEN\$. File saving occurs at a selectable speed which can be set to match Spectrum tape speeds. The header format is different from the Spectrum's and will not be recognised by a Spectrum as a header. The data block format is the same as on the Spectrum, but it may contain up to 512K. SCREEN\$ files normally contain the palette settings (40 bytes) and line interrupt table, (1 to 509 bytes), so even a screen that switches the palette part-way down a screen can be reloaded. The screen mode is set appropriately before loading of the data block begins.

Files are loaded at the correct speed automatically. Spectrum CODE file headers are converted into the SAM equivalent and then used to load the data block. Spectrum CODE files can be loaded into the Coupe as either CODE or SCREEN\$ files by specifying this after the LOAD command. (The Coupe distinguishes SCREEN\$ files from CODE files because they have to be loaded to screen memory, which can be anywhere in the memory map). Coupe CODE files can be forced to load as SCREEN\$ files, and vice versa, simply by using LOAD "name" CODE or SCREEN\$. CODE files can have an execution address.

Altering the system variable TPROMPTS (SVAR 50) can turn off the prompt before SAVE, and/or the printing of file as names they are read from tape.

- FILE HEADER FORMAT -

Tape, disk and Net use a common header format as far as the Basic interpreter is concerned. (The DOS holds information in a slightly different format for its own use, but uses information from, and passes information to, the standard header buffers). SAVE uses a single buffer, HDR (Header-requested) at 4B00H where the details of the file to be saved are built up before the header and then the data are saved. LOAD also uses this buffer, plus an extra one, HDL (Header-loaded) at 4850H which is used to load file headers for comparison with HDR (On the Coupe a "tape header reader" program just consists of a program to PEEK the HDL buffer). (NB There is an extra file type in SAMDOS - .SNP).

HEADER BUFFER FORMAT (HDR and HDL):

- | | | |
|-------|--------|--|
| 0 | - (1) | Type. 5 is a Spectrum 48K snapshot, 16 is a Basic program, 17 is a Numeric array, 18 is a String or string array, 19 is a CODE file, and 20 is a SCREEN\$ file. |
| 1-10 | - (10) | File name, padded with spaces. |
| 11-14 | - (4) | Allows longer file name if DEVICE is not T, for example 'D2:filenamexx'. SAMDOS will strip off any device identifier, so the maximum length of a filename is still ten characters. |

- 15 - (1) Flags. Bit 0 is set if the name is not to be printed on LOADING, bit 1 is set if the CODE is protected. The flags can be conveniently set during SAVE by:
- SAVE CHR\$ 1+"name" - sets bit 0
 SAVE CHR\$ 2+"name" - sets bit 1
 SAVE CHR\$ 3+"name" - sets both bits

(Characters <=3 as the first character in a file name just set the flags - they are not saved as part of the name). Flag bit 0 works in addition to the TPROMPTS system variable. Bit 1 protects CODE files; when this bit is set, an auto-running CODE file cannot be stopped by MERGE, or re-directed to another address by supplying one in, for example:
 LOAD start,length,newaddress.

- 16-26 - (11) If type is 17 or 18, holds type/length byte and array name
- 16 - (1) If type is 20, holds screen MODE.
- 16-18 - (3) If type is 16, holds program length excluding variables.
- 19-21 - (3) If type is 16, holds program length plus numeric variables.
- 22-24 - (3) If type is 16, holds program length plus numeric variables and gap length before string/array variables.

(The extra data for Basic programs allows NVARs, NUMEND and SAVARS to be set up on LOADING).

- 27-30 - (5) Reserved
- 31 - (1) 16K page that file starts in (ignored on LOADING, except for CODE files). bits 4-0 hold the page, bits 7-5 are undefined. If type is 17 or 18 and the array being LOADED does not exist in memory, this byte in HDR will be FFH.
- 32-33 - (2) Offset within page of file start (ignored on LOADING, except for CODE files). The offset is 8000H-BFFFFH, in LSB/MSB form.
- 34 - (1) File length in 16K pages (in HDL, or HDR during SAVE) or requested start for CODE files in HDR during LOAD (FFH if there was no requested start). During LOAD of an array, "file length" in HDR is the length of the existing array in memory, or FFFFFFFF if there isn't one.
- 35-36 - (2) File length MOD 16K, plus 8000H (reset bit 15 of the length word to get the true length).

- | | | |
|-------|--------|---|
| 37 | (1) | If CODE file, page of execute address, or FF if there isn't one. If Basic program, 00 if there is an auto-run line number in the next two bytes, or FF if there isn't one. |
| 38-39 | - (2) | If CODE file, offset within page of execute address (8000-BFFFFH, LSB/MSB) if there is one. If Basic program, auto-run line number if there is one. |
| 40-79 | - (40) | Comment field. Not initialised to anything, but SAVED and LOADED with the program. Could be POKED or PEEKed to carry extra information about the file. (DOS only SAVES the first 8 bytes in this area). |

SAM BASIC

Numeric variable names must start with a letter. Numbers, letters, underlines and spaces may follow the first character, to a total of up to 32 characters (spaces do not count). (FOR-NEXT variables are treated like normal numeric variables).

String and array variable names are similar but limited to 10 characters (spaces do not count). String and string array names are followed by '\$'. strings can be up to 65520 characters long. Arrays can fill all available memory, although no subscript can be over 64K. Program lines can have up to 127 statements, and can be up to 16127 bytes long.

Keywords are normally typed in full, although keys can be programmed to generate complete words. When a keyword is recognised, it is converted to capital letters in the listing. A keyword which is followed by a letter will not be recognised, so printx is assumed to be a procedure name, but print x and print1 become PRINT x and PRINT 1.

If you press the EDIT key on its own, the line with '>' will appear in the editing area. If you type a line number and then press EDIT, the desired line will appear for editing. The cursor can be moved left, right, up or down in the edited line, using the cursor keys. The delete key deletes to the left; shift-delete deletes right.

BASIC MACHINE CODE INTERFACE

NB angle brackets enclose optional items.

SAVE "name" CODE start,length<,execute address>

Produces auto-running file if an execute address is used.

LOAD "name" CODE <start><,length><,execute address>

Executes file from execute address if used. Otherwise any execute address saved with the file is used. MERGE will stop CODE a file executing unless it is protected by setting a bit in the file header.

Start, length and execute values, and the addresses used by USR, USR\$, CALL, POKE, PEEK etc. can be up to 528K minus 1.

USR n

Calls address n. Enters with BC=n. All registers can be used. USR returns the final value of BC.

USR\$ n

As USR, but returns a string BC bytes long starting at DE in page A. (Page is irrelevant if DE<8000H).

CALL n

Calls address n with a list of numeric or string parameters if desired. The values of numbers and the lengths and starts of strings are placed on the floating point calculator stack, with information on type. The A register contains the number of parameters when address n is entered. Using the FPC stack allows numbers to be removed and rounded to 2 bytes with range checking by calling JGETINT in the jump table; floating-point numbers, or strings, can be unstacked using JSTKFETCH. strings shorter than 256 bytes can be copied to a buffer in the system variables area by calling JSBUFFET. (strings can be copied from anywhere in memory, even if they are paged out). JSTKSTORE can be used to place any result on the calculator stack.

CLEAR n Set upper limit of Basic's RAM use.

OPEN n Reserve n more 16K pages for Basic to use.

OPEN TO n Allocate a total of n pages to Basic.

CLOSE n Free n 16K pages.

LENGTH

This function returns the address and dimensions of arrays and strings, and the address of numbers. Useful for passing data via Basic's CALL.

POKE n,x	POKE 1 byte
POKE n,1,2,3	POKE multiple bytes (up to 32)
DPOKE n,x	POKE 2 bytes (LSB/MSB)
POKE n,a\$	POKE entire string

PEEK n	PEEK 1 byte
DPEEK n	PEEK 2 bytes

XEM\$(n TO m) PEEK a string, for example:

LET a\$=MEN\$(70000 TO 71000) assigns 1000 bytes to a\$ POKE 72000,a\$ puts those bytes to 72000.
MEM\$S can read any RAM page (16K-528K-1) but will not read the ROM's. Use PEEK or DPEEK if you need to read R0)

Examples of base conversion:

BIN 1010=10	HEXS 74="4A"	&FF=255
BINS 128="100000000"	HEX\$ 16384="4000"	&10003=65539
	HEX\$ 65539="010003"	

VAL("&"+a\$)=255 if a\$="ff"

MAJOR POINTERS TO BASIC'S MEMORY AREA

(ALL TAKE 3 BYTES, IN THE FORM: PAGE/OFFSET)

PROC	START OF PROGRAM
NVARS	START OF NUMERIC VARIABLES
NUMEND	END OF NUMERIC VARIABLES GAP (<=512 BYTES)
SAVARS	START OF STRING/ARRAY VARIABLES
ELINE	START OF EDIT LINE
WORKSP	START OF WORKSPACE
WKEND	END of WORKSPACE
	SPARE SPACF
RAMTOP	LAST BYTE ALLOCATED TO BASIC PROGRAM,

See the section on system variables for full information.

- PAGE ALLOCATION TABLE -

The table at 5100H-5120H is very important; it holds a byte for every possible 16K RAM page in the Coupe, plus an FFH terminator byte. The first byte corresponds to the first 16K RAM page, the second to the second page, etc. Non-existent pages are also marked by FFH. Unused pages are marked as 00H. Pages used by the first Basic program in the machine are marked 40H; screen pages are marked C0H, and pages used by DOS (usually just one) are marked 60H. On a 256K Coupe, the table (ALLOCT) will look like this after DOS has loaded:

40 40 40 40 00 00 00 00 00 00 00 00 00 00 60 C0 C0 FF FF FF etc.

A "Utilities" page is marked 20H. It is divided into 16 1K sections which can be used by assorted short utility programs. The final 16 bytes in a utilities page (SLOTT) show which 'slots' are reserved - a 0 shows the corresponding slot is free, and FFH that it is reserved. (The last slot is 16 bytes short of 1K). The proper method of allocating space for a short program is to look backwards through ALLOCT for 20H. If you find it switch in the indicated page and look backwards through SLOTT for a spare slot. Mark it and use that slot. (Or slots - you could reserve several slots). If you do not find a 20H entry in ALLOCT, look for 00H; report an error if none is found, else mark it 20H, clear the last 16 bytes of that page with zeros, and then reserve yourself some space in the new SLOTT you have just created.

Free pages can be used as temporary workspaces, provided you are sure that nothing is going to overwrite the page while you are using it. (Interrupts do not do this, but the DOS might).

- KEYBOARD -

Any keyboard key in NORMAL, CAPS SHIFTED, SYM SHIFTED or CONTROL states can return any code (0-255). The 69 keys and 4 shift states give 276 key in a keyboard 'map'. This map has a seemingly haphazard arrangement that corresponds to the keyboard matrix see Appendix C for diagrams of the keyboard and the map positions, plus initial codes returned by each position. E.g. map position 0 has 98 in it - so CHR\$ 98 ('b') is produced when the actual key corresponding to that map position is pressed, without any shifts. The entire map can be altered if desired.

KEY Posn,x

KEY 23,134 makes key position 23 in the key map produce CHR\$ 134 hen pressed.

KEY 0,65 would make the normal 'b' into CHR\$ 65 ('A').

Posn must be 0-275, x must be 0-255.

When certain codes come from the keyboard, a search is made to see if an expanded definition has been made for them. Codes 192-254 can be defined in this way. If a definition does not exist, CHR\$ 192-254 will be used, otherwise the expanded definition is used. This allows, for example, function keys to be defined as RUN (enter) or LIST (enter). See below.

DEF KEYCODE

DEF KEYCODE 195: PRINT 123: PRINT "z" will cause any subsequent code of 195 coming from the keyboard to be expanded to: PRINT 123: PRINT "z"(ENTER). This makes: 123 z appear on the upper screen area. The entire line after DEF KEYCODE 195: is used. If a final colon is added to the line, the automatic (ENTER) is suppressed, for example:

```
DEF KEYCODE 193: PRINT "asd":  
would produce:  
PRINT "asd" in the editing area.
```

DEF KEYCODE can also be used with a string, rather than the rest of a line, for example:

```
DEF KEYCODE 192,"TESTING" will cause any subsequent code of 192  
coming from the keyboard to be expanded to 'TESTING' (ENTER).  
(This would cause an error report).  
DEF KEYCODE 192,"TESTING:" would suppress the (ENTER) because the  
last character is a colon.
```

A particular definition can be cleared by:

```
DEF KEYCODE 195: (followed by nothing)  
or DEF KEYCODE 195,""  
DEF KEYCODE ERASE removes all definitions.
```

'Too many definitions' is reported if space runs out in the memory area used by DEF KEYCODE.

- STREAMS & CHANNELS -

CLOSE
OPEN

Like the Spectrum, streams 0 and 1 are normally OPEN to channel 'K'; PRINT #0;"test": PAUSE will print at the bottom of the screen. PRINT #2 will print on the upper part of the screen, as usual (using channel 'S'), and PRINT #3 acts like LPRINT (using channel 'P'). You can also do something like OPEN *#;"P": PRINT #6;"testing" to send data to the printer via stream 6, or OPEN #2;"P" so that the normal screen output goes to the printer instead. INPUT normally uses channel "K" (the lower screen), but INPUT#2 is allowed and uses the upper screen, (channel "S").

For example: INPUT #2;"Value:";v will allow you to type in the value of V on the upper screen, next to the 'Value:' prompt. The line is NOT cleared after you press enter, unlike the lower screen.

The RECORD command works via stream 16 (which did not exist on the Spectrum). Stream 16 prints to the string variable specified by RECORD, and it will still do so after RECORD STOP. This might be useful to some users: ~or example, RECORD TO a\$: DIR #16;1 :RECORD STOP, will place a disk catalogue in a\$. Other streams apart from 16 can be opened to the string variable using, for example, OPEN #5;"\$".

OPEN #s;"b" (or "B") will allow stream S to send anything to the printer - this is useful for sending control codes. (The problem with the 'p' stream is that control codes are acted on, and may not be sent to the printer - the TAB control code for example, will send a number of spaces to the printer). Channel 'p' actually uses channel 'b' for output, after it has modified the data it receives. Therefore all an advanced user need do to divert output to, say, a serial printer driver, is to alter the channel 'b' output address.

SAVE, LOAD, MERGE, VERIFY

Allow programs, strings, arrays, machine code and screens images to be handled.

SAVE "name" CODE start,length,execute-address is allowed, so that
LOAD "name" CODE will start running from the address given.
MERGE "name" CODE will suppress auto-running of code files.

LOAD "name" DATA b\$() works, but also, DATA addr\$() or DATA abc\$ are allowed. Note that SAVE "name" DATA blitS is okay even if blit\$ is a simple string, such as a BLITZ string.

LOAD "name" LINE n loads the program and goes to line number n. This overrides any auto-run line number saved with the program.

SAVE "name" SCREEN\$ saves the screen image and the current mode and palette information for later reloading. (LOAD automatically switches modes if required).

DEVICE

This new command makes SAVE, LOAD, MERGE and VERIFY work with the disk or Network.

DEVICE d means use disk drive 1.

DEVICE dl ditto

DEVICE D1 ditto

DEVICE N5 use Network station 5.

DEVICE T use tape, SAVE speed similar to the spectrum's.

DEVICE t35 use tape, SAVE speed 35.

(Speed 112 is spectrum speed, 35 is much faster. Faster speeds are less reliable - but 3*spectrum speed should be feasible with many recorders. LOAD automatically adjusts to the tape speed that was used when the file was saved).

- SOUND -

```
SOUND r,d
SOUND r,dir,dir,d...
```

sends data byte D to sound chip register R. Up to 127 pairs of numbers can be used.

This explanation is based on the program in the SAM Coupe User's Guide. The program is reproduced here for ease of reference

```

10 REM sound effects
20 GO SUB 3000
30 REM steam locomotive
40 LET L=7 : GO SUB 2000
50 LET p=20 : GO SUB 1000
100 REM flying saucer
110 LET L=3 : GO SUB 2000
120 LET p=20 : GO SUB 1000
200 REM sonic scooter
210 SOUND 17,4 : SOUND 16,64
220 LET p=5 : GO SUB 1000 :
PAUSE 200
300 REM telephone
310 GO SUB 3000
320 FOR n=0 TO 3
340 SOUND 2,255 : PAUSE 18
350 SOUND 2,0 : PAUSE 8
360 SOUND 2,255 : PAUSE 18
370 SOUND 2,0 : PAUSE 80
380 NEXT n
400 REM cuckoo
410 BEEP 0.2,19 BEEP 0,4,15
420 STOP
1000 REM stereo Left to Right
1010 LET a=0 : LET b=0
1020 LET L=1 : LET R=0 :
GO SUB 1500
1030 LET L=0 : LET R=16 :
GO SUB 1500
1040 LET L=-1 : LET R=0 :
GO SUB 1500
1050 LET L=0 : LET R=-16 :
GO SUB 1500
1060 RETURN
1500 REM output subroutine
1510 SOUND 2,(a+b) : PAUSE p
1520 FOR n=1 TO 15
1530 LET a=a+L : LET b=b+R
1540 SOUND 2,(a+b)
1550 PAUSE p : NEXT n
1560 RETURN
2000 REM output sound data
2010 DATA 9,64,16,16,17,0,24,
138,28,1,21,4,20,0
2020 DATA 9,255,17,1,20,4
2030 DATA 24,142,20,4,10,111,
17,6,9,128,16,32,28,1
2040 FOR n=1 TO L
2050 READ a,d : SOUND a,d :
NEXT n
2060 RETURN
3000 REM clear the sound
3010 FOR n=0 TO 31 : SOUND n,0 :
NEXT n
3020 RETURN

```

Line 20 clears the sound chip's registers by setting them all to zero.

Line 40. L refers to the pairs of data on line 2010. The data pairs refer to setting up the various registers.

Line 50. p refers to the speed at which the sound is moved across the stereo field. If you play the sound demo program, you will find that the sonic scooter moves from left to right faster than either the steam locomotive or the flying saucer. The subroutine at line 1000 tells the computer where to place the sound across the stereo field. The subroutine at line 1500, outputs the sound on both left and right channels.

Both the flying saucer and sonic scooter are similar to the steam locomotive except that the steam locomotive uses white noise.

The sonic scooter changes the current octave, so that register 17's octave is 4 and register 16's octaves are set to 0 for generator 8, and 4 for generator 9. Notice also that the speed of movement of the scooter is faster than either the locomotive or the flying saucer.

The telephone is placed in the centre of the stereo field after clearing the sound chip again. This sound uses envelope register 24 and places a sound from tone register 10 through it using enable mixer 20 with bit 4 set. It also uses tone register 9 to control the speed of the envelope. Finally, register 28 enables the sound. The 'bleep' sound is controlled by switching the volume of amplitude register 2 between 0 and 255. This is repeated 4 times with pauses between each of the rings.

The cuckoo uses the BEEP command. This command, as on the Spectrum, does not use the sound chip at all, but the ASIC to generate the sound.

The subroutine at line 1000 sets up control data for the output subroutine at line 1500. Variables L and R set up which direction to go when 'ramping' the volume up or down on either channel, whilst the subroutine at line 1500 does the ramping itself. Register 2 is the amplitude register which controls the sound. It is also here, on line 1550 that P is used to control the speed of the movement across the stereo field.

The subroutine at line 2000 holds the register data, and actually acts upon the data presented to the chip. Its function is to output any information to the various registers as it receives the data.

The subroutine at line 3000 clears the sound chip by setting all registers to zero.

- GRAPHICS SCALING SYSTEM -

XOS, XRG,
YOS, YRG

Control graphics scale and origin. XOS and YOS are offsets added to x and y coordinates when graphics commands are used. They allow the origin to be moved from the normal position just above the editing area, on the left. RUN or CLEAR resets XOS and YOS to zero; LET alters them. XRG and YRG alter the scale of the graphics system. XRG is normally 256, or 512 if 'thin' pixels are in use. YRG is normally 192. Altering XRG to, say, 1024 would make PLOT 950,100 a legal command by doing 256/1024*950 before plotting the pixel on the screen. (Altering the ranges by powers of 2 gives faster plotting).

Normally, modes 2 and 4, and mode 3 if 'fat' pixels are used, have a graphics coordinate system with 0,0 just above the bottom editing section, at the left, and 255, 173 at the top right.

If thin' pixels are in use, the normal X is expanded so that top right is 511,173. In mode 1, the default character height is 8 pixels, rather than 9, and 2 less scans are used by the editing area, so that the top of the screen is at a Y coordinate of 175.

The bottom 2 lines of the display can be plotted on using:
PLOT 0,-10.

If the position of the origin is moved by LET XOS=-18 then 0,0 is at the very bottom left of the screen and 0,191 is the top left.

KEYWORD CODES

The Coupe's functions are stored in the program as FFH (255) followed by 3BH-83H.

Function	Dec	Hex	Function	Dec	Hex	Function	Dec	Hex
PI	59	3B	COS	84	54	VAL\$	109	6D
RND	60	3C	TAN	85	55	VAL	110	6E
POINT	61	3D	ASN	86	56	TRUNC\$	111	6F
FREE	62	3E	ACS	87	57	CHR\$	112	70
LENGTH	63	3F	ATN	88	58	STR\$	113	71
ITEM	64	40	LN	89	59	BIN\$	114	72
ATTR	65	41	EXP	90	5A	HEX\$	115	73
FN	66	42	ABS	91	5B	USR\$	116	74
BIN	67	43	SGN	92	5C	Reserved	117	75
XMOUSE	68	44	SQR	93	5D	NOT	118	76
YHOUSE	69	45	INT	94	5E	Reserved	119	77
XPEN	70	46	USR	95	5F	Reserved	120	78
YPEN	71	47	IN	96	60	Reserved	121	79
RAMTOP	72	48	PEEK	97	61	MOD	122	7A
Reserved	73	49	LPEEK	98	62	DIV	123	7B
INSTR	74	4A	DVAR	99	63	BOR	124	7C
INKEY\$	75	4B	SVAR	100	64	Reserved	125	7D
SCREEN\$	76	4C	BUTTON	101	65	BAND	126	7E
MEM\$	77	4D	EOF	102	66	OR	127	7F
Reserved	78	4E	PTR	103	67	AND	128	80
PATH\$	79	4F	Reserved	104	68	<>	129	81
STRING\$	80	50	UDG	105	69	<=	130	82
Reserved	81	51	Reserved	106	6A	>=	131	83
Reserved	82	52	LEN	107	6B	Reserved	132	84
SIN	83	53	CODE	108	6C			

Codes from 85H to FEH do not need a preceding FFH; they are single-byte compressed forms of keywords. Context allows them to appear as keywords or as UDGs, as appropriate. For example, they will appear as keywords in a listing, unless inside quotes, but will appear as UDGs when PRINTED.

