Appendix D

Control system hardware

This Appendix lists the specifications of the industrial accelerometer and air gap sensor, and the schematic diagrams for all of the control system hardware. The various system components are listed below:

D.1 Accelerometer

The Model 3110 is a general purpose, solid-state, piezo-resistive accelerometer with built-in amplification and temperature compensation. The module consists of a silicon micro-machined accelerometer.

ICSensors, accelerometer, model 3110-002, specifications.
(Supply voltage = 10 Vdc, Ambient temperature = 25 °C)

PARAMETERS	Min	Typ	Max	Units	Notes
Range		±2		g	
Frequency Response		0-350		Hz	
Mounted Resonant Frequency		600		Hz	
Full Scale Output (- Acc)		0.5		Volts	1
Full Scale Output (+ Acc)		4.5		Volts	1
Full Scale Output Span	3.96	4.00	4.04	Volts	1
Zero Acceleration Output	2.48	2.5	2.52	Volts	1
Damping Factor		0.7			2
Accuracy		0.2	1.0	±%Span	3
Transverse Sensitivity		1.0	3.0	±%Span	
Temperature Coefficient - Span		1.0	2.0	±%Span	4
Temperature Coefficient - Zero		1.0	2.0	±%Span	4
Supply Voltage	8.0	10.0	30.0	Volts	
Supply Current		5.0		mA	
Output Resistance		0.1		Ω	
Output Noise		0.5		mV p-p	
Output Load Resistance	2			kΩ	
Acceleration Limits		20x		Rated	
Operating Temperature	-20		+85	°C	
Storage Temperature	-40		+125	°C	
Weight (Excluding Cable)		23		Grams	

Notes

1. The output voltage increases from the Zero Acceleration Output for positive acceleration and decreases for negative acceleration. The sensitivity is then 2V/Range.

2. The 0.7 damping factor represents critical damping. The damping factor is controlled to within ±10% over the entire operating temperature range. Alternate damping factors are available on a special order basis.

3. Includes repeatability, hysteresis and linearity (best straight line fit).

4. Compensated temperature range: 0 to 50 °C in reference to 25 °C.

5. See Model 3021 for an accelerometer without amplification and compensation.

6. Pin 2 provides an optional 2.5 V reference which may be used, if desired, to provide a stable zero-g reference. Thus, the full scale differential output between Pin 2 and Pin 4 would be ±2 Vdc. If a single-ended output signal is preferred (0.5-4.5 Vdc), make no connection to Pin 2.

ICSensors, Model 3110, Pin connections.

Pin:	1	2	3	4	5
Function:	Ground	Zero-g ref.	Supply (+)	Output	Test point

D.2 Air gap sensor

The non-contacting air gap sensor used is a general purpose device, which uses the power loss due to eddy currents in the target to determine the air gap or material properties. For accurate measurement of air gap, the resistivity of the target must remain constant, ie. known material and constant temperature.

Pepperl+Fuchs, Inductive displacement sensor, model IA8-M1K-I3, specifications.

PARAMETERS	VALUES
Sensing Range	3mm - 8 mm
Nominal Values:	
Damping plate, 1mm St 37	35 mm x 35 mm
Linearity (rel. to FSD)	± 3%
Zero Tolerance	± 2%
Working Voltage	15 to 30 V dc
Cut-off Frequency (3 dB)	≈ 190 Hz
Repeatability Accuracy	≤ 15 µm
Hysteresis Error	≤ 30 µm
Electrical Data:	
Output Signal	0 - 20 mA
Load Resistance R_L	0..500 Ω
Quiescent Current Consumption	< 8 mA
Ripple Current (measured @ R_L=100Ω)	≈ ±1.5% FSD
Temperature Drift (target & transducer at same temperature)	≈ ±1 %/K FSD
Current Consumption max.	≤ 35 mA
Mechanical Data:	
Ambient Temperature	-10 to +70 °C
Protection class to DIN 40 050	IP 67
Permissable shock and vibration stresses	b ≤ 30 g, T ≤ 11 ms f ≤ 55 Hz, a ≤ 1 mm
Type of connection	Wire, $\phi \leq 2.5mm^2$

The useable sensing range with the MAGLEV track as target is about 3 mm - 10 mm, with distances above 8 mm being outside the rated specification (see full data sheet).

D.3 Equipment chassis configurations

All equipment chassis are 3U high and 84E wide, ie. for single height, short eurocards (160 x 100 mm). The single electromagnet suspension contains all cards and modules in one chassis, whilst the multi-magnet vehicle uses 2 chassis: one with the DAC and the power controllers, and the other with the ADCs, processors and PSUs.

