MILITARY TECHNICAL COLLEGE

CAIRO - EGYPT

IMPLEMENTATION OF SOME DIGITAL IMAGE PROCESSING ALGORITHMS ON A LABORATORY-DESIGNED DIP

Mohamed EL- Said GHONIEMY*

ABSTRACT

This work presents the use of a simple labroatory-designed DIP for executing several digital image processing algorithms. These algorithms include image enhancement and restoration, geometrical corrections and zooming, feature extraction, and others.

The system used comprises, in addition to the microcomputer, a digital memory system capable of acquiring and storing up to four images. Each image is stored in a square format of 256x256 pixels x 6 bits.

The theory , flow charting, and assembly language programs for some chosen algorithms are presented.

---

* Guidance Department, MTC, Cairo, EGYPT.

INTRODUCTION

The use of DIP is essential in most of the modern applications in industry, medicine, agriculture, defence, research, and others. This work introduces a simple laboratory-realizable DIP which is necessary for most of the above applications.

The system consists of a set of cards interconnected by a bus collecting all the main functions of the system., namely:

- a timing and control card,
- an acquisition card, and
- up to 4 memory cards.

The timing and control card is designed to generate all the signals necessary for the system functioning. The acquisition card is designed to pre-adjust the video signal, to convert it into digital form, and to superimpose on it a synthetic reticle whose position is progrommable.

The system uses up to 4 memory cards, each is capable of storing one image of 256 x 256 pixels x 6 bits. Thus the system is capable of displaying coloured images.

The algorithms applied with this system include:

- image enhancement using histogram equalization, histogram modifications, recalibration, and local contrast improvement.
- feature extraction using linear and nonlinear masks.

The theoretical analysis and assembly language programming of some processing techniques are presented.

SYSTEM PRESENTATION

As shown in fig. 1 the used DIP comprises, in addition to the microcomputer, a set of cards interconnected by a bus called system bus. These cards include :

- a timing and control card designed to generate the timing and control signals necessary for the system functioning. The card is built around the SF.F 96364 (TV controller) and is used to generate the following signals:
  - clock pulses of 7.5 mHz
  - TV synchronization
  - memory management (adressing, reading, writing, refreshing,....)

- acquisition (sampling, holding, converting into digital,....)
- monitoring and memory card selection, ...
- and others

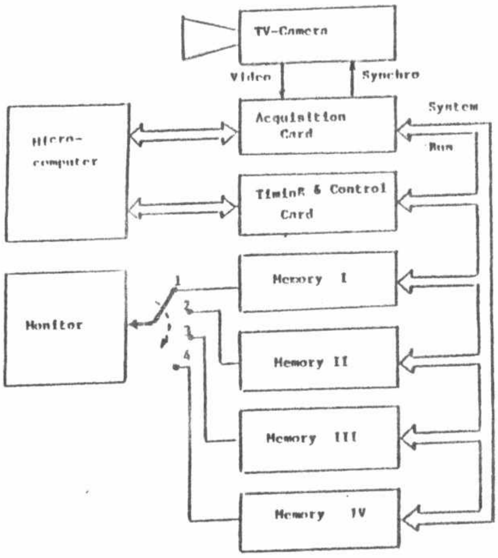
- an acquisition card (fig. 2) designed to preadjust the video signal parameters (black-level and dynamic range), to sample (at a rate of 7.5 MHZ) and hold the video signal for conversion into 6-bit digital form, and to generate a synthetic reticle with progammable position.
- Up to 4-memory cards each one (fig.3) is composed of 6 identical block of (16k x 4 bits) giving a storage capacity of 64k x 6 bits.

Thus the system is capable of storing up to 4 images of a square format of 256 x 256 pixels by 64 different grey levels. Each card is also equipped by the means of shaping the corresponding video signal for display. Of course the system is capable of storage, processing, and display of coloured signals, since it has three memory plans for R,G,B and an extra one for processing.

The memory is written once every scanning line during the flyback time- According to the sequence $(x_1 x_o)$ the demultiplexer selects one of the 4 dynamic RAMS (4116) for storing the corresponding pixel (one bit in each block). During the active time of the scanning line, the system reads all the points of the line and prepares them for display. The display is performed once every 1/5o sec, but the time of acquisition is about 5 seconds.

The used microcomputer is based on the microprocessor MC 6800, and the interfacing between it and the memory system is peformed using the peripheral interface adaptors (PIA) MC 6820.

The videa signal output from the TV-Camera is applied to the acquisition card where it is sampled at a rate of 7.5 MHZ and sent to the A/D converter. The A/D converter can be digitally controled for adjusting the black-level and the dynamic range of the video signal. The resulting 6-bit digital output is stored in one of the memory cards through the microcomputer. The stored image is sequentially read, converted into analog, and reshaped (equipped with the corresponding synchronizing pulses) for display. Thus the system is capable of displaying the input video signal and up to 4 corresponding digital ones. Hence the display and processing of coloured images is also possible.