The tokens from 85H to 8FH are qualifiers - they have no result or action on their own, but simply modify the action at other commands. (This does not prevent an action routine being assigned to them. The DOS, for example, provides an action routine for WRITE).

Token	Dec	Hex	Token	Dec	Hex	Token	Dec	Hex
USING	133	85	OFF	137	89	THEN	141	8D
WRITE	134	86	WHILE	138	8A	TO	142	8E
AT	135	87	UNTIL	139	8B	STEP	143	8
TAB	136	88	LINE	140	8C			

The tokens from 90H-FFH are commands. The command address table (see System variables - CMDADDRT) contains a 2-byte address for each of them, starting with DIR. This is the address that handles the syntax checking and run-time action for the command.

Command	Dec	Hex	Command	Dec	Hex	Command	Dec	Hex
DIR	144	90	REM	183	B7	ON	222	DE
FORMAT	145	91	READ	184	B8	GET	223	DF
ERASE	146	92	DATA	185	B9	OUT	224	EO
MOVE	147	93	RESTORE	186	BA	POKE	225	E1
SAVE	148	94	PRINT	187	BB	DPOKE	226	E2
LOAD	149	95	LPRINT	188	BC	RENAME	227	E3
MERGE	150	96	LIST	189	BD	CALL	228	E4
VERIFY	151	97	LLIST	190	BE	ROLL	229	E5
OPEN	152	98	DUMP	191	BF	SCROLL	230	E6
CLOSE	153	99	FOR	192	C0	SCREEN	231	E7
CIRCLE	154	9A	NEXT	193	C1	DISPLAY	232	E8
PLOT	155	9B	PAUSE	194	C2	BOOT	233	E9
LET	156	9C	DRAW	195	C3	LABEL	234	EA
BLITZ	157	9D	DEFAULT	196	C4	FILL	235	EB
BORDER	158	9E	DIM	197	C5	WINDOW	236	EC
CLS	159	9F	INPUT	198	C6	AUTO	237	ED
PALETTE	160	AO	RANDOMIZE	199	C7	POP	238	EE
PEN	161	A1	DEF FN	200	C8	RECORD	239	EF
PAPER	162	A2	DEF KEYCODE	201	C9	DEVICE	240	F0
FLASH	163	A3	DEF PROC	202	CA	PROTECT	241	F1
BRIGHT	164	A4	END PROC	203	CB	HIDE	242	F2
INVERSE	165	A5	RENUM	204	CC	ZAP	243	F3
OVER	166	A6	DELETE	205	CD	POW	244	F4
FATPIX	167	A7	REF	206	CE	BOOM	245	F5
CSIZE	168	A8	COPY	207	CF	ZOOM	246	F6
BLOCKS	169	A9	Reserved	208	D0	Reserved	247	F7
MODE	170	AA	KEYIN	209	D1	Reserved	248	F8
GRAB	171	AH	LOCAL	210	D2	Reserved	249	F9
PUT	172	AC	LOOP IF	211	D3	Reserved	250	FA
BEEP	173	AD	DO	212	D4	Reserved	251	FB
SOUND	174	AE	LOOP	213	D5	Reserved	252	FC
NEW	175	AF	EXIT IF	214	D6	Reserved	253	FD
RUN	176	B0	long IF	215	D7	Reserved	254	FE
STOP	177	B1	short IF	216	D8	Not usable	255	FF
CONTINUE	178	B2	long ELSE	217	D9	(function prefix)		
CLEAR	179	B3	short ELSE	218	DA			
GO TO	180	B4	END IF	219	DB			
GO SUB	181	B5	KEY	220	DC			
RETURN	182	B6	ON ERROR	221	DD			

Certain new keywords will be implemented in a disk-based extended Basic, and these words should not be used in Basic programs as procedure or variable names, or subsequent editing of the program will be inconvenient (although ALTER is a search-and-replace, so you could change every use of, for example, procedure SORT to SORTER, which would be okay). A provisional list of new keywords follows:

SORT, ALTER, USING\$, SHIFT\$, INARRAY, NUMBER, CHAR\$, JOIN.

SYSTEM VARIABLES

Note: The function SVAR N gives the result 5A00H+N.

LNCUR	5A00H	Cursor character for current line (usually '>').
LCCUR	5A01H	Cursor character when caps lock is off (usually CHR\$ 128).
UCCUR	5A02H	Cursor character when caps lock is on (usually CHR\$ 129).
BIN1DIG	5A03H	Character used by BIN\$ as "1" (usually "1").
BIN0DIG	5A04H	Character used by BIN\$ as "0" (usually "0").
INSTHASH	5A05H	Character used by INSTR as "match anything" character (usually CHR\$ 35 "#").
SLDEV	5A06H	Current device letter (usually "T" on a tape system, but can be "D", or "N").
SELNUM	5A07H	Current tape save speed, or default drive number when a disk drive is in use.
SPEEDINK	5A08H	Time between swaps of alternate PENs, in 50ths. of a second.
LINIPTR	5A09H	(2) Current position in line interrupt palette change table.
XCMDP	5A0BH	(3) Page/offset of first external command list, or FFxxxxH.
PRRHS	5A0EH	Printer right-hand column limit. (Usually 79, to give 80 columns; use 255 to give no limit)
AFTERCR	5A0FH	Character code sent to the printer after CHR\$ 13 if channel "p" is in use. (Normally 10, to give automatic line feed. Use a value of 0 if no character is to be sent).
LPTPRT1	5A10H	(2) Printer control port/01H strobe value. The port is usually 233, with port 232 (one less) used for data. The second byte should always be 1.

The following system variables are only used when the screen dump utility has been loaded:

DMPLEN	5A12H	Graphic dump length (in 8-pixel units; normally 22)
DMPWID	5A13H	Graphic dump width (in 8-fat pixel units; normally 32)
DMPWM	5A14H	Graphic dump width multiplier (1 for normal width, 2 or 3 for double or triple width).
DMPHM	5A15H	graphic dump height multiplier (1 for normal height, not 1 for double height).
GCM1	5A17H	Initial message sent to printers before a dump. The first byte is the number of characters to send. The normal values are 6,27,108,8,27,51,24,0,0 (2 bytes are spare).
GCM2	5A1FH	Message sent to printers before each row is dumped. The first byte is the number of characters to send. The normal values are 5,13,10,27,42,4,0,0 (2 bytes are spare).

GCM3	5A27H	Final message sent to printers after a dump. The first byte is the number of characters to send. The normal values are 4,13,10,27,64,0 (1 byte is spare).
DMPTL	5A2DH	(2) Address in screen of top left corner for graphic dumps. (Usually 8000H).

(End of system variables used by dump utility).

TABVAR	5A2FH	Zero for the print comma to tab by 16 columns (normal) or anything else for an 8-column tab.
M23LSC	5A30H	(2) Mode 3/4 lower screen colours. The first byte is PAPER*16+PAPER, the second is PEN*16+PEN, i.e. both nibbles in each byte match.
SOFE	5A32H	Flag for screen off enable/disable. If it is zero (normal) the screen will go blank in modes 3 and 4 when the keyboard has not been used for 22 minutes. Use a 1 to disable.
TPROMPTS	5A33H	Bit 0=1 to suppress printing of file names during tape loading; bit 1=1 to suppress prompts during tape saving.

This is the start of a block of variables saved with a screen when it is no longer the current screen.

BGFLG	5A34H	Block graphics flag. Zero if BLOCKS 1, 1 if BLOCKS0.
FL6OR8	5A35H	Zero if MODE 3 is using 6-pixel wide characters, otherwise non-zero.
CSIZEH	5A36H	Character height set by CSIZE command.
CSIZEW	5A37H	Character width set by CSIZE command.
UWRHS	5A38H	Upper window right-hand column. Starts at 31.
UWLHS	5A39E	Upper window left-hand column. Starts at 0.
UWTOP	5A3AH	Upper window top row. starts at 0.
UWBOT	5A3BH	Upper window bottom row. starts at 18.
LWRHS	5A3CH	Lower window right-hand column. Starts at 31.
LWLHS	5A3DH	Lower window left-hand column. Starts at 0.
LWTOP	5A3EH	Lower window top row. Starts at 19.
LWBOT	5A3FH	Lower window bottom row. Starts at 20.
MODE	5A40H	MODE of current screen. 0-3 for modes 1-4.
YCOORD	5A41H	Current graphics position y coordinate, with 0 at the top of the screen and 191 at the bottom.
XCOORD	5A42H	(2) current graphics position x coordinate, with 0 at the left. The range is 0-255 unless "thin" pixels are in use (in which case the second byte is used and the range is 0-511).

The following are the "permanent" graphics/print variables, set by, for example, PEN 2, PAPER 4, OVER 1.

THFATP	5A44H	Zero if "thin" pixels in use, non-zero for "fat" pixels.
ATTRP	5A45H	Attributes used by modes 1 and 2.

MASKP	5A46H	Mask used by modes 1 and 2. Bits which are 1 make the corresponding attribute bit be taken from the screen, not ATTRP.
PFLAGP	5A47H	Bit 4 is set for paper 9, bit 6 for pen 9
M23PAPP	5A48H	Mode 3/4 PAPER. Nibbles (mode 4) or double bits (mode 3) match unless striped paper is desired.
M23INKP	5A49H	Mode 3/4 PEN. Nibbles (mode 4) or double bits (mode 3) match unless a striped pen is desired.
OVERP	5A4AH	OVER status for printing. 0 for OVER 0, 1 for OVER 1 (XOR).
INVERP	5A4BH	0 for INVERSE 0, 255 for INVERSE 1.
GOVERP	5A4CH	OVER status for graphics. 0-3 for normal, XOR, OR, AND.

Temporary graphics/print variables, set by, for example:

PRINT PEN 3; PAPER 5;

They are temporary versions of the variables listed above.

THFATT	5A4DH	copied from thfatp when Mode=2, else set to not zero (fat)
ATTRT	5A4EH	
MASKT	5A4FH	
PFLAGT	5A50H	
M23PAPT	5A51H	
M23INKT	5A52H	
OVERT	5353H	
INVERT	5A54H	
GOVERT	5A55H	

Current window variables, copied from UWRHS etc. or LWRHS etc. according to which window is in use.

WINDRHS	5A56H
WINDLRS	5A57H
WXNDTOP	5A58H
WINDBOT	5A59H

The next three variables are at 5AB1H, 5B70H and 5B71H in version 1.0 ROMs.

WINDMAX	5A5AH	(2) Upper window lowest bottom row/maximum right column. Used to limit the WINDOW command. Reset by the MODE command.
ORGOFF	5A5CH	Graphics origin offset from the screen bottom, in pixels.
LSOFF	5A5DH	Size of gap between upper and lower windows, in scan lines MOD CSIZEH.
Reserved	5A5EH	(14)
SPOSNU	5A6CH	(2) Upper window position as column/row.
SPOSNL	5A6EH	(2) Lower window position as column/row.

(End of block saved with a deselected screen).

PRPOSN	5A70H	Current printer column.
Reserved	5371H	
OPCHAR	5A72H	Used by LPRINT - character being printed.

DEVICE	5A73H	0=upper window, 1=lower window, 2=printer, 3=other
CLET	5A74H	Current channel letter K/S/P/B/T/\$ etc.
IFTYPE	5A75H	Long/short IF status.
REFFLG	5A76H	Zero if a REF variable is being worked on.
CURDISP	5A77H	Current display, set by the DISPLAY command.
CUSCRNP	5A78H	Current screen page. Bit 7=0, bits 6 and 5=MODE (0-3) and bits 4-0=page number. Set by SCREEN command.
CURP	5A79H	Current upper RAM port. (Temporary store during paging).
CLRP	5A7AH	Current lower RAM port. (Temporary store during paging).
CSA	5A7BH	(2) Current statement address. Used by DOS.
FIRST	5A7DH	(2)
LAST	5A7FH	(2) Line numbers in, for example, LIST 20 TO 100.

The following variables point to the main sections of Basic's memory area. They are adjusted when space is made or reclaimed, as needed. In each set of three bytes, the first byte is the RAM page number (0-31) and the other two bytes are the offset in the page, plus 8000H. (In some circumstances the offset is allowed to be greater than 16K, but it is always less than 32K).

SAVARSP	5A81H	
SAVARS	5A82H	(2) String and array variables start
NUMENDP	5A84H	
NUMEND	5A85H	(2) Numeric variables end
NVARSP	5A87H	
NVARS	5A88H	(2) Numeric variables start
DATADDP	5A8AH	
DATADD	5A8BH	(2) Data address used by READ command.
WKENDP	5A8DH	
WKEND	5A8EH	(2) End of workspace. (Last used byte before RAMTOP).
WORKSPP	5A90H	
WORKSP	5A91H	(2) workspace start.
ELINEP	5A93H	
ELINE	5A94H	(2) Edit line start.
CHADP	5A95H	
CHAD	5A97H	(2) Current character address.
KCURP	5A99H	
KCUR	5A9AH	(2) Address of cursor in the edit line.
NXTLINEP	5A9CH	
NXTLINE	5A9DH	(2) Address of next line in Basic program.
PROGP	5A9FH	

PROG	5AA0H	(2) Program start (address of line number of first line).
XPTRP	5AA2H	
XPTR	5AA3H	(2) Address in the edit line of a syntax error.
DESTP	5AA5H	
DEST	5AA6H	(2) Used in variable assignments.
PRPTRP	5AA8H	
PRPTR	5AA9H	(2) Address of current procedure call.
DPPTRP	5AABH	
DPPTR	5AACH	(2) Address of current DEF PROC statement.
CLAPG	5AAEH	
CIA	5AAFH	(2) Address of start of current line.
Reserved	5AB1H	
STRNO	5AB2H	Current stream number. used by DOS.
LDCO	5AB3H	Offset when loading spectrum machine code (16K pages).
Reserved	5AB4H	
OPSTORE	5AB5H	(2) Temporary store for print output address.
DMPFLG	5AB7H	If non-zero, printed characters are "thrown away".
LISTFLG	5AB8H	0/1/2 for LIST FORMAT 0/1/2.
LSTFT	5AB9H	Temporary version of LISTFLG used by channel 'R'.
INQUFG	5ABAH	"In quotes" flag. Bit 0=1 if character being printed is inside quotes. LIST zeros this bit so initial state is "outside" and tokens are printed, except inside quotes. PRINT sets it to 1 so UDGs are printed instead of tokens.
SPROMPT	5ABBH	If non-Zero no "scroll?" prompts are given.

The next six variables are used by the indented listing routine.

OLDSPCS	5ABCH	Indent status of previous line.
INDOPFG	5ABDE	Flag.
NXTSPCS	5ABEH	
CURSPCS	5ABFH	
NXTHSPCS	5AC0H	
CURTHSPCS	5AC1H	
KPOS	5AC2H	(2) Screen position of editing cursor.
SOFFCT	5AC4H	Counter used by auto-screen off. Changes every 256 frames if the keyboard is not in use.
SOFLG	5AC5H	Flag for screen has been turned off" (if non-zero).
SPEEDIC	5AC6H	Counter for flashing inks.
PALFLAG	5AC7H	Bit 0 shows which palette table in use, main or alternate.

Temporary stores:

TEMPW1	53C8H	(2)
TEMPW2	5ACAH	(2)
TEMPW3	5ACCH	(2)
TEMPB1	5ACEH	
TEMPB2	5ACFH	
TEMPB3	5AD0H	
LASTSTAT	5AD1H	Status port value on last interrupt.
SPSTORE	5AD2H	(2) stack pointer store used by maskable interrupts.
JVSP	5AD5H	(2) JSVIN stack pointer store.
NMISP	5AD7H	(2) Non-maskable interrupt stack pointer store.
NMILRP	5AD9H	(1) LMPR value when NMI occurred.

Vectors (see detailed description elsewhere).

DMPV	5ADAH	(2) Screen dump.
SETIYV	5ADCH	(2) Set IY register to pixel output routine.
PRTOKV	5ADEH	(2) Print a token.
NMIV	5AE0H	(2) Non-maskable interrupt.
FRAMIV	5AE2H	(2) Frame interrupt.
LINIV	5AE4H	(2) Line interrupt.
COMSV	5AE6H	(2) Comms interrupt.
MIPV	5AE8H	(2) MIDI input interrupt.
MOPV	5AEA	(2) MIDI output interrupt.
EDITV	5AEC	(2) Editor.
RST8V	5AEE	(2) RST 08H (error handler).
RST28V	5AF0H	(2) RST 28H (floating point calculator).
RST30V	5AF2H	(2) RST 30H (user RST).
CMDV	5AF4H	(2) Command.
EVALUV	5AF6H	(2) Expression evaluator.
LPRTV	5AF8H	(2) Printer.
MTOFCV	5AFAH	(2) Match token.
MOUSV	5AFCH	(2) Mouse.
KURV	5AFEH	(2) Edit cursor.

Tables used by MODE 3 and 4 to expand character pattern data (as stored in UDGs, for example), to a form suitable for placing on the screen. In MODE 3 each table holds 16 bytes (expanded versions of each possible nibble) while in MODE 4 each table holds 16 words (expanded versions of each nibble).

CEXTAB	5B00H	(32) Coloured expansion table - current PEN, PAPER and INVERSE state are used to modify this data.
EXTAB	5B20H	(32) Uncoloured expansion table. E.g. in MODE 3 or 4, the nibble 1010b is expanded to 11001100b or 1111000011110000b.
COMPFLG	5B40H	Flag bits used by LABEL/FN/PROC compiler.
BREARDI	5B41H	Non-zero if ESC between statements is to be disabled.
ERRSTAT	5B42H	Statement to go to ON ERROR.

ERRLN	5B43H	(2) line to go to ON ERROR.
ONERRFLG	5B45H	Bit 7=temporary ON ERROR active flag, bit 0 is permanent.
ONSTORE	5B46H	ON command's statement number.
BCSTORE	5B47H	(2) Used by RST 30H to hold BC register.
M3PAPP	5B49H	(2) used to bold MODE 4 PAPER and PEN when MODE 3 is used
M3LSC	5B4BH	(2) used to hold MODE 4 lower window colours when MODE 3 is in use.
TEMPW4	5B4DH	(2) Used by ADJUST POINTERS routine.
TEMPW5	5B4FH	(2) used by ADJUST POINTERS routine.
Reserved	5B51H	

Table used by the editor showing which screen lines have line numbers.

LPT	5B52H	(30)
Reserved	5B70H	(2)
RNSTKE	5B72H	(2) Rename stack pointer used by procedures with REF.
CURCHD	5B74H	Current Basic command.
LTDFD	5B75H	LET/DEFAULT flag.
STRMX6NN	5B76H	(11) Encoded type/length and name of the variable that stream 16 prints to. Set by RECORD TO command.
GRARF	5B81H	Graphics record flag (0=off).
DHADJ	5B82H	Double height adjust. Zero unless bottom of double-height character is being printed.
PACCOUNT	5B83H	Page counter used by FARLDIR and FARLDDR.
MODCOUNT	5B84H	(2) MOD 16K counter used by FARLDIR and FARLDDR.
ECREG	5B86H	(2) calculator's BC register.
AUTOFLO	5B88H	Zero if AUTO is off, else 1.
AUTOSTEP	5B89H	(2) AUTO command's step value.
LSPTR	5B8EH	(2) Line scan pointer used by the editor.
LNPTR	5B8DH	(1) Used by the editor.
MSEDP	5B8EH	(8) Used by the mouse as a data store.
BUTSTAT	5B8FH	Mouse button status.
MXCRD	5B96H	(2) Mouse x coordinate.
MYORD	5B98H	(2) Mouse y coordinate.

Used by the PRINT A NUMBER routine:

FRACLIM	5B9AH	
NPRPOS	5B9BH	(2)
DIGITS	5B9DR	
EPOWER	5B9EH	
DECPNTD	5B9FH	
PRNBUFF	5BA0H	(16) ASCII form of number.
BCDBUFF	5BBOH	(5)
OTHER	5BB5H	Net destination station number.
Reserved	5BB6H	
SLDEVT	5BB7H	Temporary device letter (usually copied from SLDEV).