D.3.1 Single electromagnet suspension system

Logic & Power Control Chassis

Card:	EMCA	PSU	-	DAC	-	TMB	TMB	IPIF	ADC	SAP	CONN
Width:	20	10	4	4	4	10	10	4	4	4	10

D.3.2 Vehicle suspension system

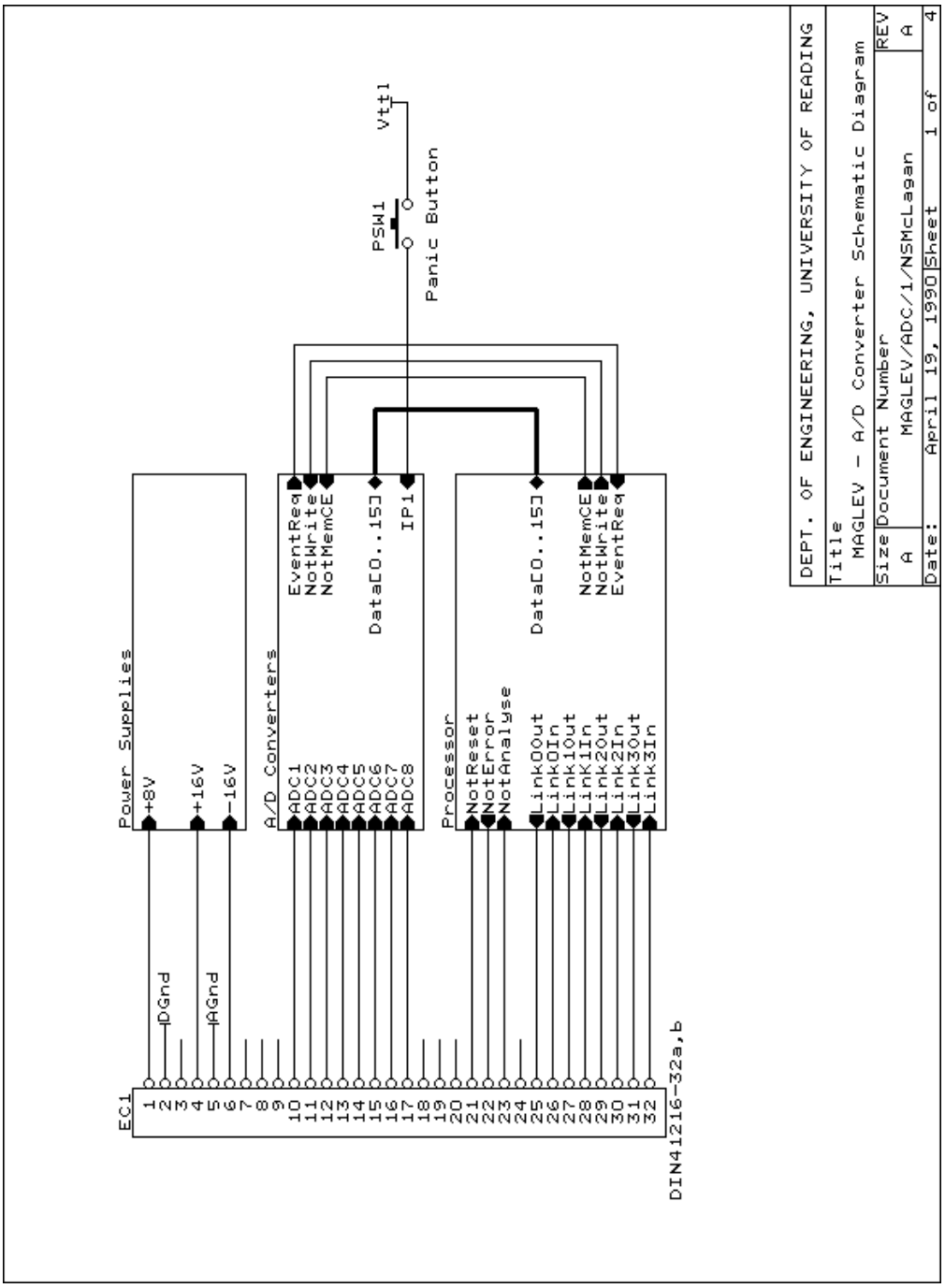
Logic Control Chassis