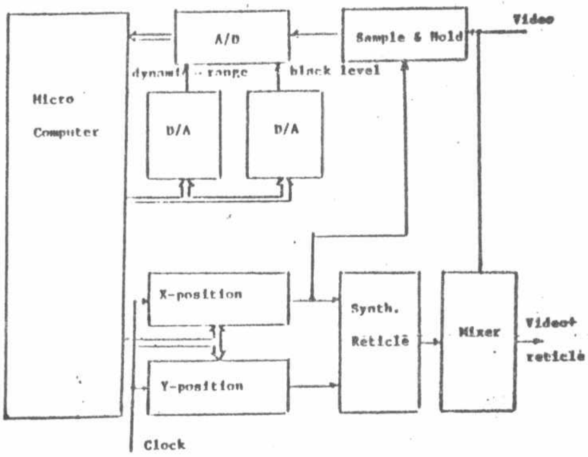


Fig.1. Block diagram of the used DIP

Fig.2. Block diagram of Acquisition unit.

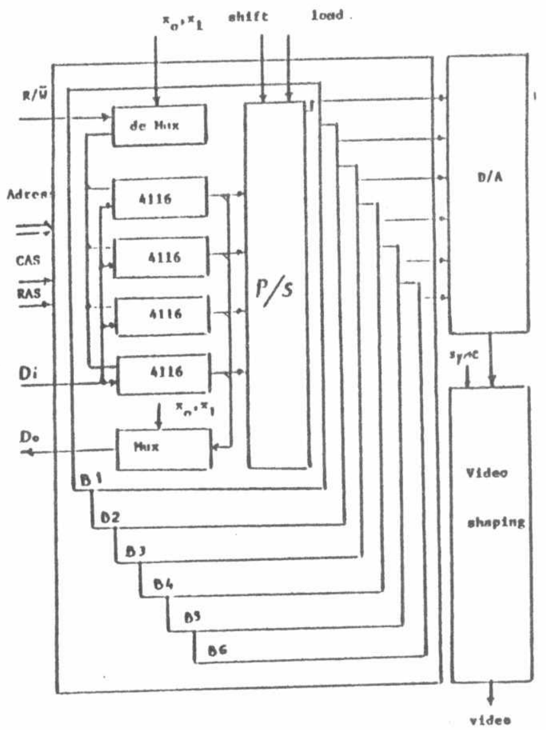


Fig.3. Block diagram of a Memory card.

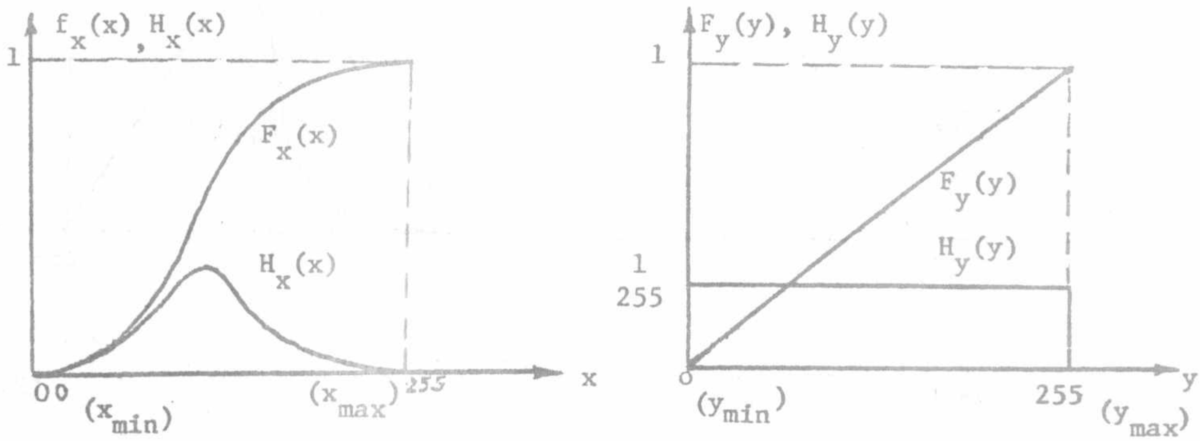
System Parameters.

- 8-bit data bus and 16-bit adress bus
- Clock frequency 7.5 MHZ
- TV standard 312 line - 50 image/sec noninterlaced.
- Digital image square format of (256 x 256) pixels
- 6-bits for representing each pixel (64 grey levels)
- minimum luminance level 00
- maximum luminance level 255 (FFH)

Image Enhancement.

1- Using histogram equalization

If the histogram of the input signal is $H_x(x)$ and the corresonding distribtion function is $F_x(x)$ then the resulting output will have the histogram $H_y(y)$ and the distribution function $F_y(y)$ as shown below :