SLNUMT	5BB8H	Temporary device number (usually copied from SLNUM).
OVERF	5BB9H	"SAVE OVER" flag used by DOS. Zero if SAVE OVER, else non-zero.
INSLV	BBBAH	(2) Block move vector.
STRLOCN	5BBCH	(2) Used by LOOK FOR A STRING/ARRAY VARIABLE routine.
TVDATA	5BBEH	(2) Used in handling control codes and their parameters.
DOSER	5BC0H	(2) If address is non-zero, DOS jumps there on exit.
DOSFLG	5BC2H	Zero if no DOS loaded, else page number containing DOS.
DOSCNT	5BC3H	Bit 0 is set if DOS is in control of the system.
BSTKEND	5BC4H	(2) End of Basic's stack (used by DO, GOSUB, procedures).
BASSTK	5BC4H	(2) Start of Basic's stack.
HEAPEND	5BC6H	(2) End of system heap.
HPST	5BC7H	(2) Start of system heap.
FPSBOT	5BCAH	(2) Start of floating point calculator stack.
DKDEF	5BDCH	(2) Start of KEYCODE definitions.
DKLIM	5BD0H	(2) Limit address of KEYCODE buffer.
PATOUT	5BD2H	(2) Address of 'printable characters' output routine.
ERRMSG	5BD4H	(2) Start of error message table.
UMSGS	5BD6H	(2) Start of utility message table.
KBTAB	5BD8H	(2) start of keyboard table.
CMDADDR	5BDAH	(2) Start of command address table.
MNOP	5BDCH	(2) Address of main output routine.
MNIP	5BDEH	(2) Address of main input routine.
PAGER	5BE0H	(14) Reserved for paging subroutine.
KBUFF	5BEEH	(18) Keyboard scan table - 2 tables of 72 bits each.
LEM1	5C00H	Used by keyscan
LASTH	5C01H	Last key hit. Zero if no key. Stops changing if keys are not being read, when buffer fills. RES 5,(FLAGS) is seen as a read. Used by keyscan.
KDATA	5C02H	Used by keyscan.
LKPB	5C03H	(2)
REPCT	5C05H	Used by keyscan.
LASTKV	5C06H	(2) shift and key codes from last key press.
KBHEAD	5C08H	Key from buffer queue head. Keeps last key value. Needs periodic resets of bit 5,(FLAGS) or buffer fills.
REPDEL	5C09H	Delay before keys auto-repeat (in 50ths. of a second); normally 33.
REPSPD	5C0AH	Delay between key repeats (in 50ths. of a second); normally 3.
Reserved	5C0BH	

STREAMS	5C0CH	(42) For streams -5 to 15, a word gives the displacement from the start of the channels area to the assigned channel. If the word is zero, the stream is closed. Stream 16 is dealt with as stream -4.
CHARS	5C36H	(2) Address 256 bytes below start of main character set.
ERRSOUND	5C38H	Length of error sound in 50ths. of a second; normally 60.
CLICK	5C39H	Length of keyboard click (normally zero).
ERRNR	5C3AH	Error number.
FLAGS	503BH	Main flags byte.
DFLAG	503CH	Display flags.
ERRSP	5C3DH	(2) SP value to use when an error occurs.
LISTSP	5C3FH	(2) SP value to use when an automatic list fills the screen.
Reserved	5C41H	
NEWPPC	5C42H	(2) New line to jump to.
NSPPC	5C44H	New statement to jump to, or FFH.
PPC	5C45H	(2) Current line number during program execution.
SUBPPC	5C47H	Current statement number.
BORDCR	5C48H	Attributes for lower screen in MODEs 1 and 2.
EPPC	5C49H	(2) Number of line with > cursor.
BORDCOL	5C4BH	Value to send to border port.
CHANS	5C4FH	(2) start of channels area.
CURCHL	5C51H	(2) start of current channel.
DEFADDP	5C53H	DEF FN address (page).
DEFADD	5C54H	(2) DEF FN address (offset)
Reserved	5C56H	(15)
STKEND	5C65H	(2) End of floating point calculator stack.
KPFLG	5C67H	Function keys if even, number pad if odd.
MEN	5C68H	(2) Start of calculator's memory area.
KLFLAG	5C6AH	8 if caps lock is on, else zero.
SDTOP	5C6CH	Line number of top line in an automatic listing.
COPPC	5C6EH	Line number that CONTINUE goes to.
COSPPC	5C70H	statement number that CONTINUE goes to.
FLAGE	5C71H	Flags used by INPUT command and the editor.
STRIL	5C72H	Used when variables are assigned to.
SEED	5C76H	Random number seed. Set by RANDOMIZE.
FRAMES	5C78H	(3) Frames since machine was switched on (LSB first).
UDG	5C7BH	(2) Address of CHR\$ 144.
HUDG	5C7DH	(2) Address of CHR\$ 169 (initially undefined).
FRAMES34	5C7FH	(2) 2 more bytes of FRAMES counter.
OLDPOS	5C82H	Used by editor in clearing lower window.
SCRCT	5C8CH	Counter used to give "scroll?" prompt.
KBQB	5C8DH	(8) Keyboard queue. At 5A5AH in v1.0 ROM.
KBQP	5C95H	(2) Keyboard queue end/head pointers. At 5A6AH in v1.0 ROM.
Reserved	5C97H	(6)
SCPTR	5C9DH	(2) Address in SCLIST at current screen's entry.
FISCRNP	5C9FH	Page of screen 1.

SCLIST	5CA0H	(16) Screens list. MODE/page of screens 1-16, or FFH if screen is closed. Bits 6 and 5=MOFLE, 4-0=page.
LASTPAGE	5CB0H	last page reserved by Basic. set by OPEN, OPEN TO or CLOSE.
RAMTOPP	5CB1H	Page of RAMTOP.
RAMTOP	5CB2H	(2) Offset of RAMTOP.
PRAMTP	5CB4H	Last 16K page physically present in machine.

VARIABLE FORMATS

The Coupe has five main variable types:

- Numeric variables
- FOR-NEXT variables
- Strings
- String arrays
- Numeric arrays

Numeric variables and FOR-NEXT variables are kept in the area pointed to by NVARs and NVARSP. This area begins with 26 2-byte entries, which hold the offset to the first variable starting with a given letter (from A-Z - hence 26 entries). If the offset is FFFFH, there are no variables starting with this letter. For each numeric variable, the start of the variable has this form:

Type/name length byte, offset LSB, MSB, character1, character2...

The type/length byte stores the name length-1 in bits 4-0 (so names can be up to 32 characters long}. Bit 5 is set if the variable is no longer in use, bit 6 is set for a FOR-NEXT variable and bit 7 is set if the variable is "hidden" (this is used by procedures to implement LOCAL variables). The offset is the distance to move from the MSB of the current offset to the type/length byte of the next variable starting with the same letter, or FFFFH if there are no more such variables. There may be from zero to 31 characters after the offset, forced to lower case if they are letters, and excluding spaces.

After this come five bytes to hold the value of the variable. (See the section on the floating point calculator for information on the makeup of these 5 bytes). If it is an ordinary numeric variable, there is just a value, but a FOR-NEXT variable has an additional 14 bytes; the complete format is:

VALUE (5): LIMIT (5): STEP (5): LOOP ADDRESS (3): STATEMENT (1)

The loop address is the page and offset (8000-BFFFH) of the start of the line to loop back to, and the statement is the number of the statement within that line to loop back to (loops to the first statement are thus the fastest).

Strings and arrays are kept in the area pointed to by SAVARS and SAVARSP. There is a buffer zone between the numeric and string/array variables, so that creation of a new numeric variable does not usually require the strings and arrays to be moved.

Variables in this area are in the order of their creation (by DIM or LET; LET a\$=aS will move aS to the end of the area, unless a\$ is an array). For each variable, the format is as follows:

Type/length byte, character1....character10, length (3)

The type/length byte holds the name length (1-10) in bits 4-0. Bit 6 is set for string arrays, bit 5 is set for numeric arrays, and both bits are reset for ordinary strings. Bit 7 is set if the variable is "hidden". Ten bytes of space follow to hold the variable name; unused bytes are undefined. The length is given as number of 16K pages, then length MOD 16K (LSB/MSB), for the rest of the array plus the 3 length bytes. For strings, the text of the string follows; for arrays, the next byte is the number of dimensions, followed by the length of dimension 1, dimension 2, etc. (2 bytes for each dimension). The array data then follows, all data with a first subscript of 1 being first, then the data with a first subscript of 2, etc. FFH terminates the list of string and array variables.

- FORMAT OF A BASIC PROGRAM -

The first line of a program is pointed to by PROG and PROGP (offset 8000-BFFFH and page). Each line has the format:

LINE NUMBER (MSB/LSB): LINE LENGTH (LSB/MSB): TEXT: ODH

Note that the line number is unusual in being stored most significant byte first. The line length is the length of the text and ODH terminator. The line text contains compressed keywords (see keyword code table) and invisible forms of all literal numbers (decimal, binary and hexadecimal). The invisible forms are OEH followed by 5 bytes to store the value. The line may also contain control codes and their parameters.

The final line in the program is followed by FFH (so the maximum line number allowed is FEFFH).

SAM DISIC OPERATING SYSTEM

INTRODUCTION

SAMDOS has been designed specifically for the SAM Coupe computer. It is similar to G+DOS as used with the MGT Plus D spectrum disk interface.

- DISK DRIVE -

The internal SAM disk drive is a Citizen 3.5" slimline drive. Each drive is cased and fitted with the MGT disk controller interface, which utilises a VL-1772-02 floppy disk controller. By default the disks are formatted as double sided, 80 track per side, 10 sectors per track, to the IBM 3740 standard.

- DISK FORMAT -

We use 80 tracks per side, giving 160 tracks per disk. A track is made up of 10 data sectors, each giving 512 bytes of storage. The first 4 tracks of the disk are given up to the SAMDOS directory, leaving 156 tracks available for storage. This leaves available 1560 data sectors of 512 bytes (798720 bytes)

Although each data sector can hold 512 bytes, only 510 bytes of them are available for storage. The last two bytes of the data sector are used by the DOS to locate the next part of the file stored. Byte 511 holds the next track used by the file, while byte 512 holds the next sector.

DISK FILE HEADER

At the beginning of each disk file there is a file header. The file header is 9 bytes long:

	SAMDOS type	Plus D type
0	File type	File type
1-2	Modulo length	Length of file
3-4	Offset Start	start Address
5-6	Unused	
7	Number of pages	
8	starting page number	

Details of the Plus D header can be found in the technical information for the Plus D.

- FILE TYPE -

Each file type in the SAM00S is allocated a numeric identifier:

5	- ZX Snapshot file	SNP 48k
16	- SAM BASIC program	BAS
17	- Numeric array	D ARRAY
18	- String array	\$ ARRAY
19	- Code file	C
20	- Screen file	SCREEN\$

- MODULO LENGTH & NUMBER OF PAGES -

In the SAMDOS header the length of the file is calculated by multiplying the number of pages (byte 7) by 16384 and adding the modulo length (word 1-2), LSB/MSE, i.e. the length MOD 16K.

- OFFSET START & STARTING PAGE NUMBER -

Read starting page number (byte 8): AND this with 1FH to get the page number in the range 0 to 31. To find the start multiply the page number by 16384, add the offset, and subtract 4000H (since the ROM occupies 0-3FFFH).

When SAMDOS is paged in it resides at 4000H, and ROM0 is placed at 0-3FFFH.

- SAMDOS DIRECTORY -

The first 4 tracks of the disk are allocated to the disk directory, starting at track 0, sector 1. These 4 tracks give us 40 sectors each split into two 256 bytes entries. Each of these entries will identify one file, thus allowing up to 80 entries in the directory.

The format of each directory entry is as follows:

(The User Information File Area CUIFA) will be described later).

Byte	UIFA	Description
0	0	STATUS/FILE TYPE. This byte is allocated one of the file types listed previously, but is also used as a file status. If the byte is 0 then the file has been erased. If the file is HIDDEN then bit 7 is set. If the file is PROTECTED then bit 6 is set.
1-10	1-10	FILENAME. This filename can be up to 10 characters
11		MSB OF THE NUMBER OF SECTORS USED IN THE FILE.
12		LSB OF THE NUMBER OF SECTORS USED IN THE FILE.
13		TRACK NUMBER FOR START OF FILE
14		SECTOR NUMBER FOR START OF FILE
15-209		SECTOR ADDRESS MAP (195 BYTES) (detailed further on).
210-219		MGT FUTURE AND PAST (10 BYTES) These were used in the PLUS D directory but are not used by the SAMDOS. They are allocated to MGT for future use.
220	15	FLAGS (MGT USE ONLY)
221-231		FILE TYPE INFORMATION
	16-26	If the file type is 17 or 18 then these bytes contain the file type/length and name.
	16	If the file type is 20 then these bytes contain the screen mode.
	16-18	If the file type is 16 then these bytes contain the program length excluding variables.
	19-21	If the file type is 16 then these bytes contain the program length plus numeric variables.
	22-24	If the file type is 16 then these bytes contain the program length plus numeric variables and the gap length before string and array variables.
232-235	27-30	SPARE 4 BYTES (reserved).

236	31	START PAGE NUMBER, in bits 4-0, bits 7-5 are undefined.
237-238	32-33	PAGE OFFSET (8000-BFFFH). This is as per file header, although when the ROM passes a file to be saved it starts it in section C of the addressing map.
239	34	NUMBER OF PAGES IN LENGTH. (as per file header)
240-241	35-36	MODULO 0 TO 16383 LENGTH, i.e. length of file MOD 16384. (as per file header)
242-244	37-39	EXECUTION ADDRESS Execution Address, if CODE file, or line number if an auto-running BASIC program.
245-253	40-47	SPARE 8 BYTES
254-255		FOR FUTURE USE BY MGT ONLY.

- SECTOR ADDRESS MAP -

SAMDOS allocates 195 bytes to the sector address map, giving 1560 bits, which is the exact number of sectors available for storage on the drive.

A sector address map is calculated for each directory entry. when a file is created a directory entry is made for that file. A sector address map is created by setting the specific bit(s) corresponding to the sector(s) allocated to the file. (Bit 0 of the first byte is allocated to track 4 sector 1). For example, if the file uses 5 sectors then five corresponding bits in the sector address map are set and saved as part of the directory entry.

- BIT ADDRESS MAP (BAM) -

The bit address map is not stored on the disk by SAMDOS. It is generated by performing a bitwise OR of each file's sector address map. This then gives SAMDOS a usage map of the disk. When a file is created the first thing SAMDOS does is calculate the BAM, and then by looking at the available sectors (i.e. bits not set), it can work out if there is room for the file. If there is room for the file, then the directory entry is created, including the sector address map specific to the new file, and the file is stored in the sectors which have been specified in the file's sector address map.

SAMDOS INTERFACING

SAMDOS's machine code interface provides pointers to specific parts of the DOS, called hook codes. These pointers perform the DOS functions, e.g., SAVE, LOAD, VERIFY, etc.

To use these hook codes various registers in the Z80B must be set up for the subroutine called to perform the required tasks. Each hook code is described later in this manual together with the necessary register information.

When a hook code is used the ROM will page SAMDOS temporarily into section B of the 64K addressing space (ie at 400011):

```
RST 08H      ; call ROM RST 8
DEFB x       ; Where x equals the specific
              ; Hook code required.
```

If an error occurs it will normally be handled by the ROM, producing an error message in the lower part of the screen. However, if the system variable DOSER (5BC0H) is loaded with the address of your own 'return from DOS' routine then this routine will be entered after SAMDOS has executed any hook codes, or examined any of BASIC's error codes, with the Accumulator holding zero for no error, or an error number. This will be either one of BASIC's error codes or a SAMDOS error code of 128 and above.

- USER INFORMATION FILE AREA (UIFA) -

When using SAMDOS hook codes the calling program must set up an area in memory, pointed to by the IX register, which details the information required for file handling, e.g., SAVE and LOAD. This file is called the UIFA.

Byte	Description
0	STATUS/FILE TYPE.
1-14	FILENAME. 14 characters are allocated to allow for device identification, for example: D1:filenamexx. SAMDOS will strip off the device identifier, so the maximum length of a filename is still ten characters.
15	FLAGS
16-26	If the file type is 17 or 18 then these bytes contain the type/length byte and the name.
16	If the file type is 20 then this byte contains the screen mode.
16-18	If the file type is 16 then these bytes contain the program length excluding variables.
19-21	If the file type is 16 then these bytes contain the program length plus the numeric variables.
22-24	If the file type is 16 then these bytes contain the program length plus the numeric variables and the gap length before the character variables.
27-30	SPARE 4 BYTES (Reserved)
31	16K PACE NUMBER START
32-33	PAGE OFFSET (8000-BFFFH) LSB/MSB
34	NUMBER OF PAGES IN LENGTH

35-36 MODULO 0 TO 16383 LENGTH ie file length MOD 16384.
 37 EXECUTE PAGE NUMBER if applicable
 38-39 EXECUTE OFFSET (8000-BFFFH) LSB/MSB if applicable
 40-47 SPARE 8 BYTES (Comment Field)

When the DOS has used the UIFA and it wants to pass a UIFA back, eq, for confirmation of load by the calling program the DOS creates a Disk Information File Area (DIFA). Both the UIFA and DIFA are 48 bytes long. This confirmation DIFA is written to an area of memory 80 bytes above the user's specified UIFA.

- SAMDOS HOOK CODES -

SAMDOS provides the user with hook (command) codes which enable the machine code programmer to use SAMDOS's facilities without having to return to or call SAM BASIC.

If an error occurs, SAMDOS set the Carry flag and put an error number into the Accumulator. If no error occurs the Accumulator will equal zero.

The Hook Codes currently available are:

INIT	128	dec	Initialise and look for AUTO file
HGTHD	129	dec	Get file header
HLOAD	130	dec	Load file
HVERY	131	dec	Verify file
HSAVE	132	dec	Save file
HVAR	139	dec	Get address of DVAR
HOFLE	147	dec	Open a File
SBYT	148	dec	Save a byte
HWSAD	149	dec	Write a sector to the disk
HSVBK	150	dec	Save a block of data
CFSM	152	dec	Close file sector map
HGFLE	158	dec	Get a file from disk
LBYT	159	dec	Load a byte
HRSAD	160	dec	Read a sector from the disk
HLDBK	161	dec	Load a block of data from disk
REST	164	dec	Restore disk drive to track 0
PCAT	165	dec	Perform a directory listing
HERAZ	166	dec	Erase a file from disk

Provision has been made for further hook codes to be added to SAMDOS.

HOOK CODE EXPLANATIONS

When the hook code explanation refers to 'RPT', it refers to the pointer used internally by SAMDOS.

INIT	This routine looks for an AUTO file on the current disk, and initialises the DVARs.
HGTHD	Get file header. This routine should be called with IX pointing to the UIFA, which should contain the file type and filename required. When completed the complete file header will be transferred in DIFA form to IX+80 bytes.
HLOAD	Load file in UIFA pointed to by IX register. The C register contains the number of 16K pages used by the file, while DE must contain the length modulo 16K. The HL register pair must point to a destination between 8000H to BFFFH, while the destination page must be paged in using the HMPR register. These values can be obtained from the header loaded by HGTHD.
HVERY	Verify the memory to the file stored on the disk. Again the IX register must be a pointer to the file UIFA. Use as HLOAD, but verifies rather than loads.
HSAVE	Save the file whose UIFA is pointed to by the IX register. The UIFA must be a complete UIFA, including file length, etc.
HVAR	This routine calls the jump table thus unstacking the number following the DVAR into BC. The routine supplies the address of the DVAR by putting it onto the BASIC floating point calculator stack.
HOFLE	Open a file on the disk. ix roust point to the UIFA. The routine will create a sector address map, and save the header to the disk and reset pointer RPT.
SBYT	Save the byte in the Accumulator to the RAM pointed to by the pointer RPT. If the sector is full the data will be stored in the next sector pointed to by the sector address map.
HWSAD	D contains the track number, and E contains the sector number. The Accumulator holds the drive number (1 or 2). Writes the sector pointed to by the DE register pair. The Accumulator contains the drive number, while the HL register pair is the pointer to the source data which must be resident in the 64K address map.
HSVBK	Save a block of data to the disk where the DE register pair points to the start of the data, and the BC register pair holds the byte count.

CFSM	Close file sector map. This routine empties the RAM and copies the header area on to the directory, closes the file, then updates the directory.
HGFLE	Get a file from the disk. The IX register must point to the UIFA. The return is made with the first sector of the file loaded into RAM and RPT pointing to the first byte.
LBYT	Load the byte pointed to by RPT from RAM, place it in the Accumulator, and increment the RPT. When the sector has all been read then the next sector is loaded from the disk and the pointer adjusted.
HRSAD	D contains the track number, and E contains the sector number. The Accumulator holds the drive number (1 or 2}. Reads the sector pointed to by the DE register pair. The Accumulator contains the drive number, while the HL register pair is the pointer to the destination.
HLDBK	Load a block of data from the disk to the memory pointed to by DE with the block count in BC.
REST	Restore disk drive to track 0. The Accumulator holds the drive number , ie, 1 or 2.
PCAT	Perform a directory listing to current stream.
HERAZ	Erase a file from the disk. Register IX must point to the UIFA of the file to be erased.

- LOCATING SAMDOS -

When SAMDOS is loaded the ROM looks at its available memory and loads SAMDOS into the last free 16K page. The ROM uses the last two 16K pages for SCREEN 1, so SAMDOS usually loads into the third from last 16K page, but the page will be different if extra screens have been opened before SAMDOS is loaded. Address 5BC2H (SVAR 450) holds the page number used by SAMDOS, or zero if SAMDOS has not been loaded. PEEK SVAR 450*16384+16384 will give the start address of SAMDOS, When a DOS command is issued the DOS is loaded into section B (4000H) of the 64k addressing space, the command is performed, and the DOS is then paged out.

- SAMDOS ERROR CODES -

81	Nonsense in SAMDOS
82	Nonsense in SNOS (SAM Network operating system)
83	statement end error
84	Escape requested
85	TRK nnn SCT nnn error
86	Format TRK nnn lost
87	Check disk in drive
88	No BOOT file
89	Invalid file name
90	Invalid Station
91	Invalid device
92	variable not found
93	verify failed
94	Wrong file type
95	Merge error
96	Code error
97	Pupil set
98	Invalid code
99	Reading a write file
100	writing a read file
101	No AUTO file
102	Network off
103	No such drive
104	Disk is write protected
105	Not enough space
106	Directory full
107	File not found
108	End of file
109	file name used
110	No SAMDOS loaded
111	Stream used
112	Channel used



Stereo sound generator for sound effects and music synthesis

All the sophisticated application software in the world can't compensate for a home computer that communicates with its user in an unattractive or confusing way. To enhance present levels of visual and audio communication from computer to user, a stereo sound generator, SAA1099, and a 64-colour encoder, TEA2000 (Ref.1), have been developed, each giving software and hardware designers the scope to add more realism to their products.

The sound generator SAA1099 is described in this article. It can produce a wide variety of sound effects including simulations of musical instruments, and the sounds required for arcade/home-computer games. Whereas most integrated sound generators have only three frequency generators, the SAA1099 has six, and the tones from each can be mixed with several kinds of noise. Because there are six frequency generators, full musical chords (including the tonic) can be produced, and two chords (excluding tonics) can overlap. All musical notes in an 8-octave range can be produced. A stereo effect that can give width to scenes in video games is produced by duplicating the six sound components to form identical left and right-channel signals, weighting the signals of each channel, and combining them to form a stereo signal.

Besides the stereo sound facility, effects such as Doppler shifts can be imitated with a minimum of software control. Outside the home computer market, the SAA1099 can be used to good effect in model railways and cars, electronic musical instruments and audible alarms, to name just a few applications.

The SAA1099 readily interfaces with most 8-bit micro-controllers and requires only a simple filter to suppress any high-frequency components in the audio output. It has been designed in such a way that a minimum of external components are required. Table 1 gives additional data on the SAA1099; see also Refs 2 and 3.

TABLE 1
Brief data on the SAA1099 (all values are typical)

supply voltage	V_{DD}	5 V
supply current	I_{DD}	70 mA
reference current (pin 6)	I_{ref}	250 μ A
total power dissipation	P_{tot}	500 mW
external clock		8 MHz
data input		8-bit parallel (TTL-compatible)
output frequency range		31 Hz to 7.81 kHz (8 octaves)
output		pulse width modulated
operating ambient temperature range	T_{amb}	0 to +70 °C
package		18-pin plastic DIL

COMPLETE SOUND GENERATOR

Figure 1 shows a complete sound generating system. From an 8-bit wide data input from a microprocessor, the SAA1099 generates a variable-amplitude stereo analogue signal chopped at a rate of 62,5 kHz. A simple external low-pass filter suppresses the high frequency components of the output signal. The incoming data which shapes the spectrum of the audio output is multiplexed to simplify interfacing, the signal A0 being used to indicate whether the data is a register address, or data for the register. The A0 signal is used with the CS and WR signals to control the data transfers from the microprocessor to the SAA1099. These control signals are compatible with a wide range of microprocessors. In addition, for optimum interfacing with an SCN68000 series microprocessor, the SAA1099 has a DTACK output. All internal timing is derived from an external 8 MHz clock.