Card:	PSU	PSU	-	OPIF	TMB	TMB	TMB	IPIF	-	ADC	SAP	CONN
Width:	10	10	4	4	10	10	10	4	4	4	4	10

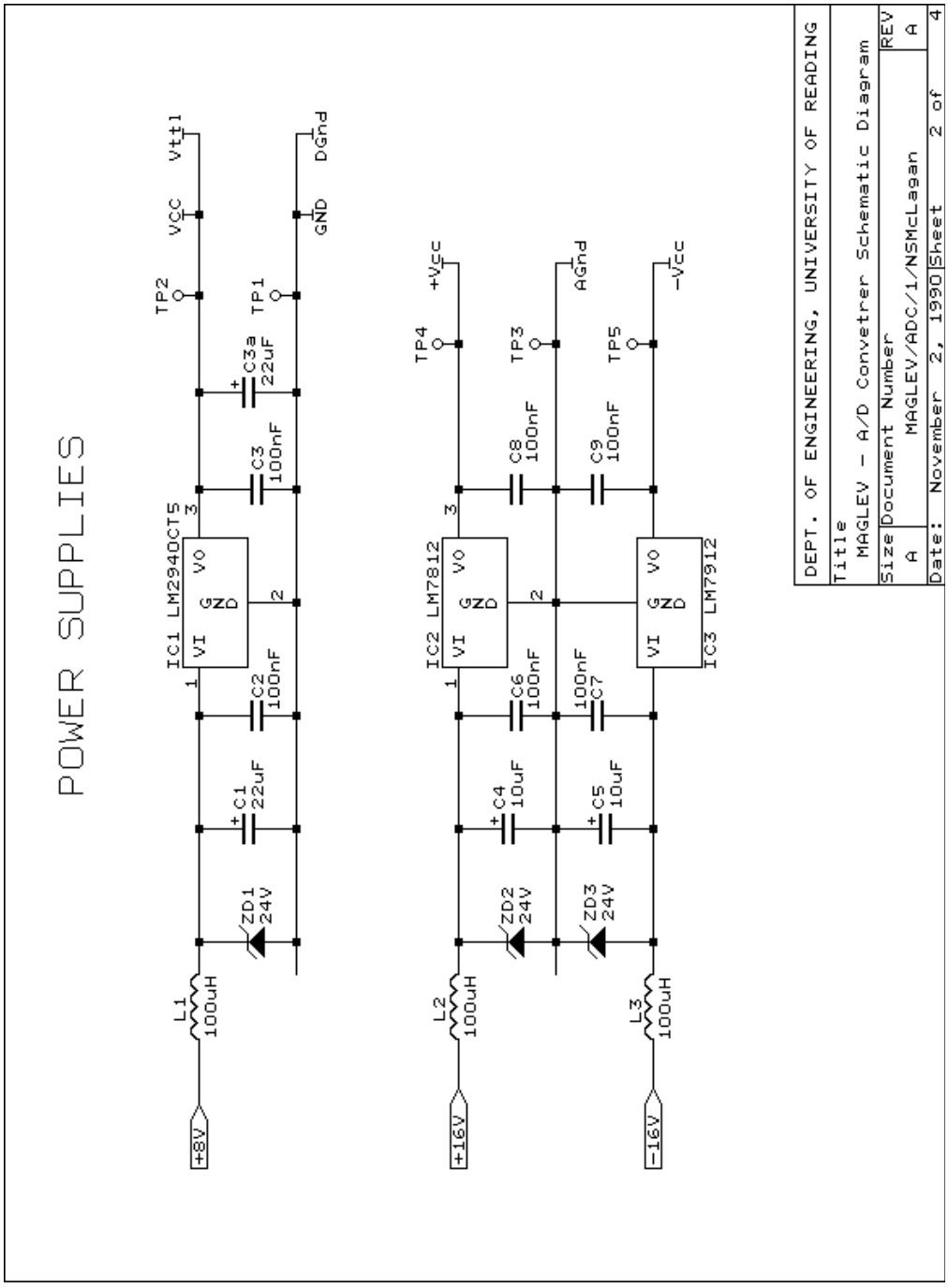
Power Control Chassis

Card:	EMCA	EMCA	EMCA	EMCA	DAC
Width:	20	20	20	20	4

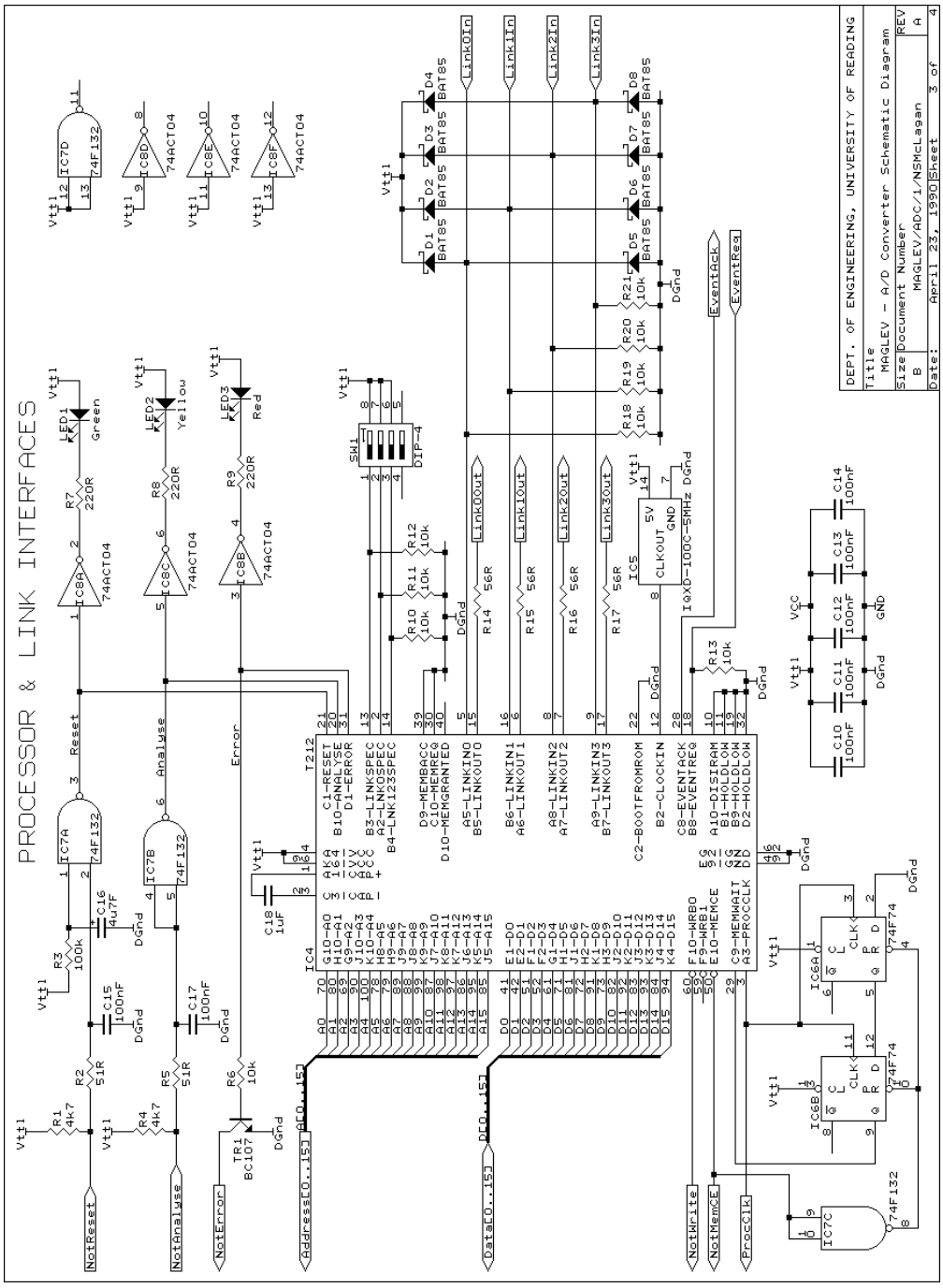
D.4 Analogue-to-digital converter (8 channel) card