$$y = T\,|x|$$

$$\int_{xmin}^{x} H(x)\,dx = \int_{ymin}^{y} H(y)\,dy \qquad (1.1)$$

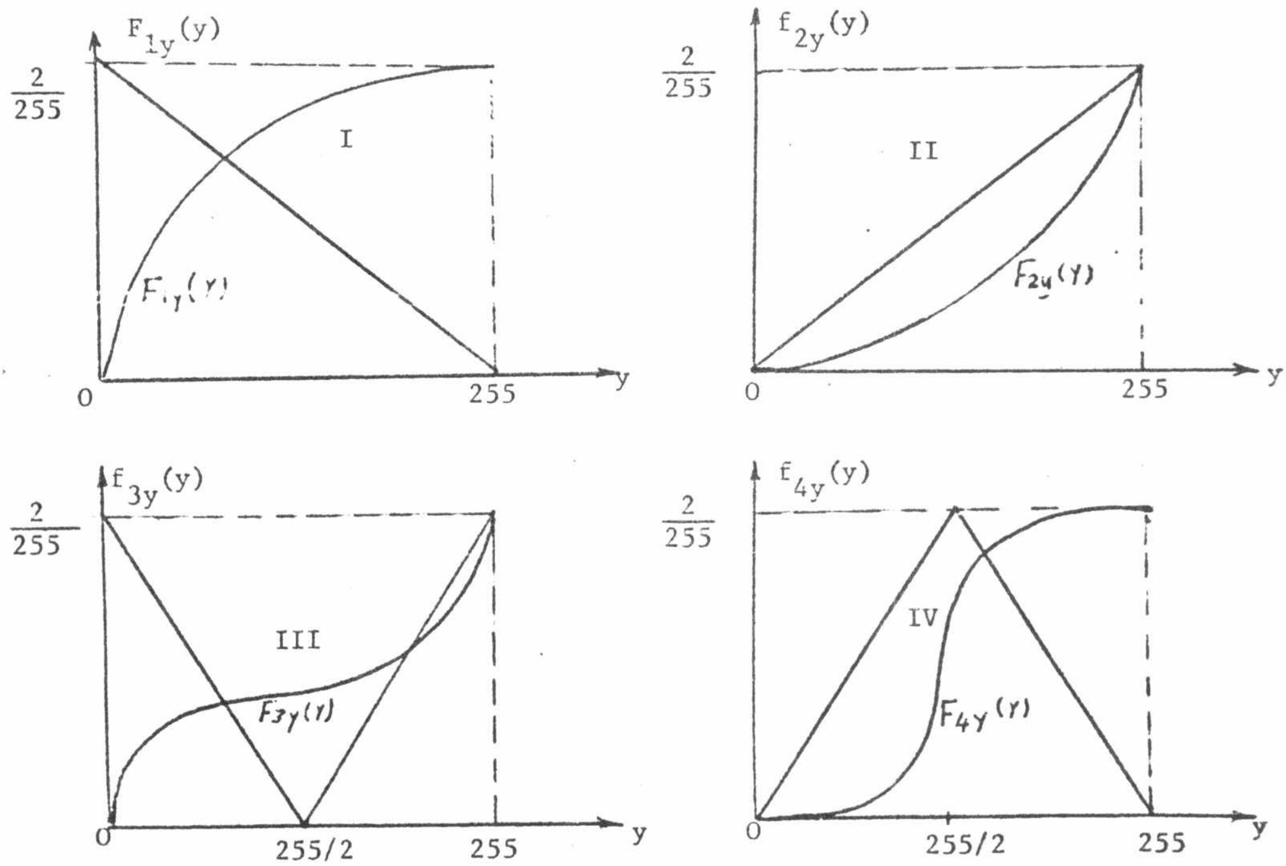
$$F_x(x) = \frac{1}{y_{max}-y_{min}} * (y-y_{min})$$

$$y = (y_{max} - y_{min}) * F_x(x) + y_{min} \qquad (1.2)$$

$$y = 255 * F_x(x)$$

2- Using histogram modification

the probability density function of the output luminance can assume one of the following forms:



$$y_1 = 255*(1-\sqrt{1-F_x(x)}) \qquad (2.1)$$

$$y_2 = 255*\sqrt{F_x(x)} \qquad (2.2)$$

$$y_{3a} = \frac{255}{2}*(1-\sqrt{1-2F_x(x)}) \qquad (2.3a)$$

$$y_{3b} = \frac{255}{2}*(1+\sqrt{2F_x(x)-1}) \qquad (2.3b)$$

$$y_{4a} = 255*\frac{F_x(x)}{2} \qquad (2.4a)$$

$$y_{4b} = 255*(1-\sqrt{\frac{1}{2} - \frac{F_x(x)}{2}}) \qquad (2.4b)$$

The following table gives the values of the output liminance as a function of the distribution function of the input luminance $F_x(x)$ for the above 4 cases.

Table 1. Histogram Modification.