TABLE 2
Function of the A0 input

A0	data bus input								function
	D7	D6	D5	D4	D3	D2	D1	D0	
0	D7	D6	D5	D4	D3	D2	D1	D0	data for internal registers, see Table 3
1	X	X	X	X	A3	A2	A1	A0	internal register address, A3 is the MSB

X = don't care

Table 2 shows the function of the A0 input. When A0 = 1, the bus data indicates the address of the control register in the SAA1099 to be written and this address is loaded into the command register. The next data byte on the bus, which contains the control information for the register that has been addressed, is written to the register when A0 = 0. Once addressed, a control register can be updated without further addressing.

CIRCUIT DESCRIPTION

Frequency generators

The SAA1099, see Fig. 2, has six frequency generators each of which can generate 256 tones in each of eight octaves from 31 Hz to 7,81 kHz. Each generator can be switched on and off individually, making it possible to preselect a tone and to make it audible when required. To simplify the software, the frequency generators can be synchronized at start-up

and when changing frequencies, octaves and envelopes using the frequency reset bit, see 'Synchronization'. The outputs of frequency generators 0 and 3 can each control a noise generator while those of generators 1 and 4 can each control an envelope generator for creating special effects.

Table 3 gives the addresses and the bit allocation of the SAA1099's internal registers used to control the frequency generators and its other sound-generating circuitry.

Noise generators

Two noise generators each have a programmable output controlled by the contents of register 16 which determines whether the output is:

- software-controlled via frequency generator 0 or 3 (which then produce no tone). The 'colour' of the noise generated is derived from twice the frequency of the frequency generator output, i.e. from 61 Hz to 15,6 kHz.
- one of three pre-defined noises based on clock frequencies of 7,8 kHz, 15,6 kHz or 31,25 kHz. In this case, the output of noise generator 0 can be mixed with the outputs of frequency generators 0, 1 and 2, and the output of noise generator 1 can be mixed with the outputs of frequency generators 3, 4 and 5, see Fig. 2. For mixing, the amplitude of the tone is increased relative to that of the noise.

Noise/frequency mixers

The SAA1099 has six mixers, one per frequency generator, for mixing tones with noise. Dependent on the status of bits D0 to D5 of registers 14 and 15, each mixer can be set:

- to mix the noise and the tone
- to pass the tone only
- to pass the noise only
- to pass neither tone nor noise.

Amplitude controllers

The SAA1099 has six amplitude controllers used, for example, to create a stereo effect. Each controller duplicates the signal from one of the noise/frequency mixers to form left and right-channel components and assigns one of sixteen amplitudes set by the contents of the control registers 00 to 05 to each component. A stereo effect can be produced simply by varying the amplitude of each component. To move a sound from one channel to another requires, per tone, only one update of the contents of the appropriate amplitude register.

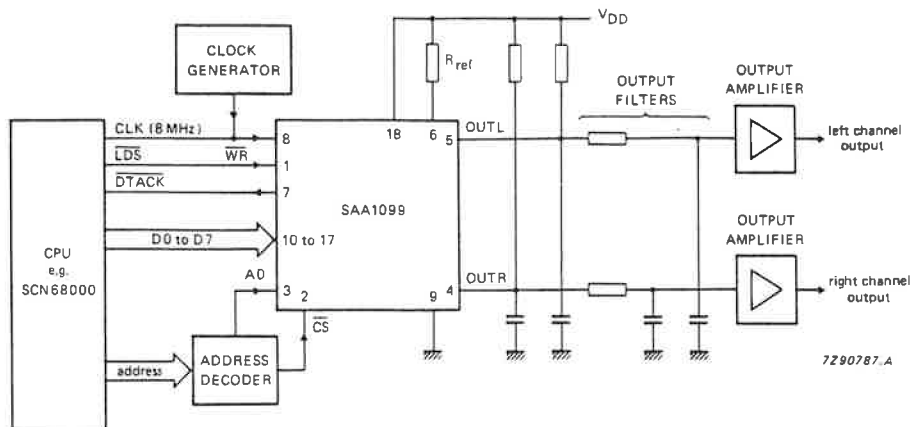


Fig.1 Sound generation system for home computers and video games equipment.

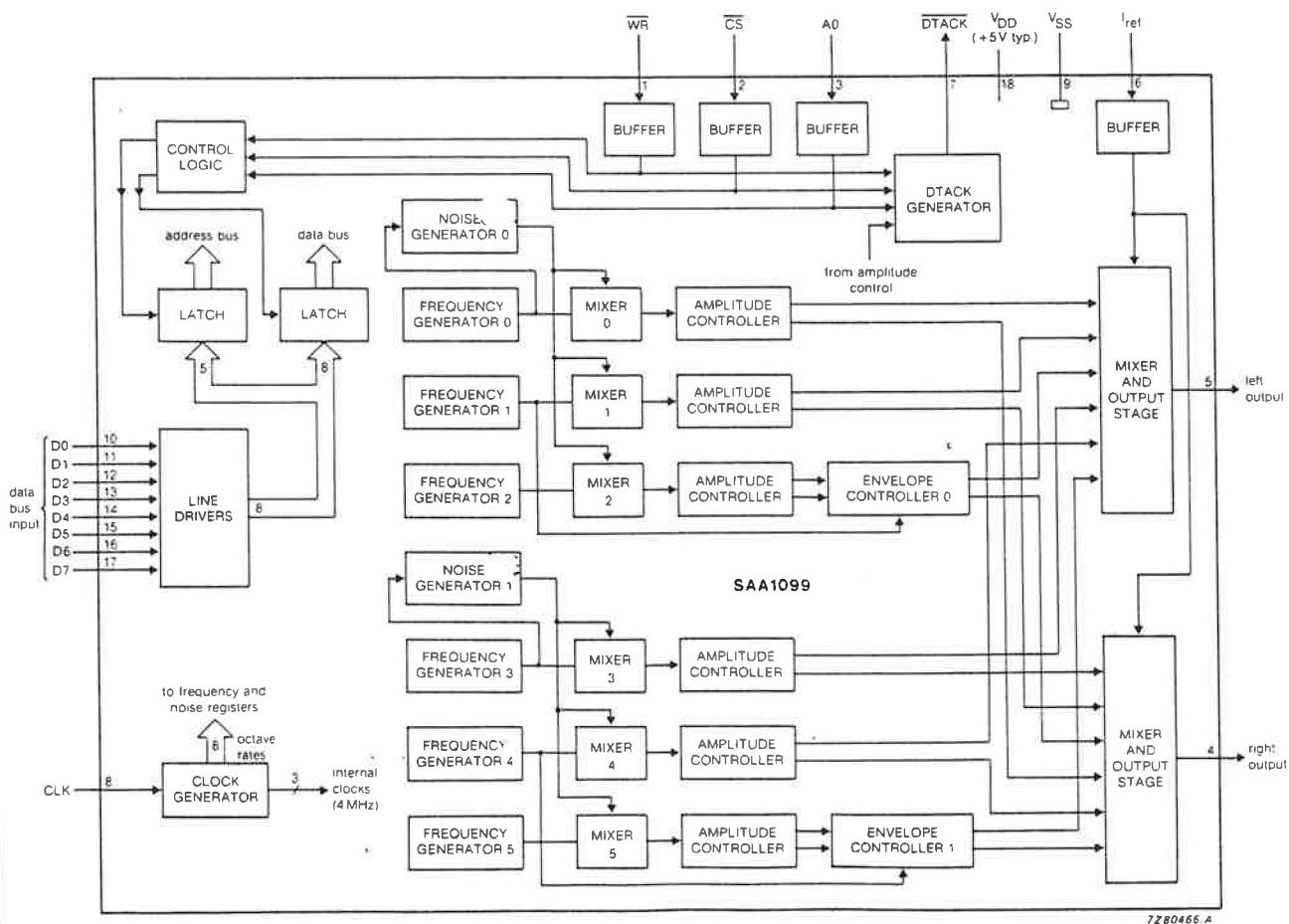


Fig.2 SAA1099 stereo sound generator.

TABLE 3
Bit allocation of the internal registers of the SAA1099; A0 = 1

register address	data bus input								description/remarks
	D7	D6	D5	D4	D3	D2	D1	D0	
	MSB							LSB	
00									controller 0
01									controller 1
02									controller 2
03									controller 3
04									controller 4
05									controller 5
06	X	X	X	X	X	X	X	X	reserved for possible expansion
07	X	X	X	X	X	X	X	X	reserved for possible expansion
08									tone number for frequency generator 0
09									tone number for frequency generator 1
0A									tone number for frequency generator 2
0B									tone number for frequency generator 3
0C									tone number for frequency generator 4
0D									tone number for frequency generator 5
0E	X	X	X	X	X	X	X	X	reserved for possible expansion
0F	X	X	X	X	X	X	X	X	reserved for possible expansion
10	X				X				$\text{frequency of tone (Hz)} = \frac{15625 \times 2^{\text{octave number}}}{(511 - \text{tone number})}$, see notes octave 0 (0 0 0): 31 Hz to 61 Hz; octave 1 (0 0 1): 61 Hz to 122 Hz octave 2 (0 1 0): 122 Hz to 244 Hz; octave 3 (0 1 1): 245 Hz to 488 Hz octave 4 (1 0 0): 489 Hz to 977 Hz; octave 5 (1 0 1): 978 Hz to 1,95 kHz octave 6 (1 1 0): 1,96 kHz to 3,91 kHz; octave 7 (1 1 1): 3,91 kHz to 7,81 kHz
11	X				X				
12	X				X				
13	X	X	X	X	X	X	X	X	
14	X	X	5	4	3	2	1	0	frequency enable (active-HIGH); 0 to 5 refer to the noise/frequency mixers
15	X	X	5	4	3	2	1	0	noise enable (active-HIGH); 0 to 5 refer to the noise/frequency mixers
16	X	X							noise generator clock frequency:
			0	0					31,25 kHz
			0	1					15,6 kHz
			1	0					7,8 kHz
			1	1					61 Hz to 15,6 kHz (freq. generator 0 or 3 controlling noise generator 0 or 1 respectively)
17	X	X	X	X	X	X	X	X	
18									see Table 4 and Fig. 3
19									see Table 4 and Fig. 3
1A	X	X	X	X	X	X	X	X	
1B	X	X	X	X	X	X	X	X	
1C	X	X	X	X	X	X	RST	SE	RST: reset for all freq. generators (active-HIGH); SE: sound enable for all channels (active-HIGH), see notes
1D	X	X	X	X	X	X	X	X	
1E	X	X	X	X	X	X	X	X	
1F	X	X	X	X	X	X	X	X	

This block of 32 registers is repeated eight times between addresses 00 and FF in the full internal memory map. All don't cares (X) should be written as zeroes.

Tone numbers of 1 to 256 are valid.

At power-on, the sound enable bit is set to 0 (all channels disabled). When the frequency reset bit is set, all frequency generators are reset and synchronized.

Envelope controllers

Two envelope controllers enable the left and the right components of two stereo channels to be modified for:

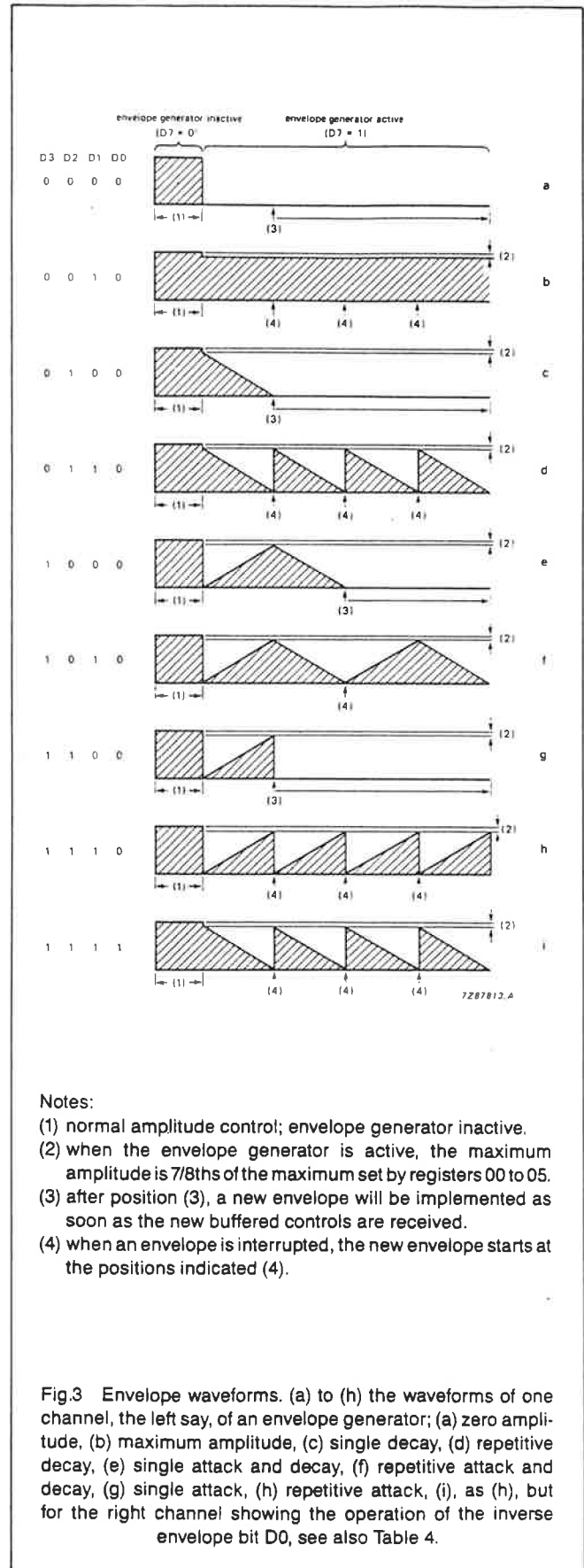
- single attack
- single decay
- single attack and decay (triangular)
- maximum amplitude
- repetitive attack
- repetitive decay
- repetitive attack and decay (triangular)
- zero amplitude.

Figure 3 shows the envelopes which are selected by bits D1 to D3 of the envelope registers 18 and 19, see Table 4. The repetition frequency of the envelopes can be software-controlled by writing to the envelope address register (the data written is irrelevant), or clocked internally at the output frequency of the frequency generator (1 or 4). An envelope will always be completed before a new envelope instruction is implemented. In the case of repetitive envelopes, the envelope returns to its starting level which may not necessarily be zero.

When the envelope facilities are used, and the maximum amplitude set by the contents of registers 00 to 05 is chosen, the amplitude is 7/8ths that normally available.

TABLE 4
Bit allocation of the envelope generator registers
(addr. 18 and 19)

bit	function
D0	
0	identical envelopes for the left and right channel components
1	inverse envelopes for the left and right channel components
D3 D2 D1	
0 0 0	zero amplitude
0 0 1	maximum amplitude
0 1 0	single decay
0 1 1	repetitive decay
1 0 0	single triangular
1 0 1	repetitive triangular
1 1 0	single attack
1 1 1	repetitive attack
D4	
0	4-bit envelope resolution
1	3-bit envelope resolution
D5	
0	internal envelope clock (frequency generator 1 or 4)
1	external envelope clock (address write pulse A0)
D6	don't care
D7	
0	reset (no envelope control)
1	envelope control enabled



Two types of envelope control are stored in the envelope registers — direct-acting controls and buffered controls. The direct-acting controls always take immediate effect and are:

- the envelope enable/reset (bit D7)
- the envelope resolution: 16 levels up to an envelope repetition frequency of 977 Hz, 8 levels above 977 Hz (bit D4).

The buffered controls are acted upon only at the times shown in Fig.3 and determine:

- the envelope waveform (bits D1 to D3)
- the type of envelope clock (bit D5)
- whether the left and right channels are inverted (bit D0).

When an external envelope clock is selected, an envelope is only created when address 18 or 19 is written to (that is when A0 is set to 1 and there is a 'write 18 or 19' command).

Six-channel mixers/output stages

The six components of the left channel are combined in a mixer. The output stage of the mixer contains six equally-weighted current sinks which provide a PWM output from which an analogue output is derived by low-pass filtering. An identical mixer is used to combine the components of the right channel.

SYNCHRONIZATION

To simplify the software writer's work, several synchronization functions are incorporated in the SAA1099. They affect:

- the starting of frequency generators
- the changing of frequencies and octaves
- the changing of envelopes.

Synchronizing frequency changes

The internal architecture of the SAA1099 is such that when a new tone in an octave different from that currently selected is required, the frequency register should be written to before the octave register. Failure to write to the registers in this order with the sound enabled, may produce a click in the audio output. The frequency and octave registers can, however, be written at any time, but data can only be acted upon by the SAA1099 on a transition of the associated frequency generator, that is, data won't be acted upon until half the period of the current frequency has elapsed. This means that:

- when the frequency and octave registers are set for the lowest frequency of 31 Hz, the new frequency data or octave data may not be acted upon for up to about 17 ms (half a period). Therefore, to ensure this interval has elapsed, a delay corresponding to half a period of the existing tone should be written in the software between writing the new frequency or octave and enabling the output.

- at the higher end of the spectrum, if it is required to change the frequency and octave registers simultaneously, both new values must be written (frequency first; octave second) within half the period of the current frequency (i.e. within 64 μ s for a 7.74 kHz tone).

Synchronization on reset

All frequency generators can be reset by setting bit D1 (RST) of the register at address 1C. In this state, frequency and octave data can still be written to the SAA1099, but will not be acted upon. Therefore, as long as RST is active, a register value can be overwritten with new data. However, any new data in the register will not be acted on until half the period of the frequency whose value is held in the register when RST was set has elapsed. This is because RST not only sets all generators to a known state, it synchronizes their start-up.

APPLICATIONS

Probably the most obvious application for the SAA1099 is in video games where the wide range of sound effects available can be used to make games more appealing. The stereo effect, for example, can be used to give width to scenes and to create the impression of movement of objects in the scene. More interesting is the possibility of relating both channel amplitudes and Doppler shift in frequency to the position of an object relative to the user. For example, the sound of passing vehicles or swooping spaceships can be realistically produced.

Many of the sounds in computer games are based on 'coloured' noise (e.g. aircraft, gunfire and car engines). The two noise generators of the SAA1099 with full software control of the noise colour, and the ability to mix the noise with tones, enable two separate 'coloured' noises to be produced in stereo for increased realism.

As mentioned earlier, the SAA1099 can produce all musical notes across eight octaves from 31 Hz to 7.81 kHz. The availability of six frequency generators enables full musical chords (including the tonic) to be produced and allows two chords (excluding tonics) to overlap.

The advanced envelope generation facilities and software control of amplitude and frequency enable musical instruments to be mimicked including vibrato and tremolo effects.

Software modules that generate specific sounds e.g. piano and trumpet, as well as modules that generate sounds that can be altered to suit the situation in a video game can be created, e.g. laser gun, sirens and error warnings.

The following sections outline how several sound effects can be produced. Programming details aren't given (these are published in Ref.3), but some salient points and data are.

Notes and chords

A scale of middle C to high C can be produced using just one frequency generator set for maximum amplitude on both outputs, with the signal from the appropriate noise generator disabled. Table 5 shows the tone numbers and octave numbers required. Note that the same note in different octaves has the same tone number, e.g. C is tone H21 in octave 3 and octave 4. With an 8 MHz crystal-derived clock, all the notes are produced to an accuracy better than 0.1%.

Chords, for example C major and A minor, can be produced using all six generators by writing the appropriate values to the tone and octave registers, then enabling the notes in sequence, without disabling those already active.

Musical arrangements are produced in a similar fashion by an appropriate combination of writing/enabling of tone and octave registers. A stereo effect is produced by giving the treble clef predominance on one channel and the bass clef predominance on the other.

TABLE 5
Chromatic scale

note	tone number (hex)	octave number	required frequency (Hz)	actual frequency*
middle C	21		261.626	261.506
C #	3C		277.183	277.162
D	55		293.665	293.427
D #	6D		311.127	310.945
E	84		329.628	329.815
F	99	03	349.228	349.162
F #	AD		369.994	369.822
G	C0		391.995	391.850
G #	D2		415.305	415.282
A	E3		440.000	440.141
A #	F3		466.164	466.418
B	05	04	493.883	494.071
C	21		523.251	523.013

* with an 8 MHz crystal-derived clock

Siren

The sound of a siren can be simulated using only one frequency generator. All possible values (from high to low) are written to a tone register, changing the octave where necessary, and repeated. A repetitive triangular envelope with the left channel set to be the inverse of that of the right gives the impression of side-to-side movement. When the envelope generator is externally clocked at 85 clocks/second using the address write pulse A0, the sound repeats every 2.7 s.

Aircraft

A dogfight between two aircraft can be simulated using both envelope controllers. One envelope should be set for repetitive attack to simulate gunfire, the other set for repetitive decay to simulate the noise of a propeller. These can be combined with two different types of noise and can be internally clocked. Writing different values to the amplitude registers to vary the volume in the two outputs creates the impression of movement.

A combination of noise and tone can be used to simulate a jet plane preparing for take-off. The colour of the noise should be held constant while the frequency of the tone should be increased smoothly by successive writing to the frequency register. A sawtooth envelope with the invert bit set suggests taxiing movement. If the envelope is clocked to its maximum value on the left output before the sound is enabled, then not clocked during tone changes, the right channel will not be heard, and the plane will appear to be located on the left of the scene.

To give an impression of movement from left to right, the envelope should be clocked eight times when the tone reaches some desired amplitude, reducing the level on the left and increasing that on the right. The left output can then be disabled and the envelope clocked another eight times to reduce the level on the right to zero, giving the impression of movement to the right.

Gun, cannon-fire and laser guns

The sound of a machine gun can be produced using an internally-clocked sawtooth envelope to shape continuous coloured noise. Another gun can be simulated using noise of a different colour and a repetitive decay envelope. Lulls in firing are produced by enabling and disabling the sound enable bit.

The sound of a cannon can be simulated in the same way as the first machine gun just described with the envelope clocked externally and much more slowly. The direction and distance of the cannon is determined by the contents of the amplitude register.

A space gun or 'laser sound' can be produced using a 500 Hz tone (tone H0F in octave 4) and a sawtooth envelope with external envelope clock.