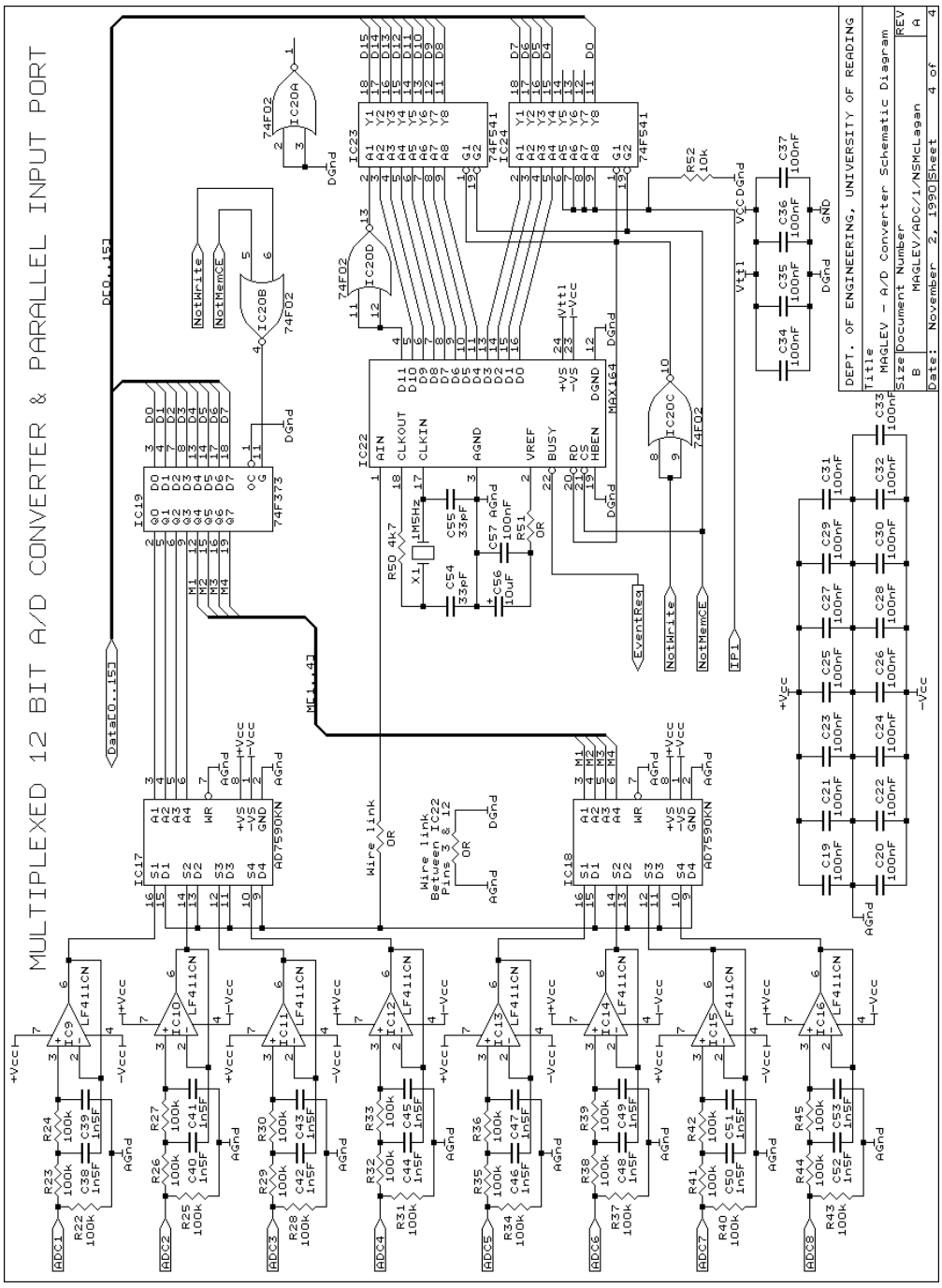
D.4.1 ADC card power supplies



D.4.2 ADC processor & link interfaces



D.4.3 ADC anti-alias filters, multiplexer & converter



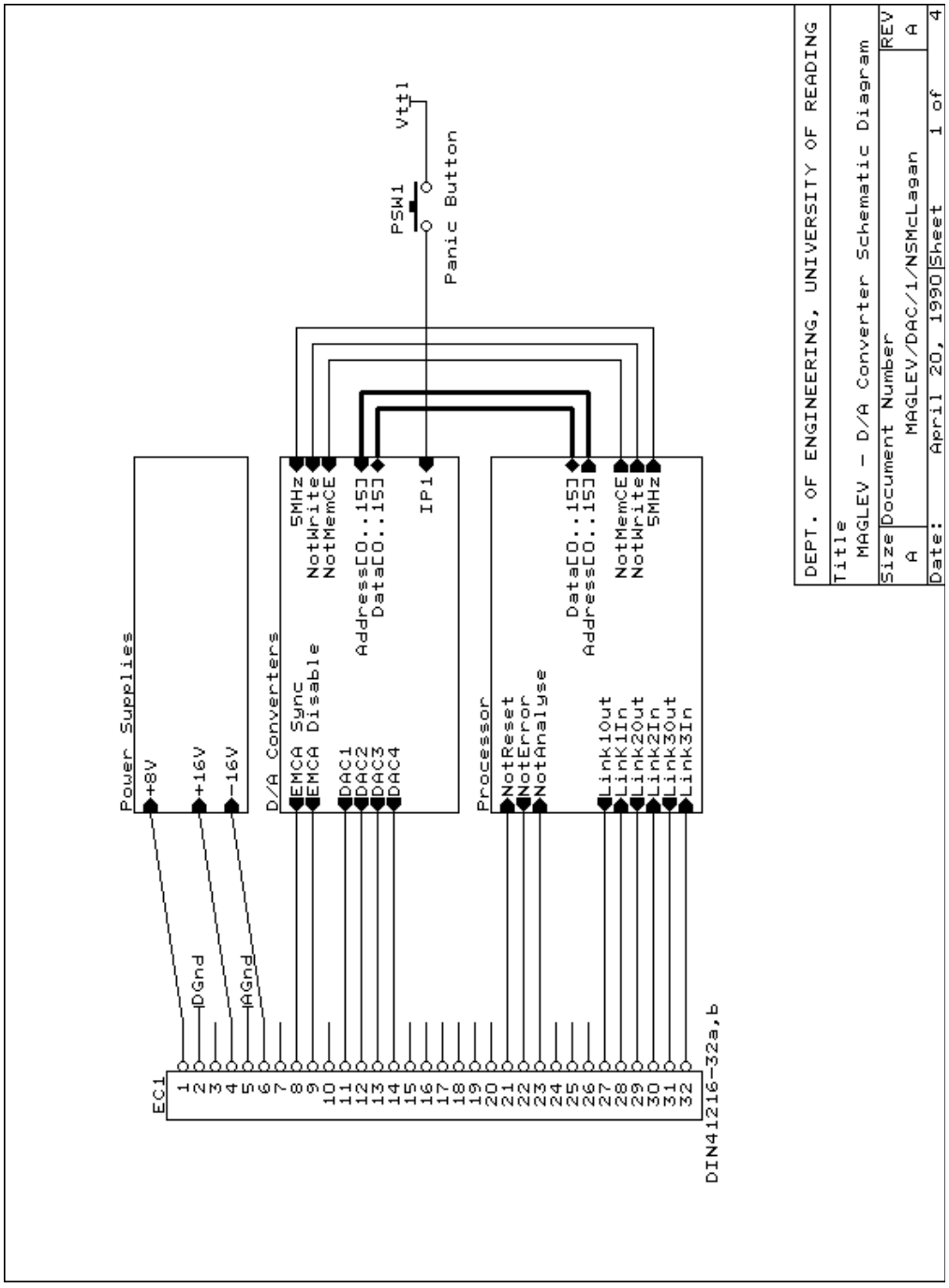
D.4.4 ADC card component parts list

MAGLEV - A/D Converter Schematic Diagram Revised: November 2, 1990
MAGLEV/ADC/1/N.S.McLagan Revision: A