$F_x(x)$			Y_1		Y_2		Y_{3a}		Y_{3b}		Y_{4a}		Y_{4b}	
F_x	$255xF_x$ Dec	Hex	Dec	Hex	Dec	Hex	Dec	Hex	Dec	Hex	Dec	Hex	Dec	Hex
0	0	0	0	00	0	00	0	00			0	00		
0.015	4	04	1	01	31	1F	1	01			22	16		
0.03	8	08	3	03	44	2c	3	03			31	1F		
0.045	12	OC	5	05	54	36	5	05			38	26		
0.06	16	10	7	07	62	3E	7	07			44	20		
0.075	20	14	9	09	70	46	9	09			49	31		
0.09	24	18	11	OB	77	4D	12	OC			54	36		
0.105	28	1C	13	OD	83	53	14	OE			58	3A		
0.120	32	20	15	OF	88	58	16	10			62	3E		
0.135	36	24	17	11	94	5E	18	12			66	42		
0.150	40	28	19	13	99	63	20	14			69	45		
0.165	44	2C	21	15	104	68	23	17			73	49		
0.180	48	30	24	18	108	6C	25	19			76	4C		
0.195	52	34	26	1A	113	71	27	1B			79	4F		
0.21	56	38	28	1C	117	75	30	1E			82	52		
0.225	60	3C	30	1E	121	79	32	20			85	55		
0.24	64	40	32	20	125	7D	35	23			88	58		
0.255	68	44	34	22	129	81	38	26			91	5B		
0.27	72	48	37	25	133	85	41	29			93	5D		
0.285	76	4C	41	27	140	8C	46	2E			98	62		
0.3	80	50	41	29	140	8C	46	2E			98	62		
0.315	84	54	43	2B	143	8F	49	31			101	65		
0.33	88	58	46	2E	146	92	53	35			103	67		
0.345	92	5C	48	30	150	96	56	38			105	69		
0.36	96	60	50	32	153	99	60	3C			108	6C		
6.375	100	64	53	35	156	9C	63	3F			110	6E		
0.39	104	68	55	37	159	9F	67	43			112	70		
0.405	108	6C	58	3A	162	A2	71	47			114	72		

SECOND A.S.A.T. CONFERENCE
21 - 23 April 1987 , CAIRO

0.42	112	70	60	3c	165	A5	76	4C			116	74		
0.435	116	74	63	3f	168	A8	81	51			118	76		
0.45	120	78	65	41	171	AB	87	57			120	78		
0.465	124	7c	68	44	174	AE	93	5D			122	7A		
0.48	128	80	71	47	177	B1	102	66			124	7C		
0.495	132	84	73	49	179	B3	114	72			126	7E		
0.51	136	88	76	4C	182	B6			145	91			128	80
0.525	140	8C	79	4F	185	B9			156	9C			130	82
0.54	144	90	82	52	187	BB			163	A3			132	84
0.555	148	94	84	54	190	BE			169	A9			134	86
0.57	152	98	87	57	193	C1			175	AF			136	88
0.585	156	9C	90	5A	195	C3			180	B4			138	8A
0.6	160	A0	93	5D	198	C6			184	B8			140	8C
0.615	164	A4	96	60	200	C8			188	BC			143	8F
0.63	168	A8	99	63	202	CA			182	C0			145	91
0.645	172	AC	103	67	205	CD			196	C4			147	93
0.66	176	B0	106	6A	207	CF			199	C7			149	95
0.675	180	B4	109	6D	210	D2			202	CA			152	98
0.69	184	B8	113	71	212	D4			206	CE			154	9A
0.705	188	BC	116	74	214	D6			209	D1			157	9D
0.720	192	C0	120	78	216	D8			212	D4			159	9F
0.735	196	C4	123	7B	219	DB			214	D6			162	A2
0.75	200	C8	127	7F	221	DD			217	D9			164	A4
0.765	204	CC	131	83	223	DF			220	DC			167	A7
0.78	208	D0	135	87	225	D1			222	DE			170	AA
0.795	212	D4	139	8B	227	E3			225	E1			173	AD
0.81	216	D8	143	8F	230	E6			227	E3			176	B0
0.825	210	D2	148	94	232	E8			230	E6			179	B3
0.84	214	D6	152	98	234	EA			232	E8			182	B6
0.855	218	DA	157	9D	236	EC			234	EA			186	BA
0.875	223	DF	164	A4	239	EF			237	ED			191	EF
0.9	230	E6	174	AE	242	F2			241	F1			197	C5
0.925	239	EC	185	B9	245	F5			245	F5			205	CD
0.95	242	F2	197	C5	249	F9			248	F8			214	D6
0.975	249	F9	214	D6	252	FC			251	FB			226	E2
1	255	FF	255	FF	255	FF			255	FF			255	FF

Recalibration

In this method, the histogram is calculated and the occupied levels are re-distributed such that the high-brightness levels are distantly interspaced in such a way that $\frac{\Delta L}{L}$ = constant for all levels.

Local improvement of contrast

This method replaces the luminance of each pixel by its difference from the mean value of a small window (3x3) centered by this pixel.

The image looses its global contrast but the local details are considerably amplified.

Contour extraction:

This is performed by the convolution of the image with a chosen mask. The used masks can be linear or nonlinear, for example.