Space-ships

To suggest two swooping space-ships, two identical envelopes clocked at different rates and each with the invert bit set are used with two tones whose frequencies are varied between preset points at different rates.

Steam locomotive

To simulate the sound of a steam locomotive, coloured noise (15,6 kHz clock) and a repetitive triangular envelope are used. With the sound disabled, the envelope is clocked through to its peak, then with the sound enabled clocked slowly to its trough to give the sound of a gentle hiss of steam. After a pause, the envelope should be clocked continuously (beginning for example at 3,5 clocks per second and increasing to 28 clocks per second to suggest a locomotive gathering speed.

The sound of a locomotive's whistle can be produced using a 480 Hz tone (tone HFF in octave 3) mixed with noise.

Telephone ringer

The sound of a telephone ringer such as that fitted to a Trimphone® is simulated using an internally-clocked sawtooth envelope mixed with an appropriate tone (3,3 kHz, tone H6F in octave 6). The cadence is produced by enabling and disabling the sound (0,46 s enabled, 0,23 s disabled, 0,46 s enabled and 2,3 s disabled).

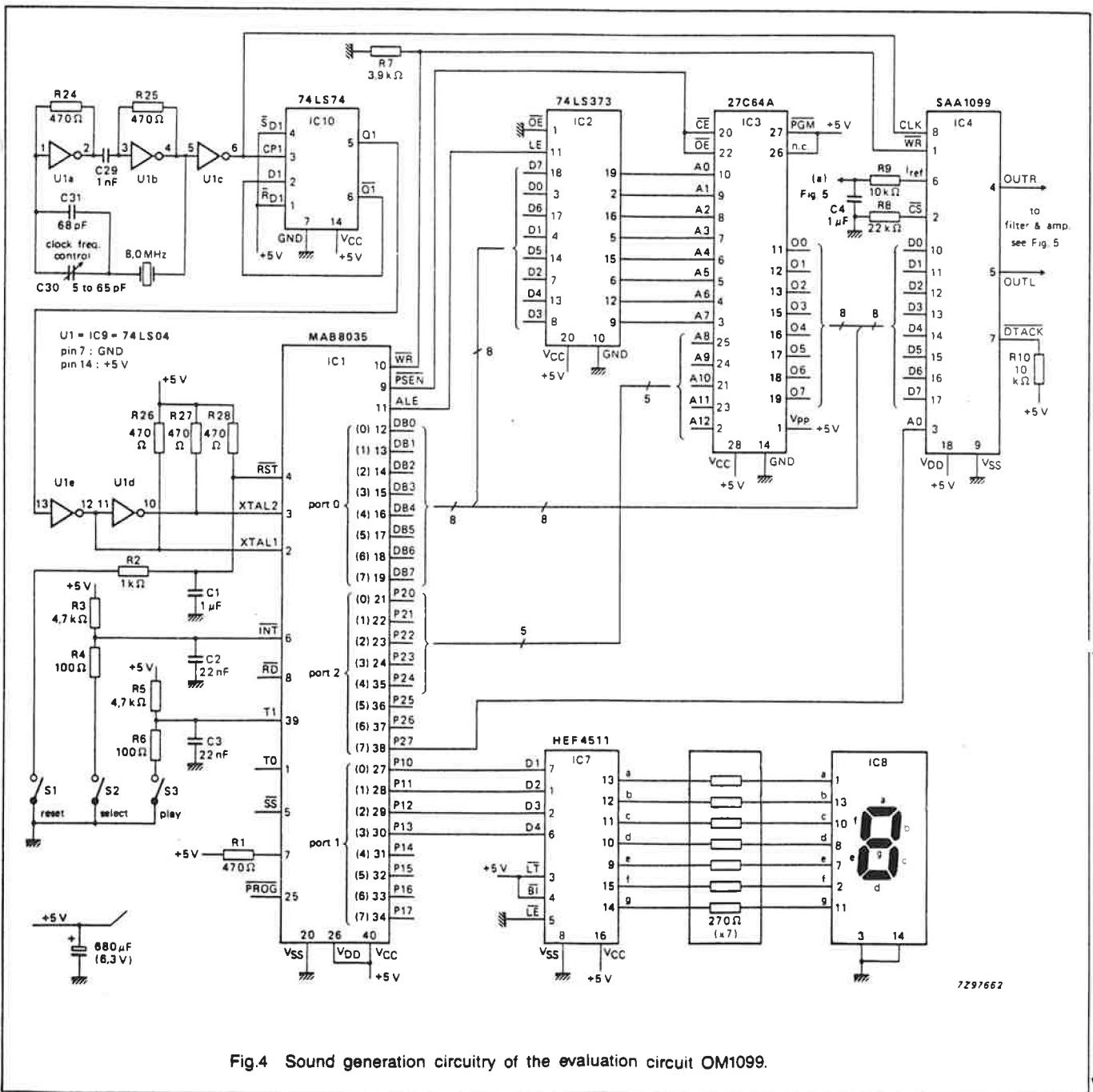
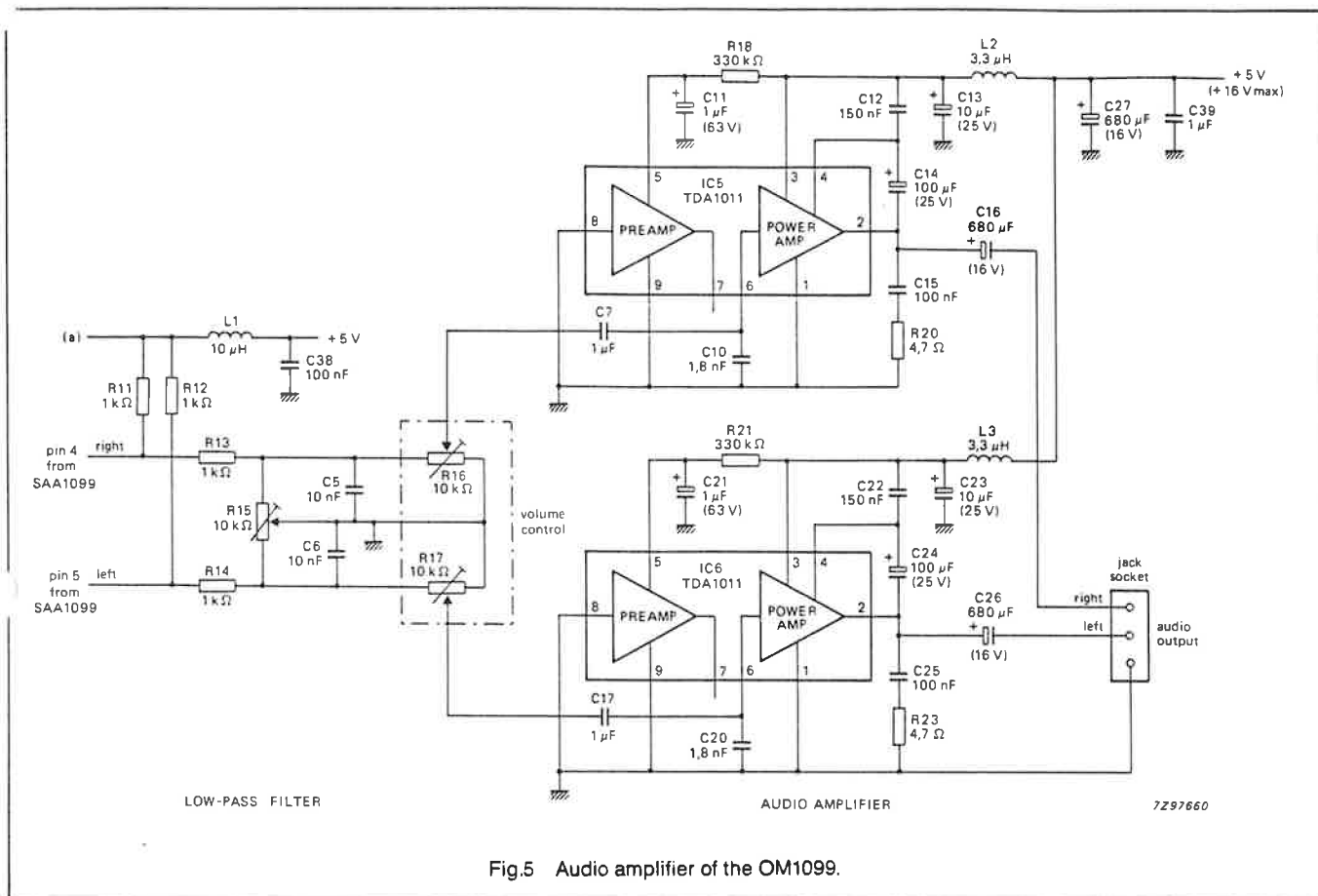


Fig.4 Sound generation circuitry of the evaluation circuit OM1099.



EVALUATION CIRCUIT

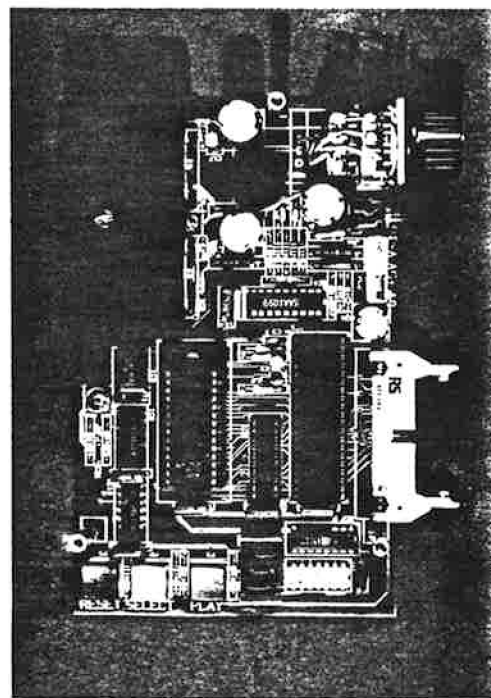
Figure 4 shows a circuit that is available for you to evaluate the SAA1099 in your application. The circuit which includes an integrated stereo power amplifier can be ordered using part number OM1099. A description of the circuit's hardware and software appears in Refs 4 and 5 respectively.

Data bytes held in an EPROM (the MAB8035HL microprocessor has no on-chip ROM) are sent via the microprocessor to the data inputs of the SAA1099 together with the A0 and WR signals.

Pre-programmed sound modules can be selected using the 'select program' key which interrupts the current sound module being played. A display indicates the program selected. The 'play' key is used to play the selected program. Software support is available on request. For timing details, the reader is referred to the SAA1099 data sheet (Ref.2).

The standard MAB8035 requires a clock in the range 1 to 6 MHz. It is convenient to use the 8 MHz crystal oscillator for the SAA1099 with a divider to provide a 4 MHz clock for the microprocessor.

Since the SAA1099 can always accept data faster than the rate at which the MAB8035 can produce it in the circuit of Fig.4, the DTACK output has not been used. However, when a faster processor such as the SCN68000 is used, DTACK must be used to prevent data being missed by the SAA1099.



Laboratory model of the sound generation circuit shown in Fig.4.

After low-pass filtering (17 kHz, -3 dB), the output of the SAA1099 is amplified by two TDA1011 integrated amplifier circuits. Because the output of the SAA1099 is about 1.3 V (peak-to-peak), only the power amplifier sections of the TDA1011s are used, providing about 23 dB gain which is equivalent to an audio output of about 6 W per channel in a 4 Ω system with a supply voltage of 16 V. Even though the pre-amp sections are not used, some components (R18, R21, C11 and C21) are necessary to ensure correct biasing of the output stage. Some additional filtering has been added to reduce any high frequency coupling between the amplifiers and the SAA1099 via the supply lines.

SAA1099 AS A HOME COMPUTER PERIPHERAL

Figure 6 shows how the SAA1099 can be connected to a typical home computer — the BBC Model B. Although the following description is based on this arrangement, it is applicable for many home computers.

The audio amplifier is a TDA7050 stereo integrated amplifier providing about 140 mW output power per channel in a 16 Ω system with a 4.5 V supply. The TDA7050 requires few external components and is therefore suitable for low-cost applications.

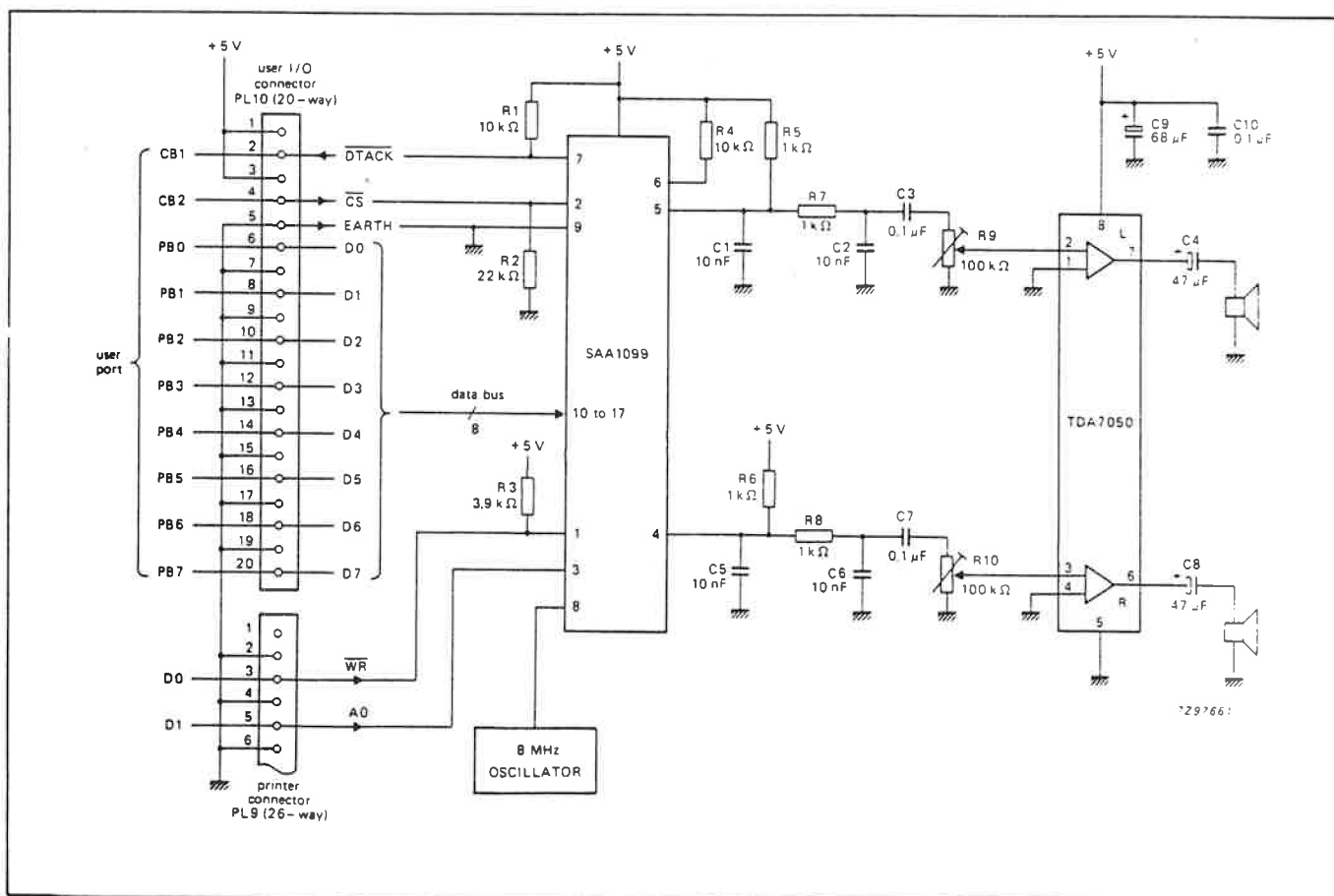
The operation of the inputs to the SAA1099 is entirely software-controlled. Therefore, the software must provide suitable timing, for example, for the length of the write pulse and its timing relative to the data and changes of A0.

DTACK

Because the $\overline{\text{DTACK}}$ signal is too fast to be acknowledged by the BBC home computer, the $\overline{\text{DTACK}}$ pin is connected to one of the user ports (CB1), which is configured in a non-driving state (HIGH) so that when $\overline{\text{DTACK}}$ is LOW, the sink current is limited to about 3 mA.

Chip select

The chip select ($\overline{\text{CS}}$) line is connected to earth via a 22 k Ω resistor and therefore the SAA1099 is normally enabled. The $\overline{\text{CS}}$ input is also connected to CB2 on the microcomputer and this port or equivalent should be held LOW for normal operation and HIGH to inhibit the SAA1099.



Linear section

The performance of the audio amplifier section of Fig.6 is poorer than that of Fig.4, but the circuit is cheaper. An integrated stereo amplifier circuit TDA7050 provides a voltage gain of 26 dB per channel, corresponding to about 50 mW per channel output power with 50 Ω loudspeakers. The low-frequency response of the amplifier (70 Hz, -3 dB point with 50 Ω loudspeakers) is mainly determined by the value of the coupling capacitor C4 or C8 (47 μ F).

Before amplification, each signal is filtered to suppress the high-frequency content of the signal (62,5 kHz and above) due to the amplitude and envelope control of the SAA1099. The filter network produces a 3 dB attenuation at 17 kHz. If small speakers are used, their lack of low-frequency response emphasizes the higher harmonics in the SAA1099 output, producing a rather harsh sound which can be removed by additional high-frequency attenuation of the audio signal.

REFERENCES

1. TEA2000, PAL/NTSC colour encoder, Philips Elcoma data sheet, ordering code 9397 085 70142, Sept. 1985.
2. SAA1099, Microprocessor controlled stereo sound generator for sound effects and music synthesis, Philips Elcoma data sheet, Data Handbook IC14, Microprocessors, micro-controllers and peripherals, 1985. Ordering code 9398 132 40011.
3. Sound generator with an added dimension, Mullard laboratory report MTH8503, 1985, Mullard Application Laboratory, Mitcham, England.
4. A demonstration board for the SAA1099 stereo sound processor, Mullard Laboratory report THM85102, 1985, Mullard Application Laboratory, Mitcham, England.
5. Control programs and sound modules for the SAA1099 stereo sound processor, Mullard laboratory report THM85104, 1985, Mullard Application Laboratory, Mitcham, England.



VL1772-02

SIGNAL DESCRIPTIONS

Signal Name	Pin Number	Signal Description																									
\overline{CS}	1	Chip Select - A logic-low on this input selects the chip and enables host communication with the device.																									
\overline{RW}	2	Read/Write - A logic-high on this input controls the placement of data on the \overline{DQ} - $\overline{D7}$ lines from a selected register, while a logic-low causes a write operation to a selected register.																									
A0, A1	3, 4	Address 0, 1 - These two inputs select a register to read or write data:																									
<table><tr><th>\overline{CS}</th><th>A1</th><th>A0</th><th>$\overline{RW} = 1$</th><th>$\overline{RW} = 0$</th></tr><tr><td>0</td><td>0</td><td>0</td><td>Status Register</td><td>Command Register</td></tr><tr><td>0</td><td>0</td><td>1</td><td>Track Register</td><td>Track Register</td></tr><tr><td>0</td><td>1</td><td>0</td><td>Sector Register</td><td>Sector Register</td></tr><tr><td>0</td><td>1</td><td>1</td><td>Data Register</td><td>Data Register</td></tr></table>			\overline{CS}	A1	A0	$\overline{RW} = 1$	$\overline{RW} = 0$	0	0	0	Status Register	Command Register	0	0	1	Track Register	Track Register	0	1	0	Sector Register	Sector Register	0	1	1	Data Register	Data Register
\overline{CS}	A1	A0	$\overline{RW} = 1$	$\overline{RW} = 0$																							
0	0	0	Status Register	Command Register																							
0	0	1	Track Register	Track Register																							
0	1	0	Sector Register	Sector Register																							
0	1	1	Data Register	Data Register																							
DAL0 - DAL7	5 - 12	Data Access Lines 0 through 7 - Eight-bit bidirectional bus used for transfer of data, control, or status. This bus is enabled by \overline{CS} and \overline{RW} . Each line drives one TTL load.																									
\overline{MR}	13	Master Reset - A logic-low pulse on this line resets the device and initializes the status register (internal pull-up).																									
GND	14	Ground - Ground																									
VCC	15	Power Supply - +5 V $\pm 5\%$ power supply input.																									
STEP	16	Step - The Step output contains a pulse for each step of the drive's \overline{RW} head. This is a pulse to the disk drive.																									
DIRC	17	Direction - The Direction output is high when stepping in towards the center of the diskette, and low when stepping out.																									
CLK	18	Clock - This input requires a free-running 50% duty cycle clock (for internal timing) at 8 MHz $\pm 1\%$.																									
\overline{RD}	19	Read Data - This active-low input is the raw data line containing both clock and data pulses from the drive.																									
MO	20	Motor On - Active high output used to enable the spindle motor prior to read, write, or stepping operations.																									
WG	21	Write Gate - This output is made valid prior to writing on the diskette.																									
WD	22	Write Data - FM or MFM clock and data pulses are placed on this line to be written on the diskette.																									
$\overline{TR00}$	23	Track 00 - This active-low input informs the VL1772-02 that the drive's \overline{RW} heads are positioned over Track zero (internal pull-up).																									
\overline{IP}	24	Index Pulse - This active-low input informs the VL1772-02 when the physical index hole has been encountered on the diskette (internal pull-up).																									
\overline{WPRT}	25	Write Protect - This input is sampled whenever a Write Command is received. A logic-low on this line prevents any Write Command from executing (internal pull-up).																									
\overline{DDEN}	26	Double Density Enable - This input pin selects either single (FM) or double (MFM) density. When $\overline{DDEN} = 0$, double density is selected (internal pull-up).																									
DRQ	27	Data Request - This active-high output indicates that the Data Register is full (on a Read) or empty (on a Write) operation.																									
\overline{INTRO}	28	Interrupt Request - This active-high output is set at the completion of any command or a read of the Status Register.																									

4-12



VL1772-02

5 1/4 - INCH FLOPPY DISK CONTROLLER/FORMATTER

FEATURES

- Built-in data separator
- Built-in write precompensation
- 5 1/4-inch single and double density
- Motor control
- TTL compatible
- 128, 256, 512, or 1024 sector lengths
- 8-bit bidirectional data bus
- Fast step rates
- 28-pin DIP
- Single 5 V power supply

DESCRIPTION

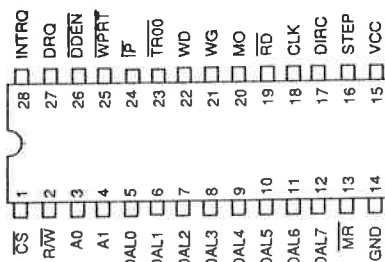
The VL1772-02 is a MOS/LSI device that performs the functions of a 5 1/4-inch floppy Disk Controller/Formatter. It replaces the older 1770-type device.