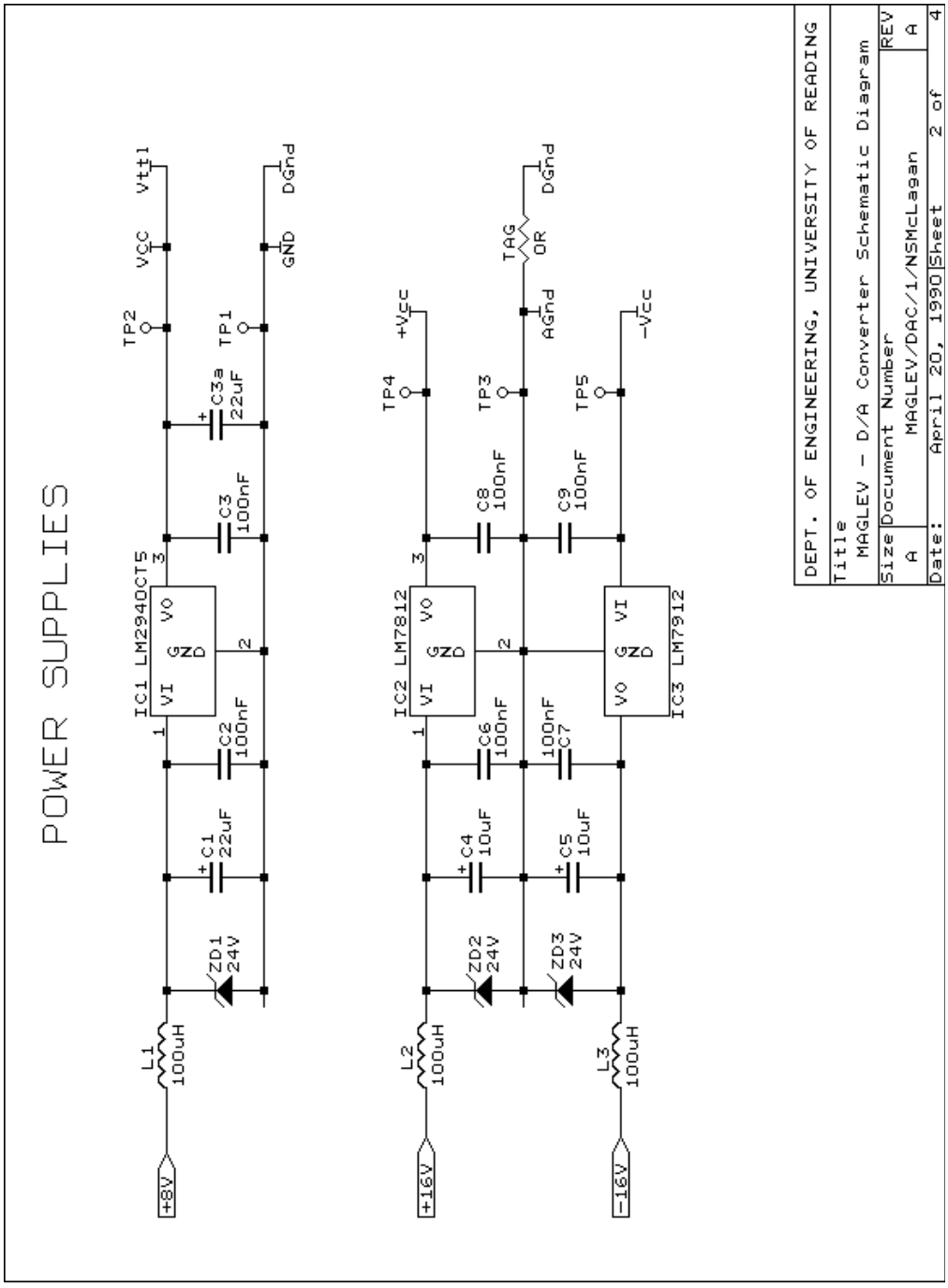
Bill Of Materials November 2, 1990 16:09:26 Page 1

Quantity	Reference	Part
1	C1	22uF
1	C16	4u7F
1	C18	1uF
34	C2,C3,C6,C7,C8,C9,C10, C11,C12,C13,C14,C15,C17, C19,C20,C21,C22,C23,C24, C25,C26,C27,C28,C29,C30, C31,C32,C33,C34,C35,C36, C37,C57,C58	100nF
16	C38,C39,C40,C41,C42,C43, C44,C45,C46,C47,C48,C49, C50,C51,C52,C53	1n5F
3	C4,C5,C56	10uF
2	C54,C55	33pF
8	D5,D1,D2,D3,D4,D6,D7,D8	BAT85
1	EC1	DIN41216-32a,b
1	IC1	LM2940CT5
8	IC16,IC9,IC10,IC11,IC12, IC13,IC14,IC15	LF411CN
2	IC17,IC18	AD7590KN
1	IC19	74F373
1	IC2	LM7812
1	IC20	74F02
1	IC22	MAX164BCNG
2	IC23,IC24	74F541
1	IC3	LM7912
1	IC4	T212
1	IC5	IQXD-100C-5MHz
1	IC6	74F74
1	IC7	74F132
1	IC8	74ACT04
3	L2,L1,L3	100uH
1	LED1	Green
1	LED2	Yellow
1	LED3	Red
1	PSW1	Push Switch
3	R1,R4,R50	4k7
4	R15,R14,R16,R17	56R
2	R2,R5	51R
25	R3, R22,R23,R24,R25,R26, R27,R28,R29,R30,R31,R32, R33,R34,R35,R36,R37,R38, R39,R40,R41,R42,R43,R44, R45	100k
1	R51	Wire link
10	R6,R10,R11,R12,R13,R18, R19,R20,R21,R52	10k
3	R7,R8,R9	220R
1	SW1	DIP-4 way SPST
5	TP2,TP1,TP3,TP4,TP5	Test pins
1	TR1	BC107
1	X1	1.5 MHz crystal
3	ZD1,ZD2,ZD3	24V