- Linear masks

  - Laplacian masks: for example

$$M_{L1} = \begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

$$M_{L2} = \begin{bmatrix} 1 & -2 & 1 \\ -2 & 4 & -2 \\ 1 & -2 & 1 \end{bmatrix}$$

$$M_{L3} = \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

  - Compass masks : for example

$$M_{CN} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & -2 & 1 \\ -1 & -1 & -1 \end{bmatrix}$$

$$M_{CE} = \begin{bmatrix} -1 & 1 & 1 \\ -1 & -2 & 1 \\ -1 & 1 & 1 \end{bmatrix}$$

$$M_{CS} = \begin{bmatrix} -1 & -1 & -1 \\ 1 & -2 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

$$M_{CW} = \begin{bmatrix} 1 & 1 & -1 \\ 1 & -2 & -1 \\ 1 & 1 & -1 \end{bmatrix}$$

Nonlinear masks

Robert method

it replaces the luminance of the pixel (i,j) by :

$$R(i,j) = L(i,j)-L(i+1,j+1) + L(i,j+1)-L(i+1,j)$$

Sobel method

it replaces the luminance of the pixel (i,j)

by

$$S(i,j) = \left| L(i-1,j-1) + 2L(i-1,j)+ L(i-1,j+1) - L(i+1,j-1)+2L(i+1,j)+L(i+1,j+1) \right| + \left| L(i-1,j-1)+2L(i,j-1)+L(i+1,j-1) - L(i-1,j+1)+2L(i,j+1)+L(i+1,j+1) \right|$$

Appendix A includes the following subroutines (written using the Motorolla 6800 assembly language):

MDFN : image enhancement using histogram modifications

LAPMSK, LAPMSK1 : Contour extraction using Laplace Masks

RORBGRD,ROBMOD : Contour extraction using Robert and Sobel Masks.

CONCLUSION

The system, although simple, is suitable for development works in most of the scientific branches. The system capabilities in performing most of the algorit-ms used in digital image processing for B & W - and coloured images encourage to expand the system for better performance. The system can be expanded to allow for greater resolution . In addition the system can be modified for faster processing allowing for some real time applications.

REFERENCES

1- William K.Pratt" Digital Image Processing"

2- Rosenfeld & Kak" Digital Picture Processing"

3- M.Cattoen " Memoire Magerique d'Image"INPT-ENSIEEHT-GTTSI. Prance.

4- Congress AFCET-IRIA-France

5- 2eme Congres AFCET-IRIA-France.

6- PDS users guide (Motorolla Semiconductors Products Inc.