The drive side of the interface needs no additional logic except for buffers/receivers. Designed for 5 1/4-inch single-or double-density operation, the device contains a programmable Motor On signal.

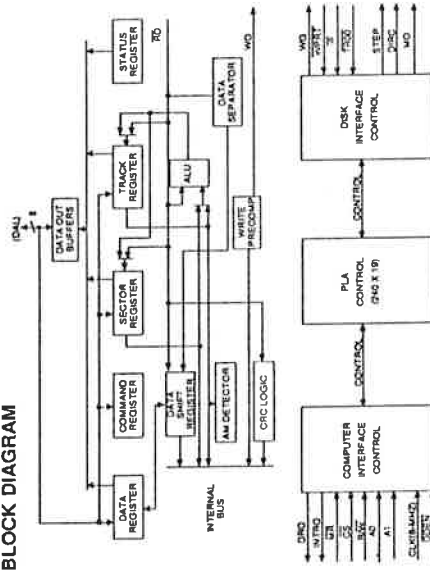
The VL1772-02 is implemented in NMOS silicon gate technology and is available in a 28-pin dual-in-line package. It is a low-cost version of the WD179X Floppy Disk Controller/Formatter and is compatible with generic 179X types. It also has a built-in digital data separator and write precompensation circuits. A single read line (\overline{RD} , pin 19) is the only input required to recover serial FM or MFM data from the disk drive. The device has been specifically designed for control of 5 1/4-inch floppy disk or three LS bards.

PIN DIAGRAM

VL1772-02



BLOCK DIAGRAM



ORDER INFORMATION

Part Number	Package
VL1772-02PC	Plastic DIP
VL1772-02OC	Plastic Leaded Chip Carrier
VL1772-02CC	Ceramic DIP

Note:
Operating temperature range: 0°C to +70°C.

4-11



ARCHITECTURE

The VL1772-02 Floppy Disk Controller/Formatter block diagram is illustrated on the front page. The Track Register can be loaded from or transferred to the DAL. This register should not be loaded when the device is busy.

Data Shift Register (SR) - This 8-bit register holds the address of the desired sector position. The contents of the register are compared with the recorded sector number in the ID field during disk read or write operations. The Sector Register contents can be loaded from or transferred to the DAL. This register should not be loaded when the device is busy.

Command Register (CR) - This 8-bit register holds the command presently being executed. This register should not be loaded when the device is busy, unless the new command is a forced interrupt. The Command Register can be loaded from the DAL but not read onto the DAL.

Status Register (STR) - This 8-bit register holds device status information. The meaning of the status bits is a function of the type of command previously executed. This register can be read onto the DAL but not loaded from the DAL.

Track Register - This 8-bit register holds the track number of the current read/write head position. It is incremented by one every time the head is stepped in and decremented by one every time the head is stepped out (towards Track 00). The contents of the register are compared with the recorded

polynomial is:

$$G(x) = x^{16} + x^{12} + x^5 + 1$$

The CRC includes all information starting with the address mark and up to the CRC characters. The CRC register is preset to ones prior to data being shifted through the circuit.

Arithmetic Logic Unit (ALU) - The ALU is a serial comparator, incrementer, and decrementer and is used for register modification and comparisons with the disk-recorded ID field.

Timing and Control - All computer and floppy disk interface controls are generated through this logic. The internal device timing is generated from an external crystal clock. The VL1772-02 has two different modes of operation according to the state of DDEN: When DDEN = 0, double density (MF) is enabled. When DDEN = 1, single density is enabled.

Address Mark Detector - The AM detector detects ID, data, and Index address marks during read and write operations.

Data Separator - A digital data separator, consisting of a ring shift register and data window detection logic, provides read data and a recovery clock to the AM detector.

FUNCTIONAL DESCRIPTION

The interface to the processor is accomplished through the eight data access lines (DALs) and associated control signals. The DALs are used to transfer data, status, and control words out of, or into the VL1772-02. The DALs are three-state buffers that are enabled as output drivers when Chip Select (CS) = 0 and R/W = 1 are active, or act as input receivers when CS and R/W = 0 are active.

When transfer of data with the Floppy Disk Controller is required by the host processor, the device address is decoded and CS is made low. The signal RW during a read or write operation, are interpreted as selecting the following registers:

A1 - A0	READ (RW = 1)	WRITE (RW = 0)
0 0	Status Register	Command Register
0 1	Track Register	Track Register
1 0	Sector Register	Sector Register
1 1	Data Register	Data Register

After any register is written to, the same register cannot be read from until 16 μ s in MF or 32 μ s in FM have elapsed. During direct memory access (DMA) types of data transfers between the Data Register of the VL1772-02 and the processor, the Data Request (DRQ) output is used in data transfer control. This signal also appears as status bit 1 during read and write operations.

On disk read operations, the Data Request is activated (set high) when an assembled serial input byte is transferred in parallel to the Data Register. This bit is cleared when the Data Register is read by the processor. If the Data Register is read after one or more characters are lost, by having new data transferred into the register prior to processor readout, the Lost Data bit is set in the Status Register. The read operation continues until the end of

sector is reached. On disk write operations, the Data Request is activated when the Data Register transfers its contents to the Data Shift Register, and requires a new data byte. It is reset when the Data Register is loaded with new data by the processor. If new data is not loaded at the time the next serial byte is required by the floppy disk, a byte of zeros is written on the diskette and the Lost Data bit is set in the Status Register.

At the completion of every command an INTRQ is generated; it is reset by either reading the status register or by loading the command register with a new command. In addition, INTRQ is generated if a Force Interrupt command condition is met.

Writing is inhibited when the Write Protect input is a logic low, in which case any Write command is immediately terminated, an interrupt is generated, and the Write Protect status bit is set.

For write operations, the VL1772-02 provides Write Gate to enable a write condition, and Write Data which consists of a series of active-high pulses. These pulses contain both clock and data information in FM and MF. Write Data provides the unique missing clock patterns for recording address marks.

The Precompensation Enable bit in Write commands allow automatic write precompensation to take place. The outgoing write data stream is delayed or advanced from nominal by 18/ths according to the following table:

PATTERN	FM	FM
X 1 1 1 0	Early	N/A
X 0 1 1 1	Late	N/A
0 0 0 1 1	Early	N/A
1 0 0 0 0	Late	N/A

Precompensation is typically enabled on the innermost tracks where bit shifts usually occur and bit density is at its maximum.

SECTOR LENGTH FIELD INDEX	NUMBER OF BYTES IN SECTOR (DECIMAL)
00	128
01	256
02	512
03	1024

Sector lengths are determined at format time by the fourth byte in the "ID" field.

DDEN should be placed to a logical "0".

On disk read operations, the Data Request is activated (set high) when an assembled serial input byte is transferred in parallel to the Data Register. This bit is cleared when the Data Register is read by the processor. If the Data Register is read after one or more characters are lost, by having new data transferred into the register prior to processor readout, the Lost Data bit is set in the Status Register. The read operation continues until the end of

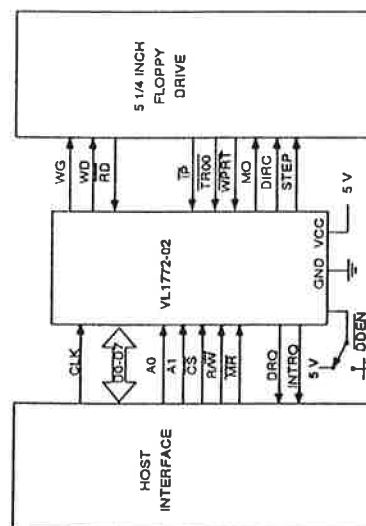


FIGURE 1. SYSTEM BLOCK DIAGRAM

FIGURE 2. TYPE I COMMAND FLOWCHART (CON'L)

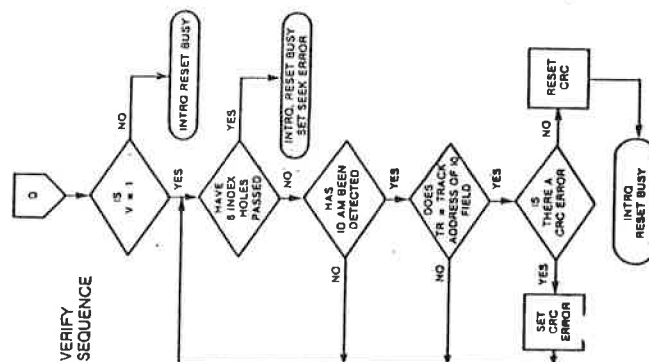
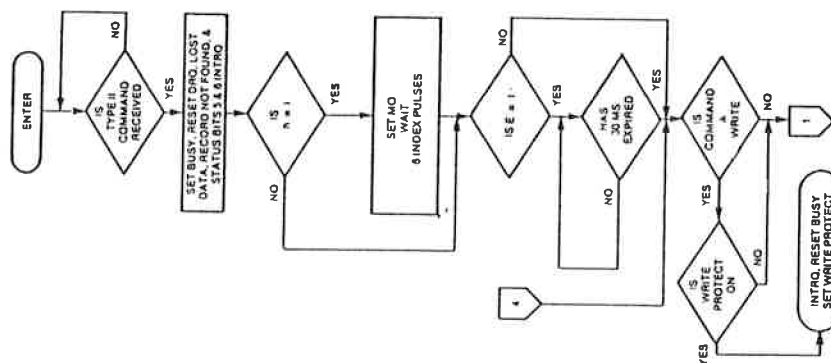


FIGURE 3. TYPE II COMMAND FLOWCHART



SEEK

This command assumes that the **Track Register** contains the track number of the current position of the read/write head and the **Data Register** contains the desired track number. The VL1772-02 will update the **Track Register** and issue stepping pulses in the appropriate direction until the contents of the **Track Register** are equal to the contents of the **Data Register** (the desired track).

TYPE II COMMANDS

The Type II Commands (see Figure 3) are the Read Sector and Write Sector commands. Prior to loading the Type II Command into the Command Register, the computer must load the Sector Register with the desired sector number. Upon receipt of the Type II command, the controller checks the status of the busy status bit is set. If the flag = 1, the command executes after a 15 ms delay.

READ SECTOR

Upon receipt of the Read Sector command, the Busy status bit is set, and when an ID field is encountered that was the correct track number, correct sector number, and correct CRC, the data field is presented to the computer. The data address mark (DAM) of the data field must be found within 30 bytes of an single density and 43 bytes in double density of the last ID field CRC byte; if not, the ID field is searched for and verified again followed by the data address mark search. If, after five revolutions the DAM cannot be found, the Record Not Found Status Bit is set and the operation is terminated. When the first character or byte of the data field has been shifted through the DSR, it is transferred to the DR, and DRQ is generated. If the computer has not read the previous contents of the DR before a new character is transferred, that character is lost and the Last Data Status Bit is set. This sequence continues until the complete data field has been input to the computer. If there is a CRC error at the end of the data field, the CRC Error Status Bit is set, and the command is terminated (even if it is a multiple record command). At the end of the read operation, the type of data address mark encountered in the data field is stored in the Register (Rlt 5) as shown:

STATUS BIT 5	
1	Deleted Data Mark
0	Data Mark

WHITE SECTOR

Upon receipt of the **Write Sector** command, the Busy status bit is set. When an ID field is encountered that has the correct track number, correct sector number, and correct CRC, a DRQ is generated. The VL1772-02 counts off 11 bytes in single density and 22 bytes in double density from the CRC field and the Write Gate (WG) outputs its made or not made response. If the response is affirmative if the DRQ is serviced (i.e., the DRQ has not been serviced, the command is terminated and the Last Data status bit is set. If the DRQ has not been serviced, the WG is made active and six bytes of zeros in single density and 12 bytes in double density are then written on the disk. At this time, the

FIGURE 1. TYPE II COMMAND FLOWCHART (Cont.)

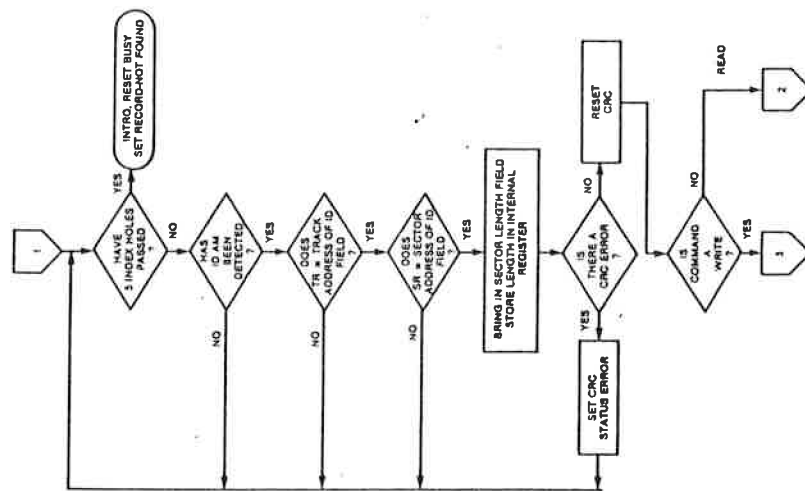


FIGURE 1. TYPE II COMMAND FLOWCHART (Cont.)

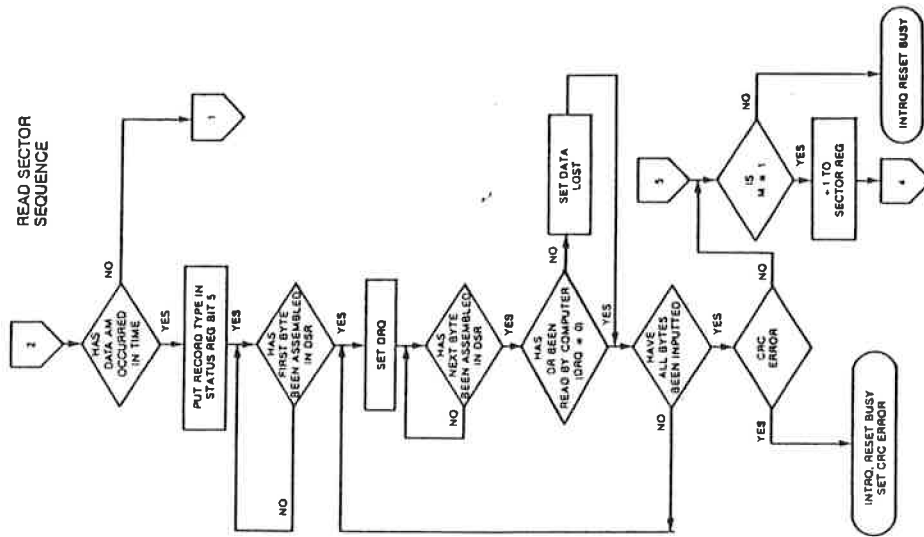
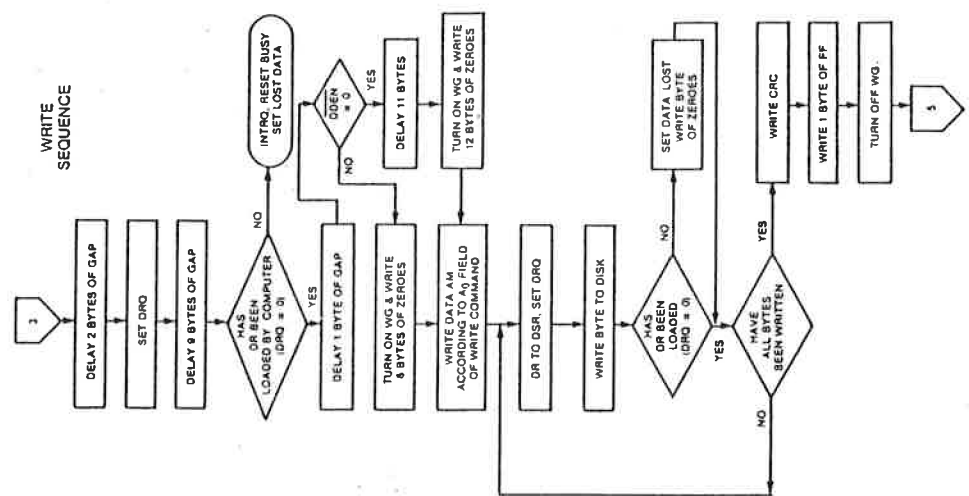


FIGURE 1. TYPE II COMMAND FLOWCHART (Cont.)



data address mark is then written on the disk as determined by the A0 field of the command as shown below:

DATA ADDRESS MARK (BIT 0)	
1	Deleted Data Mark
0	Data Mark

The VL1772-02 then writes the data field and generates DRQs to the computer. If the DRQ is not serviced in time for continuous writing, the Lost Data Status Bit is set and a byte of zeros is written on the disk. The command is not terminated. After the last data byte has been written on the disk, the two-byte CRC is computed internally and written on the disk followed by one byte of logic ones in FM or in MFM. The WG output is then deactivated. INTRO will set 24 μ s (MFM) after the last CRC byte is written. For partial sector writing, the proper method is to write data and fill the balance with zeros.

TYPE III COMMANDS

Read Address - Upon receipt of the Read Address command, the Busy Status Bit is set. The next-encountered ID field is then read in from the disk, and six data bytes of the ID field are assembled and transferred to the DR. A DRQ is generated for each byte. The six bytes of the ID field are shown below:

TRACK ADDR	SIDE	SECTOR	SECTOR ADDR	LENGTH	CRC	CRC ADDR
1	2	3	4	5	6	7

Although the CRC characters are transferred to the computer, the VL1772-02 checks for validity and the CRC Error Status Bit is set if there is a CRC error. The track address of the ID field is written into the Sector Register so that a

WRITE TRACK FORMATTING THE DISK

Data and gap information are provided at the computer interface. Formatting the

disk is accomplished by positioning the R/W head over the desired track number and issuing the Write Track command. Upon receipt of the Write Track command, the Busy Status Bit is set.

Writing starts with the leading edge of the first encountered index pulse and continues until the next index pulse, at which time the interrupt is activated. The Data Request is activated immediately upon receiving the command, but writing will not start until after the first byte has been loaded into the Data Register. If the DR has not been loaded within three byte times, the operation is terminated, making the device Not Busy, the Lost Data Status Bit is set, and the interrupt is activated.

If a byte is not present in the DR when needed, a byte of zeros is substituted. This sequence continues from one index mark to the next index mark. Normally, whatever data pattern appears in the data register is written on the disk with a normal clock pattern. However, if the VL1772-02 detects a data pattern of F5 through FE in the data register, this is interpreted as a data address mark with missing checks or CRC generation. The CRC generator is initialized when any data byte from F8 to FE is about to be transferred from the DR to the DSR in FM or by receipt of F5 in MFM. An F7 pattern generates two CRC characters in FM or MFM. As a consequence, the patterns F5 through FE must not appear in the gaps, data fields, or ID fields. Also, CRCs must be generated by an F7 pattern.

Disks may be formatted in IBM 3740 or System 34 formats with sector lengths of 128, 256, 512, or 1024 bytes.

TABLE 2. DATA PATTERN DECODE

DATA PATTERN IN DR (HEX)	IN FM (DDEN = 1)	IN MFM (DDEN = 0)
00 thru F4	Write 00 thru F4 with CLK = FF	Write 00 thru F4 in MFM
F5	Not Allowed	Write A1* in MFM. Present CRC
F6	Not Allowed	Write C2** in MFM
F7	Generate 2 CRC bytes	Generate 2 CRC bytes
F8 thru FB	Write F8 thru FB, CLK = C7. Preset CRC	Write F8 thru FB in MFM
FC	Write FC with CLK = D7	Write FC in MFM
FD	Write FD with CLK = FF	Write FD in MFM
FE	Write FE, CLK = C7. Preset CRC	Write FE in MFM
FF	Write FF with CLK = FF	Write FF in MFM

*Missing clock transition between bits 4 and 5.
**Missing clock transition between bits 3 and 4.

TYPE IV COMMANDS

The Forced Interrupt Command is generally used to terminate a multiple secure read or write command or to ensure a Type I status in the status register. This command can be loaded into the command register at any time. If there is a current command under execution (Busy Status Bit set) the command is terminated and the Busy Status Bit reset.

The lower four bits of the command determine the conditional interrupt as follows:

- I0 = Don't Care
- I1 = Don't Care
- I2 = Every Index Pulse
- I3 = Immediate Interrupt

The conditional interrupt is enabled when the corresponding bit positions of the command (I3-I0) are set to a 1.

Then, when the condition for interrupt is met, the INTRO line goes high signifying that the condition specified has occurred. If I3-I0 are all set to zero (HEX D0), no interrupt occurs but any command presently under execution is immediately terminated. When using the immediate interrupt condition (I3 = 1) an interrupt immediately is generated and the current command terminated.

Reading the Status or writing to the Command Register does not automatically clear the interrupt. The HEX D0 is the only command that enables the immediate interrupt (HEX D8) to clear on a subsequent load command register or read status register operation. Follow a HEX D8 with D0 command.

Wait 16 μ s (double density) or 32 μ s (single density) before issuing a new command after issuing a forced interrupt. Loading a new command sooner than this nullifies the forced interrupt.

Force Interrupt Command stops any command at the end of an internal micro instruction and generates INTRO when the specified condition is met. Force interrupt waits until ALU operations in progress are complete (CRC calculations, compares, etc.).

Status Register - Upon receipt of any command, except the Force Interrupt command, the Busy Status Bit is set and the rest of the status bits are updated or cleared for the new command. If the Force Interrupt Command is received when there is a

current command under execution, the Busy status bit is reset, and the rest of the status bits are unchanged. If the Force Interrupt command is received when there is not a current command under execution, the Busy Status Bit is reset and the rest of the status bits are updated or cleared. In this case, Status reflects the Type I commands.

The user has the option of reading the status register through program control or using the DRQ line with DMA or interrupt methods. When the Data Register is read the DRQ bit in the Status Register and the DRQ line are automatically reset. A write to the Data Register also causes both DRQ's to reset.

The Busy Bit in the status may be determined with a user program to determine when a command is complete, in lieu of using the INTRO line. When using the INTRO, a Busy status check is not recommended because a read of the Status Register to determine the condition of busy resets the INTRO line.