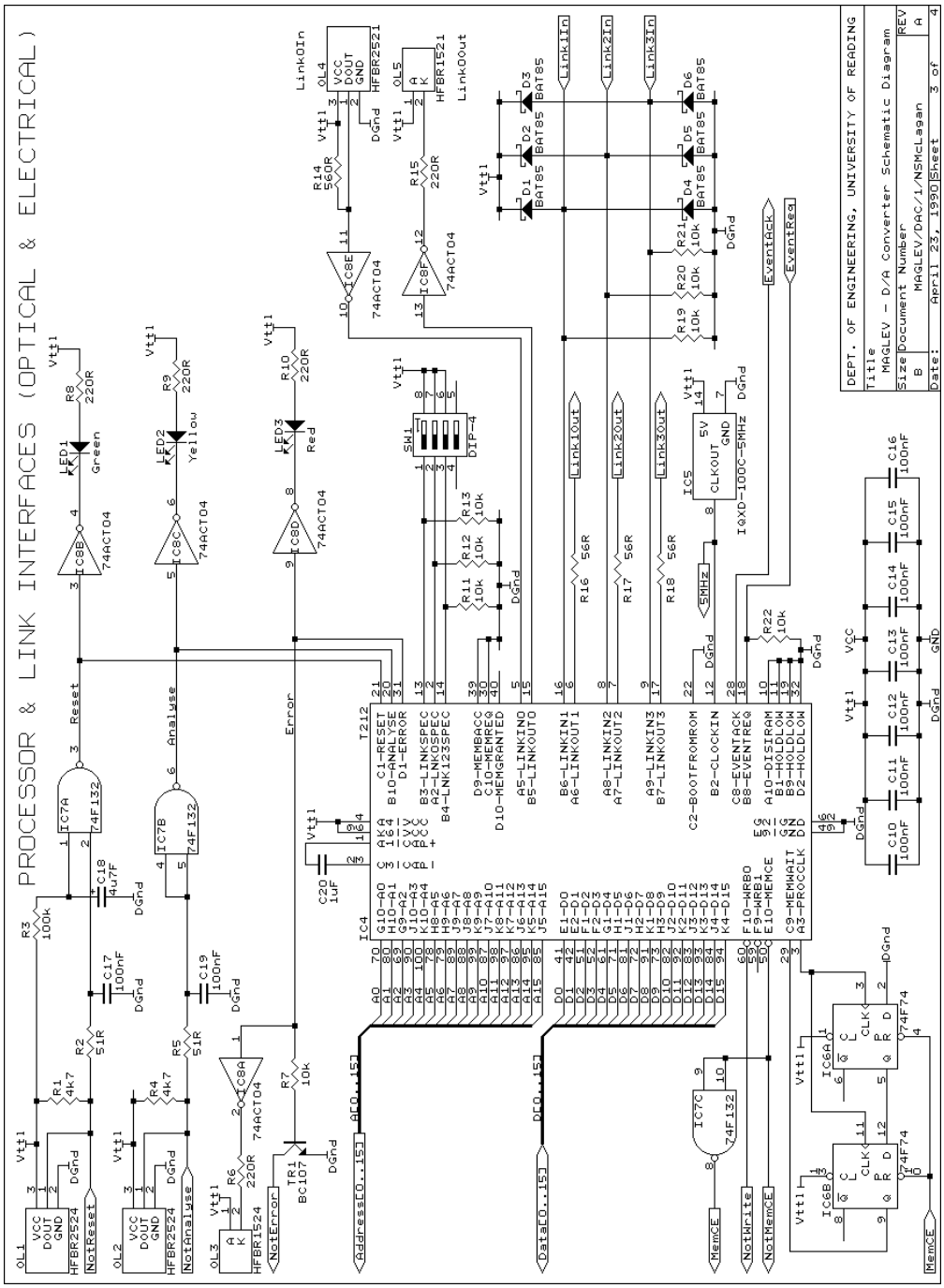
D.5 Digital-to-analogue converter (4 channel) card