IP-1 1213

APPENDIX A

```
4701 BD 4261   LDPMSK  JSR    MASK1
4704 BD 4304           JSR    MASK
4707 4F                CLR A
4708 B7 7064           STA A  AP1
470B B7 7065           STA A  AP2
470E 86 01             LDA A  #$01
4710 B7 7067           STA A  AP1
4713 B7 7068           STA A  AP2
4716 B6 7064   PM2     LDA A  AP1
4719 B7 D000           STA A  PIA
471C B6 7065           LDA A  AP2
471F B7 D002           STA A  PIA+2
4722 BD 4084           JSR    INLEC
4725 BD 40F3           JSR    ECP
4728 B6 D004           LDA A  PIA+4
472B 44                LSR A
472C B7 7069           STA A  AL1
472F 7C D000           INC    PIA
4732 BD 40F3           JSR    ECP
4735 B6 D004           LDA A  PIA+4
4738 44                LSR A
4739 BB 7069           ADD A  AL1
473C 44                LSR A
473D B7 7069           STA A  AL1
4740 7C D000           INC    PIA

4743 BD 40F3           JSR    ECP
4746 B6 D004           LDA A  PIA+4
4749 44                LSR A
474A B7 706A           STA A  AL2
474D 7C D002           INC    PIA+2
4750 BD 40F3           JSR    ECP
4753 B6 D004           LDA A  PIA+4
4756 44                LSR A
4757 BB 706A           ADD A  AL2
475A 44                LSR A
475B B7 706A           STA A  AL2
475E 7C D002           INC    PIA+2
4761 BD 40F3           JSR    ECP
4764 B6 D004           LDA A  PIA+4
4767 44                LSR A
4768 B7 706B           STA A  AL3
476B 7A D000           DEC    PIA
476E BD 40F3           JSR    ECP
4771 B6 D004           LDA A  PIA+4
4774 44                LSR A
4775 BB 706B           ADD A  AL3

4778 44                LSR A
4779 B7 706B           STA A  AL3
477C 7A D000           DEC    PIA
477F BD 40F3           JSR    ECP
4782 B6 D004           LDA A  PIA+4
4785 44                LSR A
4786 B7 706C           STA A  AL4
4789 7A D002           DEC    PIA+2
478C BD 40F3           JSR    ECP
478F B6 D004           LDA A  PIA+4
4792 44                LSR A
4793 BB 706C           ADD A  AL4
4796 44                LSR A
4797 B7 706C           STA A  AL4
479A B6 7069           LDA A  AL1
479D BB 706A           ADD A  AL2
47A0 44                LSR A
47A1 B7 7069           STA A  AL1
47A4 B6 706B           LDA A  AL3
47A7 BB 706C           ADD A  AL4
47AA 44                LSR A

47AB [illegible]       ADD A  AL1
47AE B7 706D           STA A  AL
47B1 7C D000           INC    PIA
47B4 BD 40F3           JSR    ECP
47B7 B6 D004           LDA A  PIA+4
47BA B1 706D           CMP A  AL
47BD 24 0[illegible]   BCC    PM7
47BF 16                TAB
47C0 F6 706D           LDA A  AL
47C3 1[illegible]      SBA
47C4 7E 47C[illegible] JMP    PM5
47C7 F0 706D   PM7     SUB A  AL
47CA B7 706E   PM5     STA A  AS
[illegible]            LDA A  AP1
[illegible]            STA A  PIA
[illegible]            LDA A  AP2
[illegible]            STA A  PIA+2
[illegible]            JSR    INLEC
[illegible]            LDA A  AS
[illegible]            JSR    ECP
47E2 7C D000           INC    PIA

47E5 B6 D000           LDA A  PIA
[illegible]            STA A  AP1
[illegible]            BNE    PM3
[illegible]            INC    PIA+2
[illegible]            LDA A  PIA+2
[illegible]            STA A  AP2
[illegible]            BEQ    PM1
[illegible]    PM3     INC    AP1
[illegible]            BNE    PM1
[illegible]            INC    AP2
[illegible]            BNE    PM1
[illegible]            RTS
[illegible] 4716       PM1     JMP    PM2

4306 BD 4261   LPMSK1  JSR    MASK1
4309 BD 4304           JSR    MASK
430C 4F                CLR A
430D B7 7064           STA A  AP1
4310 B7 7065           STA A  AP2
4313 86 01             LDA A  #$01
4315 B7 7067           STA A  AP1

4318 B7 7068           STA A  AP2
431B B6 7064   MP2     LDA A  AP1
431E B7 D000           STA A  PIA
4321 B6 7065           LDA A  AP2
4324 B7 D002           STA A  PIA+2
4327 BD 4084           JSR    INLEC
432A BD 40F3           JSR    ECP
432D B6 D004           LDA A  PIA+4
4330 44                LSR A
4331 B7 7069           STA A  AL1
4334 7C D000           INC    PIA
4337 BD 40F3           JSR    ECP
433A B6 D004           LDA A  PIA+4
433D 44                LSR A
433E BB 7069           ADD A  AL1
4341 44                LSR A
4342 B7 7069           STA A  AL1
4345 7C D000           INC    PIA
4348 BD 40F3           JSR    ECP
434B B6 D004           LDA A  PIA+4
434E 44                LSR A

434F B7 706A           STA A  AL2
4352 7C D002           INC    PIA+2
4355 BD 40F3           JSR    ECP
4358 B6 D004           LDA A  PIA+4
435B 44                LSR A
435C BB 706A           ADD A  AL2
435F 44                LSR A
4360 B7 706A           STA A  AL2
4363 7C D002           INC    PIA+2