The format of the Status Register is shown below:

BITS									
7	6	5	4	3	2	1	0		
S7	S6	S5	S4	S3	S2	S1	S0		

Because of internal synchronization cycles, certain time delays are observed when operating under program I/O as shown.

Operation	Next Operation	Delay Req'd
Write to Command Reg.	Read Busy Bit (Status Bit 0)	48 μ sec
Write to Command Reg.	Read Status Register	84 μ sec
Write to Command Reg.	Read Status Register	32 μ sec
Write to Command Reg.	Read Status Register	16 μ sec

Shown below is the recommended single-density format with 128 bytes/sector. In order to format a diskette, the user must issue the Write Track command, and load the data register with the following values. For every byte to be written,

NUMBER OF BYTES	HEX VALUE OF BYTE WRITTEN
0	FF (or 00)
1	FE (ID Address Mark)
2	FD (ID Address Mark)
3	FC (ID Address Mark)
4	FB (ID Address Mark)
5	FA (ID Address Mark)
6	F9 (ID Address Mark)
7	F8 (ID Address Mark)
8	F7 (ID Address Mark)
9	F6 (ID Address Mark)
10	F5 (ID Address Mark)
11	F4 (ID Address Mark)
12	F3 (ID Address Mark)
13	F2 (ID Address Mark)
14	F1 (ID Address Mark)
15	F0 (ID Address Mark)
16	FF (or 00)
17	FE (or 01)
18	FD (or 02)
19	FC (or 03)
20	FB (or 04)
21	FA (or 05)
22	F9 (or 06)
23	F8 (or 07)
24	F7 (or 08)
25	F6 (or 09)
26	F5 (or 0A)
27	F4 (or 0B)
28	F3 (or 0C)
29	F2 (or 0D)
30	F1 (or 0E)
31	F0 (or 0F)

there is one Data Request.

**Continue writing until VL1772-02 interrupts out. Approximately 369 bytes.

256 BYTES/SECTOR

Shown below is the recommended dual-density format with 256 bytes/sector. In order to format a diskette, the user must issue the Write Track command and load the Data Register with the following values. For every byte to be written, there is one data request.

NUMBER OF BYTES	HEX VALUE OF BYTE WRITTEN
0	FE (ID Address Mark)
1	FD (ID Address Mark)
2	FC (ID Address Mark)
3	FB (ID Address Mark)
4	FA (ID Address Mark)
5	F9 (ID Address Mark)
6	F8 (ID Address Mark)
7	F7 (ID Address Mark)
8	F6 (ID Address Mark)
9	F5 (ID Address Mark)
10	F4 (ID Address Mark)
11	F3 (ID Address Mark)
12	F2 (ID Address Mark)
13	F1 (ID Address Mark)
14	F0 (ID Address Mark)
15	FF (or 00)
16	FE (or 01)
17	FD (or 02)
18	FC (or 03)
19	FB (or 04)
20	FA (or 05)
21	F9 (or 06)
22	F8 (or 07)
23	F7 (or 08)
24	F6 (or 09)
25	F5 (or 0A)
26	F4 (or 0B)
27	F3 (or 0C)
28	F2 (or 0D)
29	F1 (or 0E)
30	F0 (or 0F)
31	FF (or 00)

** Continue writing until VL1772-02 interrupts out. Approximately 668 bytes.

Non-Standard Formats - Variations in the recommended formats are possible to a limited extent, if the following requirements are met:

- Sector size must be 128, 256, 512, or 1024 bytes.
- Gap 2 cannot be varied from the recommended format.
- Three bytes of A1 must be used in MFM.

In addition, the Index Address Mark is not required for operation by the VL1772-02. Gap 1, 3, and 4 can be as short as two bytes for VL1772-02 operation; however, PLL lock-up time, motor speed variation, write-splice area, etc., add more bytes to each gap to achieve proper operation. For highest system reliability, use the recommended format.

TABLE 3. STATUS REGISTER

BIT NAME	MEANING
S7 MOTOR ON	This bit reflects the status of the Motor On output.
S6 WRITE PROTECT	On Read Record: Not Used. On Read Track: Not Used. On any Write: It indicates a Write Protect. This bit is reset when updated.
S5 RECORD TYPE/SPIN-UP	When set, this bit indicates that the Motor Spin-Up sequence has completed (5 revolutions) on Type I commands. Type 2 & 3 commands, this bit indicates record type. 0 = Data Mark. 1 = Deleted Data Mark.
S4 RECORD NOT FOUND (RNF)	When set, it indicates that the desired track, sector, or side were not found. This bit is reset when updated.
S3 CRC ERROR	If S4 is set, an error is found in one or more ID fields; otherwise it indicates error data field. This bit is reset when updated.
S2 LOST DATA/ BYTE	When set, it indicates the computer did not respond to DRQ in one byte time. This bit is reset to zero when updated. On Type I commands, this bit reflects the status of the TRQ signal.
S1 DATA REQUEST INDEX	This bit is a copy of the DRQ output. When set, it indicates the DR is full on a Read Operation or the DR is empty on a Write operation. This bit is reset to zero when updated. On Type 1 commands, this bit indicates the status of the IP signal.
S0 BUSY	When set, command is under execution. When reset, no command is under execution.

**Byte counts must be exact.
**Byte counts are minimum, except exactly 3 bytes of A1 must be written.

FIGURE 4. TYPE III COMMAND WRITE TRACK FLOWCHART (Cont.)

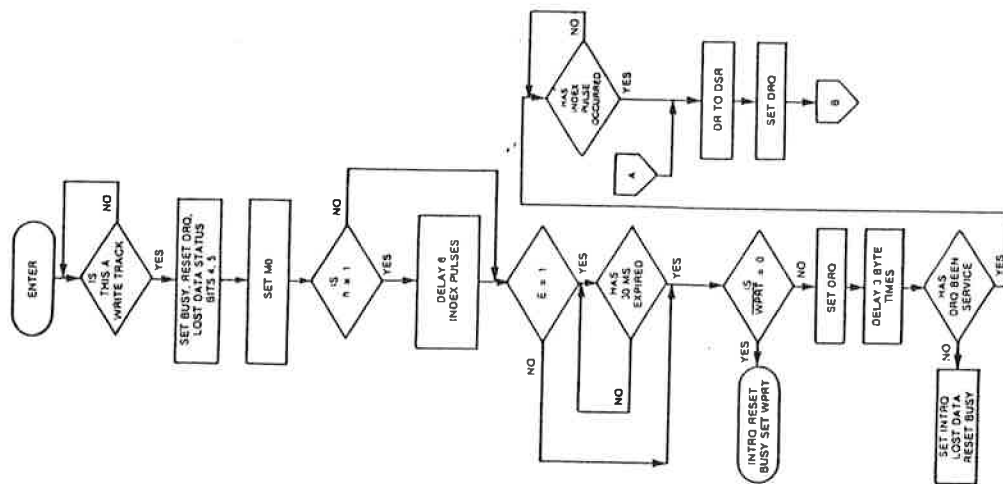


FIGURE 4. TYPE III COMMAND WRITE TRACK FLOWCHART (Cont.)

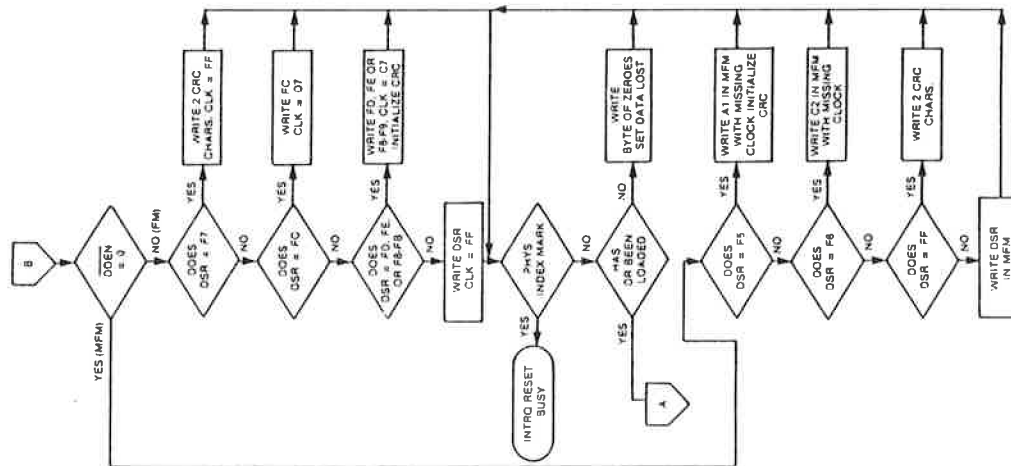


TABLE 4. READ DATA TIMING

CHARACTERISTIC	MIN	TYP	MAX	UNITS	CONDITIONS
t_{wR} Read Pulse Width	200		3	μ sec	MFM
t_{wC} Read Cycle Time	400		3	μ sec	FM

TABLE 5. READ ENABLE TIMING

WRITE ENABLE TIMING - \overline{WE} such that: $RW = 1$, $CS = 0$.

SYMBOL	CHARACTERISTIC	MIN	TYP	MAX	UNITS	CONDITIONS
t_{se}	\overline{RE} Pulse Width of \overline{CS}	200			nsec	$C_L = 50$ pF
t_{vR}	DRQ Reset from \overline{RE}		200	300	nsec	$C_L = 50$ pF
t_{vH}	Data Valid from \overline{RE}		100	200	nsec	$C_L = 50$ pF
t_{oH}	Data Hold from \overline{RE}	20		150	nsec	$C_L = 50$ pF
	INTRQ Reset from \overline{RE}			8	μ sec	

t_{vH} Worst case service time for DRQ is 23.5 μ sec for MFM and 47.5 μ sec for FM.

TABLE 6. WRITE ENABLE TIMING

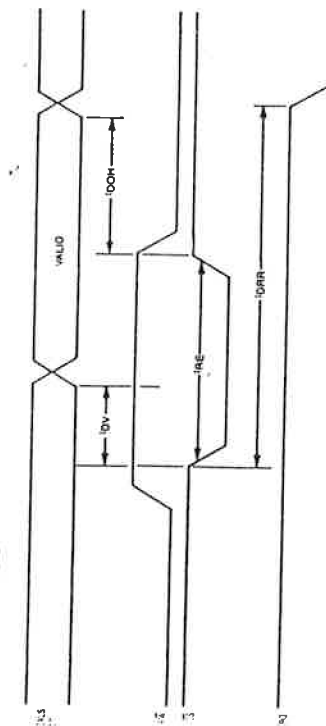


TABLE 6. WRITE ENABLE TIMING

WRITE ENABLE TIMING - \overline{WE} such that: $RW = 0$, $CS = 0$.

SYMBOL	CHARACTERISTIC	MIN	TYP	MAX	UNITS	CONDITIONS
t_{sW}	Setup ADDR to \overline{CS}	50			nsec	
t_{hW}	Hold ADDR to \overline{CS}	0			nsec	
t_{hH}	Hold ADDR from \overline{CS}	10			nsec	
t_{wE}	\overline{WE} Pulse Width	200			nsec	
t_{sR}	DRQ Setup to \overline{WE}	150	100	200	nsec	
t_{oH}	Data Hold from \overline{WE}	0		8	μ sec	

FIGURE 8. WRITE ENABLE TIMING

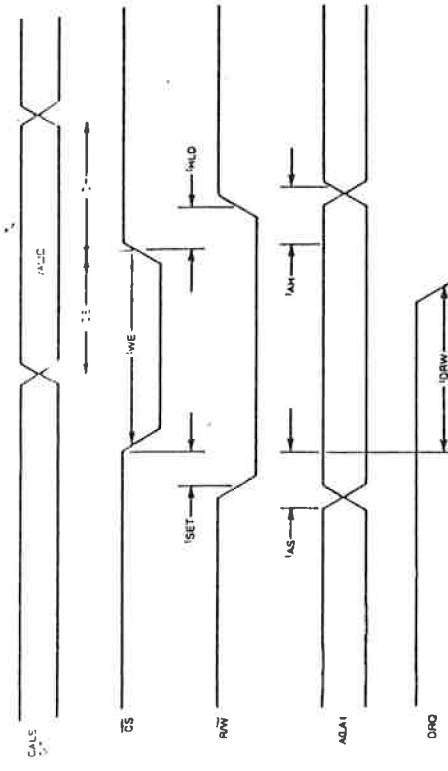


TABLE 7. WRITE DATA TIMING

SYMBOL	CHARACTERISTIC	MIN	TYP	MAX	UNITS	CONDITIONS
t_{wp}	Write Gate to Write Data		4		μsec	FM
	Write Data Cycle Time		2		μsec	MFM
	Write Gate off from WD		4, 6, 8		μsec	FM
	Write Data Pulse Width		2		μsec	MFM
			820		nsec	Early MFM
			690		nsec	Nominal MFM
			570		nsec	Late MFM
			1.38		μsec	FM

FIGURE 7. WRITE DATA TIMING

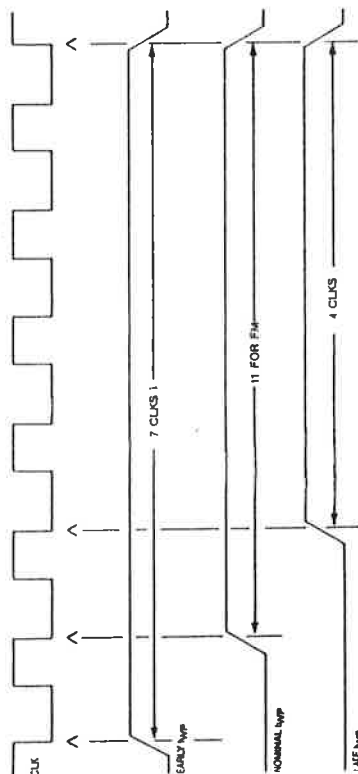
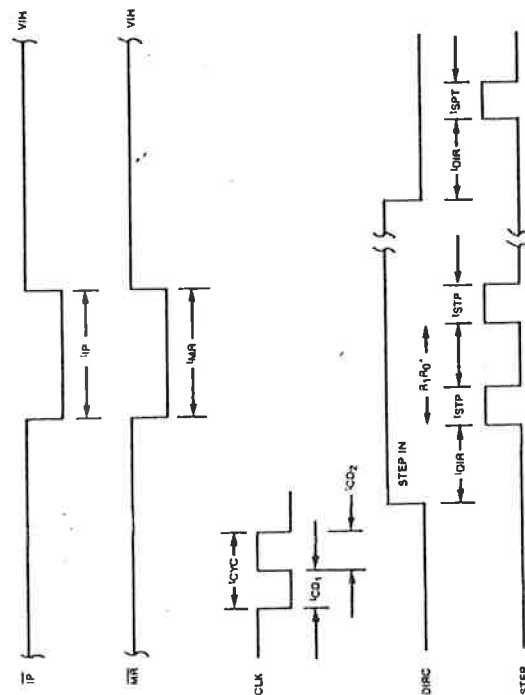


TABLE 8. MISCELLANEOUS TIMING

SYMBOL	CHARACTERISTIC	MIN	TYP	MAX	UNITS	CONDITIONS
t_{cp1}	Clock Duty (low)	50	67		nsec	
t_{cp2}	Clock Duty (high)	50	67		nsec	
t_{stp}	Step Pulse Output		4		μsec	MFM
			8		μsec	FM
t_{dir}	Dir Setup to Step		24		μsec	MFM
t_{mr}	Master Reset Pulse Width	50	48		μsec	FM
t_{ip}	Index Pulse Width	20			μsec	

FIGURE 8. MISCELLANEOUS TIMING



APPLICATION INFORMATION

VL1772-02: AN
IMPROVED VERSION
OF THE 1770-00

The 177X family of flexible disk controllers has attracted a great deal of interest from system designers. Following compactness and superior performance characteristics, this family of advanced PCs has proven to be a success in the marketplace. The original 1770-00 won much approval with its 28-pin package. Its digital data separator allowed consistent operation over temperature, but more was required. The error rate of this data recovery circuit was too high, and a reliable data separator with lower error rates was seen as an important need for computer systems of all types.

In addition, a small change of step rate selections could ensure faster throughput, while maintaining compatibility with existing designs.

stream of read data pulses coming from a floppy drive. The clock and data pulses are both in this signal, combined in a simple encoding format. In each bit cell, the data separator chooses a time period within which pulses are recognized as data pulses. The better the resolution for defining this window for the data pulses, the greater the jitter in the signal can be before ones and zeros are incorrectly recognized. This is incorrect recognition, and the resultant soft errors are the basic limiting factor in floppy drive error rates. The VL1772-02, with a wider data window, has a lower chance of incorrect recognition, resulting in fewer error rates. This effect will be particularly evident as the user's media degrades with use and jitter increases. This increased reliability of the VL1772-02 can result in fewer returns and greater user satisfaction.

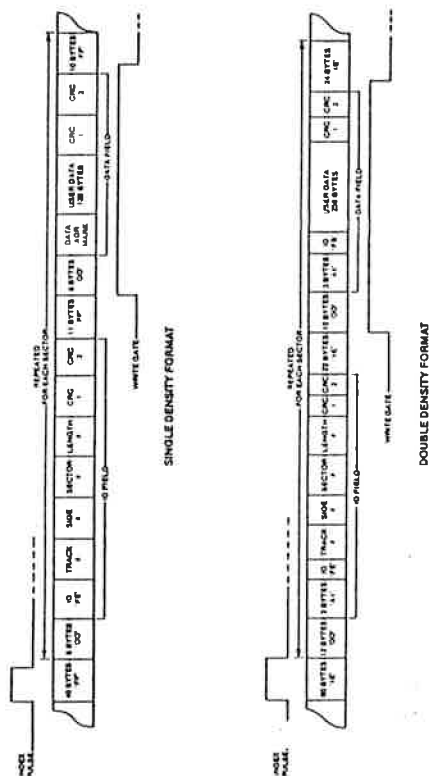
STEP RATES

With a different selection of step rates than the VL770-02 (see table 9), the VL1772-02 allows the use of drives with minimum settle times up to 12 ms. At the same time, performance is enhanced to take advantage of floppy drives that require only 2 or 3 ms of delay. If a design is currently using head settle times of 6 or 12 ms (as most hard), no modifications are required to use the VL1772-02 in the VL770-02 socket. If the current choice of r1 and r2 calls for 20 or 30 ms of delay, use of the VL1772-02 requires:

TABLE 9. STEP RATE SELECTION: 1770-00
AND VL1772-02

Step Rate Select Bits	Step Rate (ms)	
	r1	r0
	0	0
	0	1
	1	0
	1	1

4-12



ABSOLUTE MAXIMUM RATINGS

Ambient Operating Temperature	-10°C to +80°C	Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only. Functional operation of this device at these or other conditions above those indicated in the
Storage Temperature	-65°C to +140°C	
Supply Voltage to Ground	-0.5 V to +7.0 V	
Applied Output Voltage	-0.5 V to +7.0 V	
Applied Input Voltage	-0.5 V to +7.0 V	
Power Dissipation	800mW	

operational sections of this specification is not implied and exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC CHARACTERISTICS TA = 0°C to 70°C, VCC = 5 V ± 5%

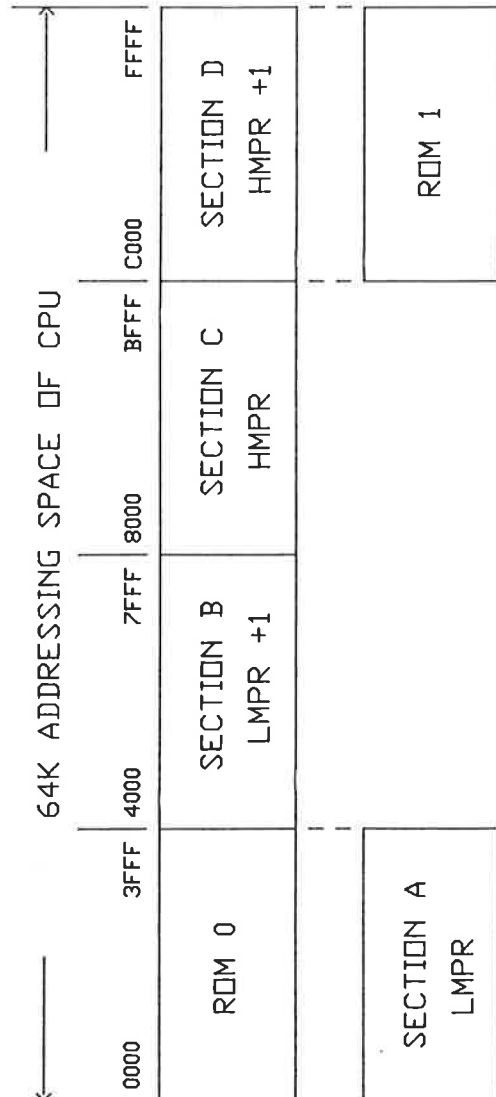
Sym	Parameter	Min	Typ	Max	Unit	Conditions
VOH	Output High Voltage	2.4			V	IO = -100 μ A
VOL	Output Low Voltage			0.4	V	IO = 1.6 mA
VIH	Input High voltage	2.0			V	
VIL	Input Low Voltage			0.8	V	
IIL	Input Leakage Current			10	μ A	VIN = VCC
IOL	Output Leakage Current			10	μ A	VOUT = VCC
RFU	Internal Pull-up	100		1700	μ A	VIN = 0 V
ICC	Operating Supply Current		75	150	mA	
PD	Power Dissipation		780		mW	

17

DIAGRAMS

< IF FITTED >

BANK 0		BANK 1	
PAGE 0		PAGE 16	
PAGE 1		PAGE 17	
PAGE 2		PAGE 18	
PAGE 3		PAGE 19	
PAGE 4		PAGE 20	
PAGE 5		PAGE 21	
PAGE 6		PAGE 22	
PAGE 7		PAGE 23	
PAGE 8		PAGE 24	
PAGE 9		PAGE 25	
PAGE 10		PAGE 26	
PAGE 11		PAGE 27	
PAGE 12		PAGE 28	
PAGE 13		PAGE 29	
PAGE 14		PAGE 30	
PAGE 15		PAGE 31	



LMPR PORT 250							
RAM 0 WRITE	ROM 1	RAM 0	BANK 0 - 1	PAGE 8	PAGE 4	PAGE 2	PAGE 1
HMPR PORT 251							
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VMPR PORT 252							
MIDI BIT	MDE 1	MDE 0	BANK 0 - 1	PAGE 8	PAGE 4	PAGE 2	PAGE 1