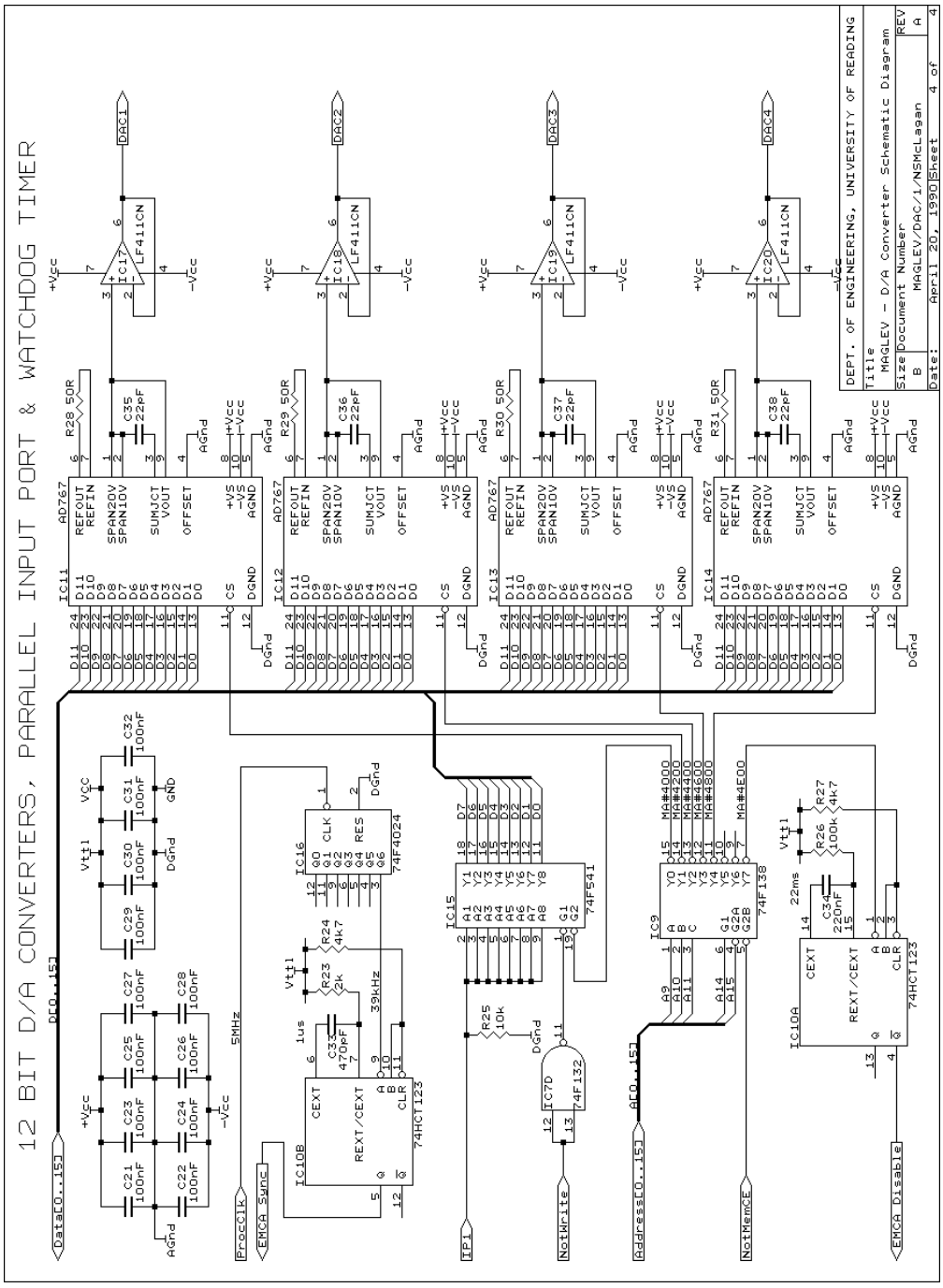
D.5.1 DAC card power supplies



D.5.2 DAC processor & link interfaces (optical & electrical)



D.5.3 DAC converters & watchdog timer



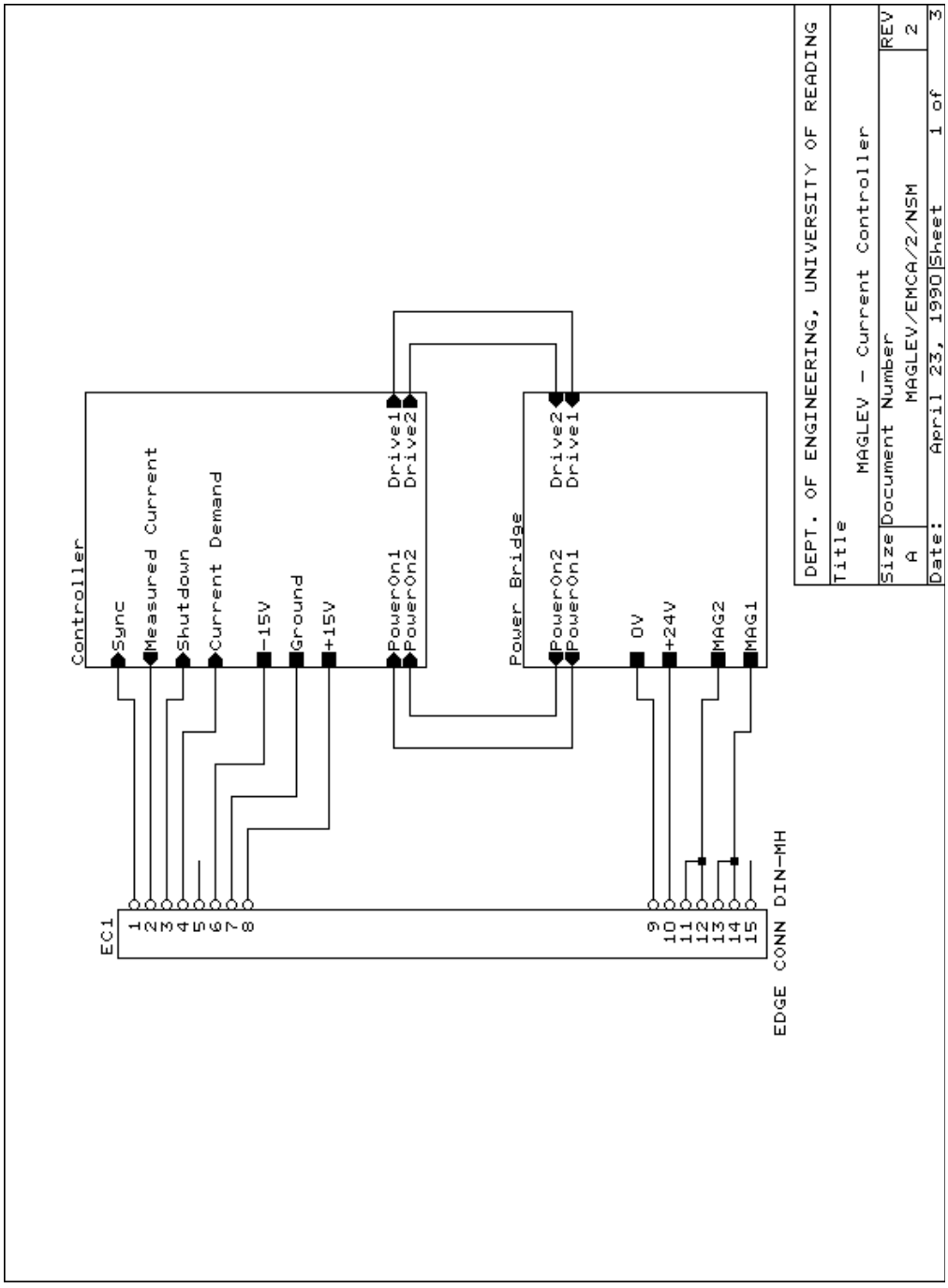
D.5.4 DAC card component parts list

MAGLEV - D/A Converter Schematic Diagram Revised: January 24, 1990
MAGLEV/DAC/1/N.S.McLagan Revision: A