4366 BD 40F3           JSR    ECP
4369 B6 D004           LDA A  PIA+4
436C 44                LSR A
436D B7 706B           STA A  AL3
4370 7A D000           DEC    PIA
4373 BD 40F3           JSR    ECP
4376 B6 D004           LDA A  PIA+4
4379 44                LSR A
437A BB 706B           ADD A  AL3
437D 44                LSR A
437E B7 706B           STA A  AL3
4381 7A D000           DEC    PIA

4384 BD 40F3           JSR    ECP
4387 B6 D004           LDA A  PIA+4
438A 44                LSR A
438B B7 706C           STA A  AL4
438E 7A D002           DEC    PIA+2
4391 BD 40F3           JSR    ECP
4394 B6 D004           LDA A  PIA+4
4397 44                LSR A
4398 BB 706C           ADD A  AL4
439B 44                LSR A
439C B7 706C           STA A  AL4
439F B6 7069           LDA A  AL1
43A2 BB 706A           ADD A  AL2
43A5 44                LSR A
43A6 B7 7069           STA A  AL1
43A9 B6 706B           LDA A  AL3
43AC BB 706C           ADD A  AL4
43AF 44                LSR A
[illegible]            ADD A  AL1
43B3 B7 706D           STA A  AL
43B6 7C D000           INC    PIA

43B9 BD 40F3           JSR    ECP
43BC B6 D004           LDA A  PIA+4
43BF B0 706D           SUB A  AL
43C2 B7 706E   MP5     STA A  AS
[illegible] 7062       LDA A  AP1
[illegible]            STA A  PIA
[illegible] 7063       LDA A  AP2
43CE B7 D002           STA A  PIA+2
43D1 BD 4084           JSR    INLEC
43D4 B6 706E           LDA A  AS
43D7 BD 40F3           JSR    ECP
43DA 7C D000           INC    PIA
43DD B6 D000           LDA A  PIA
43E0 B7 7062           STA A  AP1
43E3 26 0[illegible]   BNE    MP3
[illegible]            INC    PIA+2
[illegible]            LDA A  PIA+2
[illegible] 7063       STA A  AP2
[illegible]            BEQ    MP1
[illegible]    MP3     INC    AP1
[illegible] 26 06      BNE    MP1

43F5 7C 7063           INC    AP2
43F8 26 01             BNE    MP1
43FA 39                RTS
43FB 7E 431B   MP1     JMP    MP2

4?FE BD 43E1   FURGPD  JSR    MASK1
4?01 BD 4304           JSR    MASK
4?04 4F                CLR A
4?05 B7 706F           STA A  PP0
4?08 B7 7070           STA A  PP2
4?0B B7 D000           STA A  PIA
4?0E B7 D002           STA A  PIA+2
4?11 BD 4?14   ZXZ1    JSR    INLEC
4?14 BD 40F3           JSR    ECP
4?17 B6 D004           LDA A  PIA+4
4?1A B7 7071           STA A  XZ1
4?1D 7C D000           INC    PIA
4?20 7C D002           INC    PIA+2
4?23 BD 40F3           JSR    ECP
4?26 B6 D004           LDA A  PIA+4
4?29 B7 7072           STA A  XZ2

4?2C B1 7071           CMP A  XZ1
4?2F 25 0?             BCS    XXX
4?31 E0 7071           SUB A  XZ1
4?34 44                LSR A
4?35 B7 7073           STA A  XZ
4?38 7E 4?45           JMP    INCR
4?3B B6 7071   XXX     LDA A  XZ1
4?3E B0 7072           SUB A  XZ2
4?41 44                LSR A
4?42 B7 7073           STA A  XZ
4?45 7A D002   INCR    DEC    PIA+2
4?48 BD 40F3           JSR    ECP
4?4B B6 D004           LDA A  PIA+4
4?4E B7 7074           STA A  ZX1
4?51 7A D000           DEC    PIA
4?54 7C D002           INC    PIA+2
4?57 BD 40F3           JSR    ECP
4?5A B6 D004           LDA A  PIA+4
4?5D B7 7075           STA A  ZX2
4?60 B1 7074           CMP A  ZX1
4?63 25 0?             BCS    ZZZ

4?65 E0 7074           SUB A  ZX1
4?68 44                LSR A
4?69 B7 7076           STA A  ZX
4?6C 7E 4?79           JMP    XXZ1
4?6F B6 7074   ZZZ     LDA A  ZX1
4?72 B0 7075           SUB A  ZX2
4?75 44                LSR A
4?76 B7 7076           STA A  ZX
4?79 BB 7073   XXZ1    ADD A  XZ
4?7C B7 7077           STA A  ZZY
[illegible] BD [illegible]  JSR  INEC
[illegible] B6 706F    LDA A  PP0
4?83 B7 D000           STA A  PIA
4?86 B6 7070           LDA A  PP2
4?8B B7 D002           STA A  PIA+2
4?8E B6 7077           LDA A  ZZY
4?91 BD 40F3           JSR    ECP
4?94 7C D000           INC    PIA
4?97 B6 D000           LDA A  PIA
4?9A B7 706F           STA A  PP0
4?9D 26 0C             BNE    ZXZ

4?9F 7C D002           INC    PIA+2
4?A2 B6 D002           LDA A  PIA+2
4?A5 B7 7070           STA A  PP2
4?A8 26 01             BNE    ZXZ
4?AA 39                RTS
4?AB 7E 4?11   ZXZ     JMP    ZXZ1
```

```
4A2A FD 43E1   MOTMOF JSR   MASKI
4A2D FD 43D4          JSR   MASK
4A30 4F               CLR A
4A31 B7 706F          STA A PPA
4A34 B7 7070          STA A PP2
4A37 B7 D000          STA A PIA
4A3A B7 D002          STA A PIA+2
4A3D BD 4614   ZXZ11  JSR   INTEC
4A40 BD 40F3          JSR   ECP
4A43 B6 D004          LDA A PIA+4
4A46 B7 7006          STA A X11
4A49 7C D000          INC   PIA
4A4C 7C D000          INC   PIA
4A4F 7C D000          INC   PIA
4A52 7C D002          INC   PIA+2