SCREEN BIT MAP

0000	LINE 1		001F
0100	LINE 2		011F
0200	LINE 3		021F
0300	LINE 4		031F
0400	LINE 5	} ROW 1	041F
0500	LINE 6		051F
0600	LINE 7		061F
0700	LINE 8		071F
0020			003F
		ROW 2	
0720			073F
0040			005F
		ROW 3	
0740			075F
0060			007F
		ROW 4	
0760			077F
0080			009F
		ROW 5	
0780			079F
00A0			00BF
		ROW 6	
07A0			07BF
00C0			00DF
		ROW 7	
07C0			07DF
00E0			00FF
		ROW 8	
07E0			07FF
0800			081F
		MIDDLE GROUP	
0FE0			0FFF
1000			101F
		BOTTOM GROUP	
17E0			17FF

SCREEN ATTRIBUTE MAP

1800			181F
		TOP GROUP	
18E0			18FF
1900			191F
		MIDDLE GROUP	
19E0			19FF
1A00			1A1F
		BOTTOM GROUP	
1AE0			1AFF

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SCREEN BIT MAP

0000	LINE 1		001F
0020	LINE 2		003F
0040	LINE 3		005F
0060	LINE 4		007F
0080	LINE 5	ROW 1	009F
00A0	LINE 6		00BF
00C0	LINE 7		00DF
00E0	LINE 8		00FF
0100			011F
		ROW 2	
01E0			01FF
0200		ROW 3	021F
02E0		ROW 4	02FF
0300			031F
		ROW 5	03FF
03E0			041F
0400		ROW 6	04FF
			051F
04E0		ROW 7	05FF
0500			061F
		ROW 8	06FF
05E0			071F
0600			07FF
06E0			081F
0700			
07E0			
0800			
		MIDDLE GROUP	
0FE0			0FFF
1000			101F
		BOTTOM GROUP	
17E0			17FF

SCREEN ATTRIBUTE MAP

2000		201F
	TOP GROUP	
27E0		27FF
2800		281F
	MIDDLE GROUP	
2FE0		2FFF
3000		301F
	BOTTOM GROUP	
37E0		37FF

C3

SCREEN 2 BITS PER PIXEL - MODE 3

LINE 1	PIXEL 1	0000	PIXEL 2	0000	PIXEL 3	0000	PIXEL 4	0000	PIXEL 5	0001	PIXEL 6	0001	PIXEL 7	0001	PIXEL 8	0001	PIXEL 9	0002	PIXEL 10	0002	PIXEL 11	0002	PIXEL 12	0003	PIXEL 13	0003	PIXEL 14	0003	PIXEL 15	0003	PIXEL 16	PIXEL 509	007E	007F	PIXEL 510	007F	PIXEL 511	007F	PIXEL 512	007F
LINE 2	PIXEL 1	0080	PIXEL 2	0080	PIXEL 3	0080	PIXEL 4	0080	PIXEL 5	0081	PIXEL 6	0081	PIXEL 7	0081	PIXEL 8	0081	PIXEL 9	0082	PIXEL 10	0082	PIXEL 11	0082	PIXEL 12	0083	PIXEL 13	0083	PIXEL 14	0083	PIXEL 15	0083	PIXEL 16	PIXEL 509	007E	007F	PIXEL 510	007F	PIXEL 511	007F	PIXEL 512	007F
LINE 3	PIXEL 1	0100	PIXEL 2	0100	PIXEL 3	0100	PIXEL 4	0100	PIXEL 5	0100	PIXEL 6	0100	PIXEL 7	0100	PIXEL 8	0100	PIXEL 9	0100	PIXEL 10	0100	PIXEL 11	0100	PIXEL 12	0100	PIXEL 13	0100	PIXEL 14	0100	PIXEL 15	0100	PIXEL 16	PIXEL 509	007E	007F	PIXEL 510	007F	PIXEL 511	007F	PIXEL 512	007F
LINE 128	PIXEL 1	3F80	PIXEL 2	3F80	PIXEL 3	3F80	PIXEL 4	3F80	PIXEL 5	3F80	PIXEL 6	3F80	PIXEL 7	3F80	PIXEL 8	3F80	PIXEL 9	3F80	PIXEL 10	3F80	PIXEL 11	3F80	PIXEL 12	3F80	PIXEL 13	3F80	PIXEL 14	3F80	PIXEL 15	3F80	PIXEL 16	PIXEL 509	3F80	3FFF	PIXEL 510	3FFF	PIXEL 511	3FFF	PIXEL 512	3FFF

NEXT PAGE

LINE 129	PIXEL 1	0000	PIXEL 2	0000	PIXEL 3	0000	PIXEL 4	0000	PIXEL 5	0001	PIXEL 6	0001	PIXEL 7	0001	PIXEL 8	0001	PIXEL 9	0002	PIXEL 10	0002	PIXEL 11	0002	PIXEL 12	0003	PIXEL 13	0003	PIXEL 14	0003	PIXEL 15	0003	PIXEL 16	PIXEL 509	007F	007F	PIXEL 510	007F	PIXEL 511	007F	PIXEL 512	007F
LINE 192	PIXEL 1	1F80	PIXEL 2	1F80	PIXEL 3	1F80	PIXEL 4	1F80	PIXEL 5	1F80	PIXEL 6	1F80	PIXEL 7	1F80	PIXEL 8	1F80	PIXEL 9	1F80	PIXEL 10	1F80	PIXEL 11	1F80	PIXEL 12	1F80	PIXEL 13	1F80	PIXEL 14	1F80	PIXEL 15	1F80	PIXEL 16	PIXEL 509	1F80	1FFF	PIXEL 510	1FFF	PIXEL 511	1FFF	PIXEL 512	1FFF

SCREEN 4 BITS PER PIXEL - MODE 4

	PIXEL 1	PIXEL 2	PIXEL 3	PIXEL 4	PIXEL 5	PIXEL 6	PIXEL 7	PIXEL 8		PIXEL 255	PIXEL 256
LINE 1	0000		0001		0002		0003			007E	007F
LINE 2	0080		0081		0082		0083			00FD	00FE
LINE 3	0100										
LINE 128	3F80										3FFF

NEXT PAGE

LINE 129	0000	0001	0002	0003							007F
LINE 192	1F80										1FFF

INPUT - OUTPUT PORT MAP																							
PORT	READ	WRITE												SOUND									
		80	40	20	10	8	4	2	1	0	80	40	20	10	8	4	2	1	0	PORT			
FF	255	ATTRIBUTES	FLASH	BRIGHT	RED PAPER	GREEN PAPER	BLUE PAPER	GREEN INK	RED INK	BLUE INK	DATA ESS	ADDR 511	7	D7	D6	D5	D4	D3	D2	D1	D0	255	FF
FE	254	KEYBOARD	FLASH	BRIGHT	RED PAPER	GREEN PAPER	BLUE PAPER	GREEN INK	RED INK	BLUE INK	DATA ESS	ADDR 511	7	D7	D6	D5	D4	D3	D2	D1	D0	254	FE
FD	253	MIDI-IN	FLASH	BRIGHT	RED PAPER	GREEN PAPER	BLUE PAPER	GREEN INK	RED INK	BLUE INK	DATA ESS	ADDR 511	7	D7	D6	D5	D4	D3	D2	D1	D0	253	FD
FC	252	V-PAGE	FLASH	BRIGHT	RED PAPER	GREEN PAPER	BLUE PAPER	GREEN INK	RED INK	BLUE INK	DATA ESS	ADDR 511	7	D7	D6	D5	D4	D3	D2	D1	D0	252	FC
FB	251	HM-PAGE	FLASH	BRIGHT	RED PAPER	GREEN PAPER	BLUE PAPER	GREEN INK	RED INK	BLUE INK	DATA ESS	ADDR 511	7	D7	D6	D5	D4	D3	D2	D1	D0	251	FB
FA	250	LM-PAGE	FLASH	BRIGHT	RED PAPER	GREEN PAPER	BLUE PAPER	GREEN INK	RED INK	BLUE INK	DATA ESS	ADDR 511	7	D7	D6	D5	D4	D3	D2	D1	D0	250	FA
F9	249	STATUS	FLASH	BRIGHT	RED PAPER	GREEN PAPER	BLUE PAPER	GREEN INK	RED INK	BLUE INK	DATA ESS	ADDR 511	7	D7	D6	D5	D4	D3	D2	D1	D0	249	F9
F8	248	PEN	FLASH	BRIGHT	RED PAPER	GREEN PAPER	BLUE PAPER	GREEN INK	RED INK	BLUE INK	DATA ESS	ADDR 511	7	D7	D6	D5	D4	D3	D2	D1	D0	248	F8

E0	224	DISC 1	RANGE 224 TO 231	USING A0, A1, A2	
E8	232	PRINTL	RANGE 232 TO 239	USING A0, A1, A2	
F0	240	DISC 2	RANGE 240 TO 247	USING A0, A1, A2	

LOWER MEMBRANE CONNECTOR

	9	10	11	12	13	14	15	16	17
PIN 8	49	33	17	34	14	62	68	60	
PIN 7	48	32	16	18	13	30	45	64 59	
PIN 6	47	31	15	1	12	29	44	58	
PIN 5	54	39	23	6	7	24	40	55	72
PIN 4	53	38	22	5	8	25	41	56	70
PIN 3	52	37	21	4	9	26	42	57	71
PIN 2	51	36	20	3	10	27	43	65 69	63
PIN 1	50 61	35	19	2	11	28	46	67	66

UPPER MEMBRANE
CONNECTOR

KEYS = 72

CODES = 69

DUPLICATE
50-61
59-64
65-69

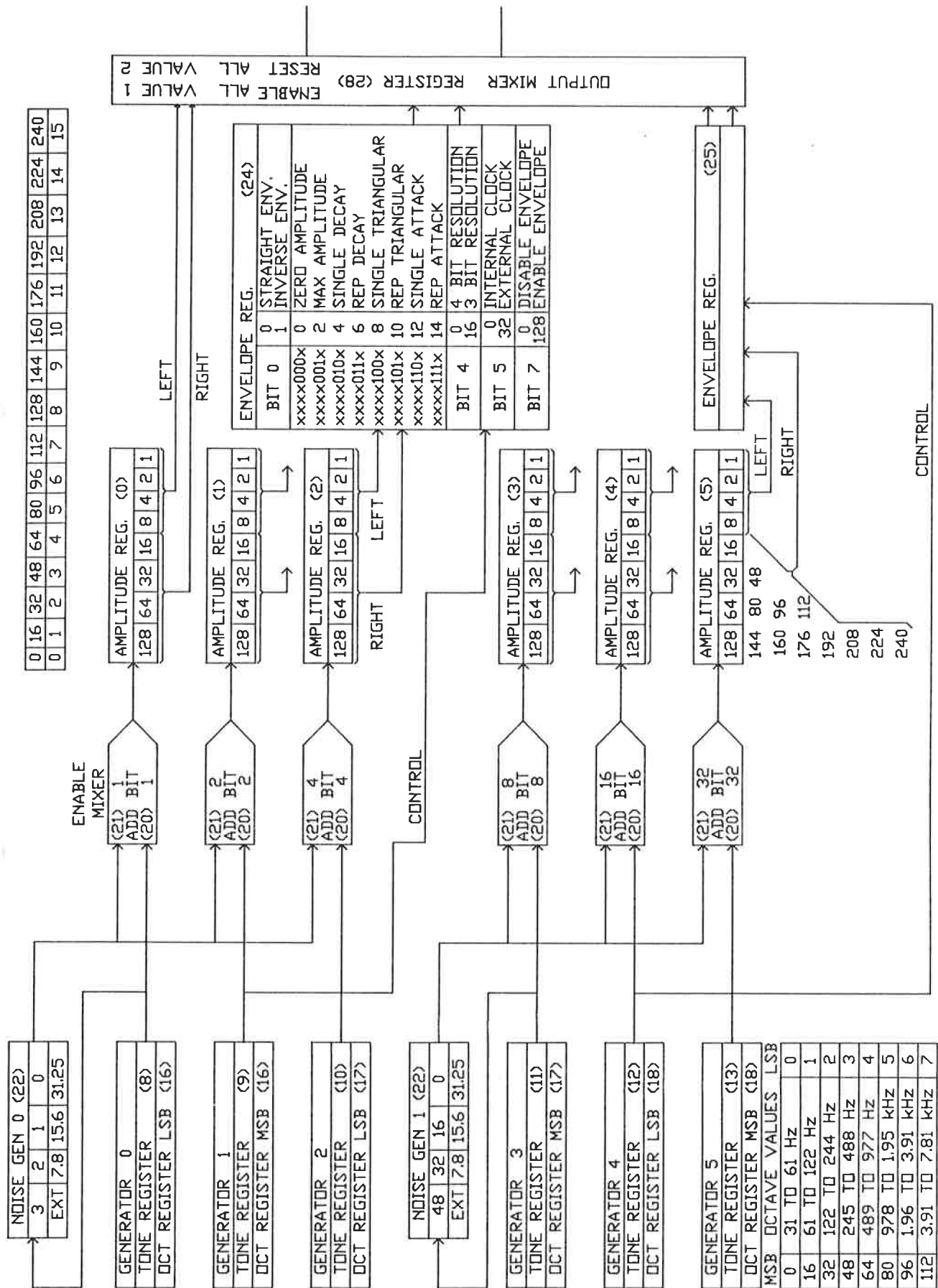
SWITCH NUMBERS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
18	19	20	21	22	23	24	25	26	27	28	29	30				
34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	
50	51	52	53	54	55	56	57	58	59	60	61	62	63	64		
65	66	67														
											68	69	70	71	72	

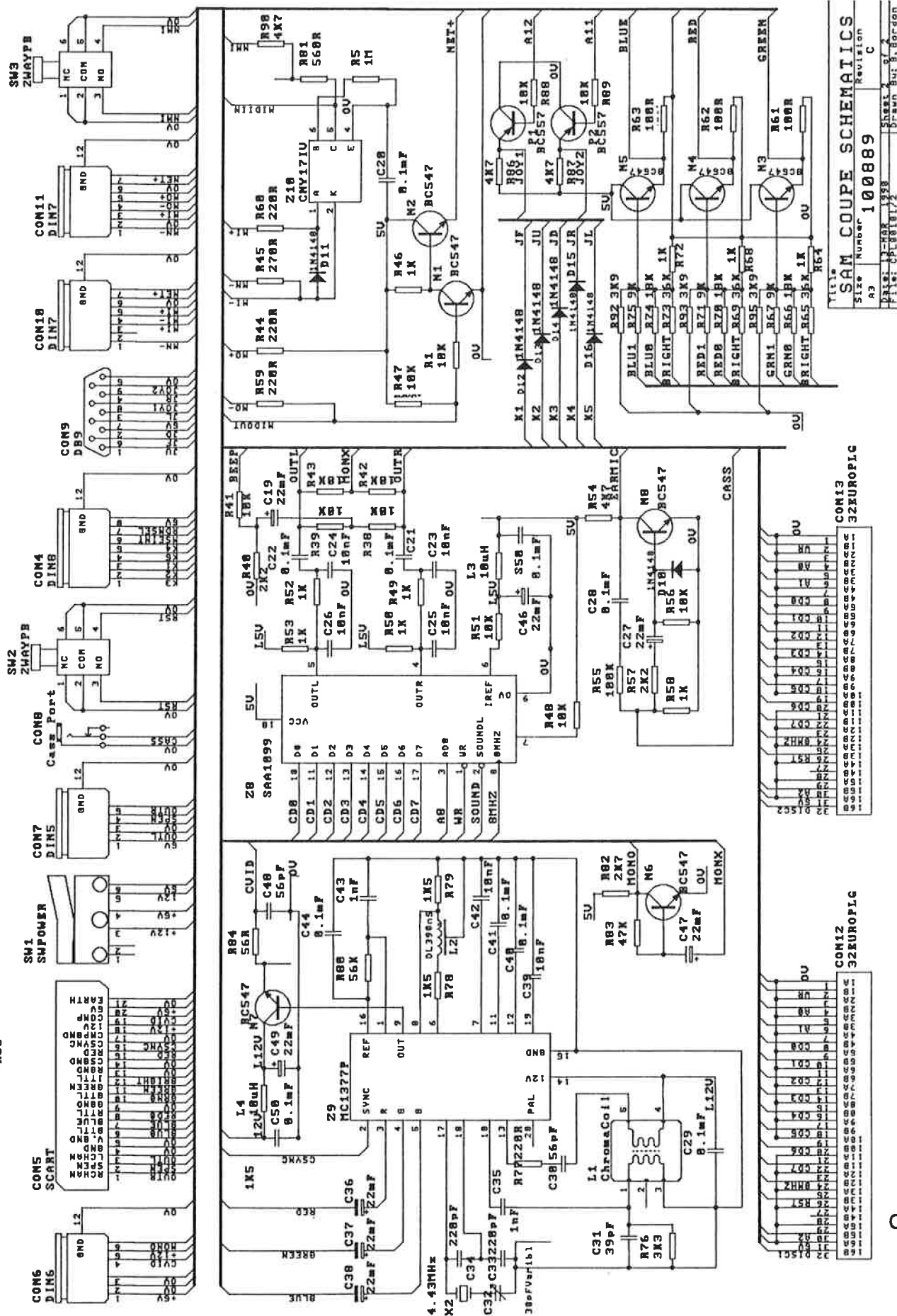
SAM-KEY 260789

PLAN VIEW

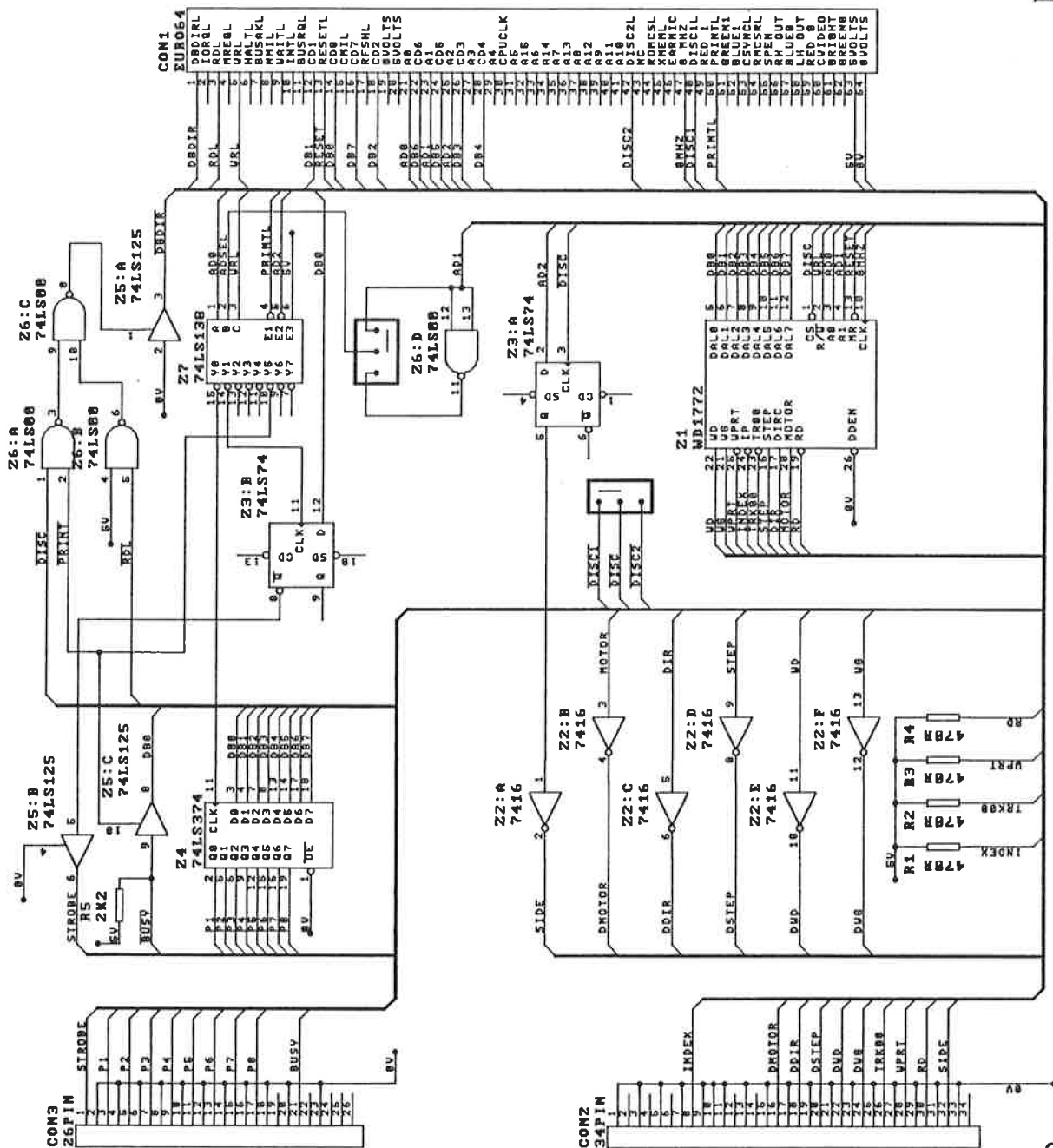
ESC	1	2	3	4	5	6	7	8	9	0	DELETE	F7	F8	F9	
TAB	<	>	Q	W	E	R	T	Y	U	I	O	P	F4	F5	F6
CAPS	A	S	D	F	G	H	J	K	L	RETURN	F1	F2	F3		
SHIFT	Z	X	C	V	B	N	M	INV	SHIFT	F0	<	>			
SYMBOL	CNTRL											EDIT	SYMBOL	<	>



R85



Title: SAM COUPE SCHEMATICS
 Size: A3
 Number: 100889
 Revision: C
 Date: 12-NOV-1988
 File: C:\PC801\2
 Drawn By: B. Gordon



C13



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5B70H
ANYIV

This address is jumped to when any interrupt occurs. Normally ANYIV contains the address of the ROM's interrupt handler (0049H). On entry to the address stored in ANYIV, the B register holds the LMPR state when the interrupt occurred, the C register holds the status port state 6-9 microseconds after the interrupt occurred. The AF, BC and HL register pairs have been stacked with the values they had when the interrupt occurred. The system variables (page 0) is paged in at 4000H. (This may have switched out the stack!) HL holds the contents of ANYIV. Your code will be entered 19-23 microseconds after the interrupt signal occurred.

For example:

```
LD    A,B
OUT   (LMPR),A
POP   HL
POP   BC
POP   AF
EI
RET
```

No keyscan or other interrupt events will happen. Alternatively, JP back to 0049H (the ROM's interrupt handler), with the B register unchanged.