4A55 7C D002          INC   PIA+2
4A58 7C D002          INC   PIA+2
4A5B BD 40F3          JSR   ECP
4A5E B6 D004          LDA A PIA+4
4A61 B1 7006          CMP A X11

6

4A64 23 0A            BLS   B11
4A66 B0 7006          SUB A X11
4A69 44               LSR A
4A6A B7 7003          STA A Z11
4A6D 7E 4A79          JMP   B21
4A70 16        B11    TAB
4A71 B6 7006          LDA A X11
4A74 10               SBA
4A75 44               LSR A
4A76 B7 7003          STA A Z11
4A79 7A D002   B21    DEC   PIA+2
4A7C 7A D002          DEC   PIA+2
4A7F 7A D002          DEC   PIA+2
4A82 BD 40F3          JSR   ECP
4A85 B6 D004          LDA A PIA+4
4A88 B7 7007          STA A X21
4A8B 7A D000          DEC   PIA
4A8E 7A D000          DEC   PIA
4A91 7A D000          DEC   PIA
4A94 7C D002          INC   PIA+2
4A97 7C D002          INC   PIA+2

6

4A9A 7C D002          INC   PIA+2
4A9D BD 40F3          JSR   ECP
4AA0 B6 D004          LDA A PIA+4
4AA3 B1 7007          CMP A X21
4AA6 23 0A            BLS   B31
4AA8 B0 7007          SUB A X21
4AAB 44               LSR A
4AAC B7 7002          STA A Z21
4AAF 7E 4ABB          JMP   B41
4AB2 16        B31    TAB
4AB3 B6 7007          LDA A X21
4AB6 10               SBA
4AB7 44               LSR A
4AB8 B7 7002          STA A Z21
4ABB BB 7003   B41    ADD A Z11
4ABE 44               LSR A
4ABF 44               LSR A
4AC0 44               LSR A
4AC1 44               LSR A
[illegible]           STA A M1
[illegible] 7A D002   DEC   PIA+2
```

```
43CB 00        EX     FCB   0,4,3,$D,$F,$13,$17,$1B,$1F,$22,$26,$2A,$2E,$32,$36
3D
43DC 41               FCB   $41,$45,$49,$4D,$50,$54,$59,$5C,$60,$63,$67,$6B,$6F
77,$7A
43EC 7E               FCB   $7E,$82,$86,$8A,$8E,$91,$95,$99,$9D,$A1,$A4,$A8,$AC
B1,$B3
43FC B0               FCB   $B0,$BF,$C2,$C6,$CA,$CE,$D2,$D6,$DA,$DF,$E6,$EC,$F2
FF
440B 00        AM1    FCB   0,$1F,$2C,$36,$3E,$46,$4D,$53,$59,$5E,$63,$68,$6C,$
,$7[illegible]
441B 7D               FCB   $7D,$81,$85,$88,$8C,$8F,$92,$96,$99,$9C,$9F,$A2,$A5
[illegible]
[illegible] B1        FCB   $B1,$B3,$B6,$B9,$BB,$BE,$C1,$C3,$C6,$C8,$CA,$CD,$CF
[illegible]
[illegible] D3        FCB   $D3,$D8,$DD,$DF,$E1,$E3,$E6,$E8,$EA,$EC,$EF,$F2,$F5
FC,$[illegible]
[illegible] 00 AM2    FCB   0,1,3,5,7,9,$B,$D,$F,$11,$13,$15,$18,$1A,$1C,$1E,$A
[illegible]
[illegible] 27        FCB   $27,$29,$2B,$2E,$30,$32,$35,$37,$3A,$3C,$3F,$41,$44
[illegible]
[illegible] 4F        FCB   $4F,$52,$54,$57,$5A,$5D,$60,$63,$67,$6A,$6D,$71,$74
[illegible]
[illegible] 27        FCB   $[illegible],$C5,$D4,$FF
[illegible] 00 [illegible] FCB 0,1,3,5,7,9,$C,$E,$10,$12,$14,$17,$1B,$1B,$1E,$20,$
[illegible] 29        FCB   $[illegible],$2E,$31,$35,$38,$3C,$3F,$43,$47,$4C,$51,$57
[illegible]
[illegible] 91        FCB   $91,$[illegible],$C6,$C4,$C7,$CA,$CE
[illegible]
[illegible] D3        FCB   $D3,$DC,$DE,$E1,$E3,$E6,$E9,$EA,$ED,$F1,$F9,$F8,$F9
[illegible] 00 AM1    FCB   0,$[illegible],$1F,$26,$2C,$31,$36,$3A,$3E,$42,$45,$49,$4C,$
[illegible]

6                           IDF-ASSEMBLEUR    PAGE 10

[illegible] 53        FCB   $53,$[illegible],$6C,$6E,$70,$72,$74
[illegible]
[illegible] 7C        FCB   $7C,$7F,$[illegible],$8C,$8F,$91,$93,$95
[illegible]
[illegible]           FCB   $[illegible],$B3,$B6,$BA,$BF,$C8,$CB
[illegible]
4A00 BD 4337   MDEM   JSR   INCP
4A03 BD [illegible]   JSR   MASK
4A10 CE 20[illegible] LDX   #[illegible]
4A13 BD [illegible]   JSR   [illegible]
4A16 BD [illegible]   JSR   [illegible]
4A19 B7 2033          STA A [illegible]
4A1C 81 31            CMP A #$31
4A1E 27 0B            BEQ   MOD1
4A20 81 32            CMP A #$32
4A22 27 10            BEQ   MOD2
[illegible] 81 [illegible] CMP A #[illegible]
[illegible] 27 15     BEQ   MOD3
[illegible] 7E [illegible] JMP MOD4
4A2B CE [illegible] MOD1 LDX #M01
4A2E FF 2031          STX   BT
4A31 7E 4A4C          JMP   MDF
4A34 CE 4319   MOD2   LDX   #M02
4A37 7E 4A4C          JMP   MDF
4A3A CE 43[illegible] MOD3 LDX #M03
4A3D FF 2031          STX   BT
4A40 7E 4A4C          JMP   MDF
4A43 CE 43[illegible] MOD4 LDX #M04
4A46 FF 2031          STX   BT
4A49 4F        MDF    CLR A
4A4A B7 D000          STA A PIA
4A4D B7 D002          STA A PIA+2
4A50 [illegible]      LDA A #$[illegible]
[illegible] B7 20[illegible] STA A [illegible]
[illegible] FE 20[illegible] MOD1 LDX BT
[illegible] FF [illegible]   STX BT1
[illegible]           LDX   [illegible]
[illegible]           STX   [illegible]
[illegible] BD [illegible]   JSR   INTEC
[illegible] BD [illegible]   JSR   ECP
[illegible] B6 D004          LDA A PIA+4
[illegible] 44               LSR A
[illegible] 44               LSR A
[illegible] B7 201B          STA A [illegible]
```