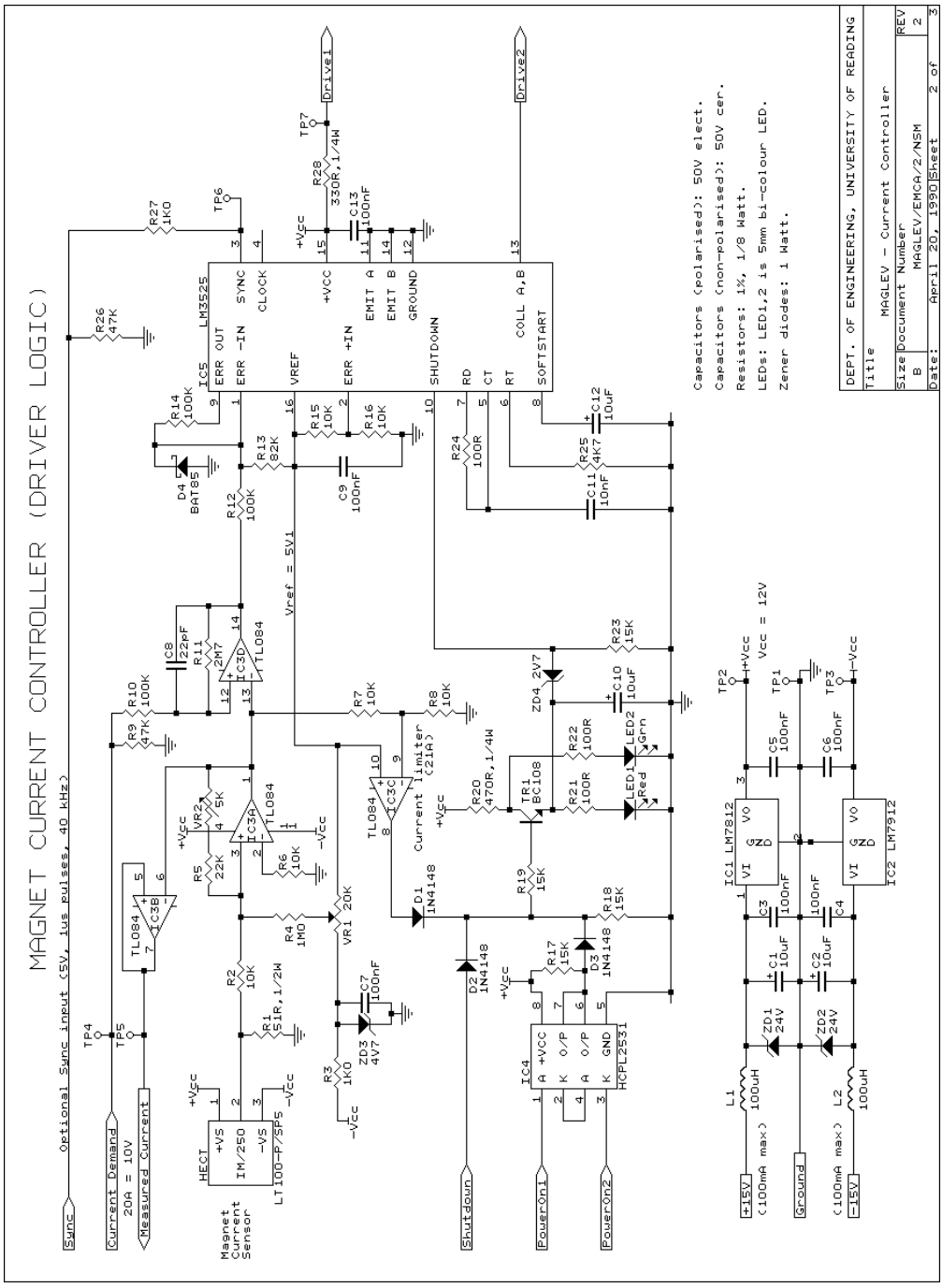
Bill Of Materials January 25, 1990 16:09:15 Page 1

Quantity	Reference	Part
1	C1	22uF
1	C18	4u7F
27	C2,C3,C6,C7,C8,C9,C10, C11,C12,C13,C14,C15,C16, C17,C19,C21,C22,C23,C24, C25,C26,C27,C28,C29,C30, C31,C32	100nF
1	C20	1uF
1	C33	470pF
1	C34	220nF
4	C35,C36,C37,C38	22pF
2	C4,C5	10uF
6	D6,D2,D3,D4,D7,D8	BAT85
1	EC1	DIN41216-32a,b
1	IC1	LM2940CT5
1	IC10	74HCT123
4	IC11,IC12,IC13,IC14	AD767
1	IC15	74F541
1	IC16	74ACT4024
4	IC17,IC18,IC19,IC20	LF411CN
1	IC2	LM7812
1	IC3	LM7912
1	IC4	T212
1	IC5	IQXD-100C-5MHz crystal
1	IC6	74F74
1	IC7	74F132
1	IC8	74ACT04
1	IC9	74F138
3	L2,L1,L3	100uH
1	LED1	Green
1	LED2	Yellow
1	LED3	Red
2	OL1,OL2	HFBR2524
1	OL3	HFBR1524
1	OL4	HFBR2521
1	OL5	HFBR1521
1	PSW1	Push switch
4	R1,R4,R24,R27	4k7
2	R15,R6	100R
3	R16,R17,R18	56R
2	R2,R5	51R
1	R23	2k
4	R28,R29,R30,R31	50R
2	R3,R26	100k
1	R14	560R
9	R7,R11,R12,R13,R19,R20, R21,R22,R25	10k
3	R8,R9,R10	220R
1	SW1	DIP-4 way SPST
1	TAG	Earth tag
5	TP2,TP1,TP3,TP4,TP5	Test pins
1	TR1	BC107
3	ZD1,ZD2,ZD3	24V

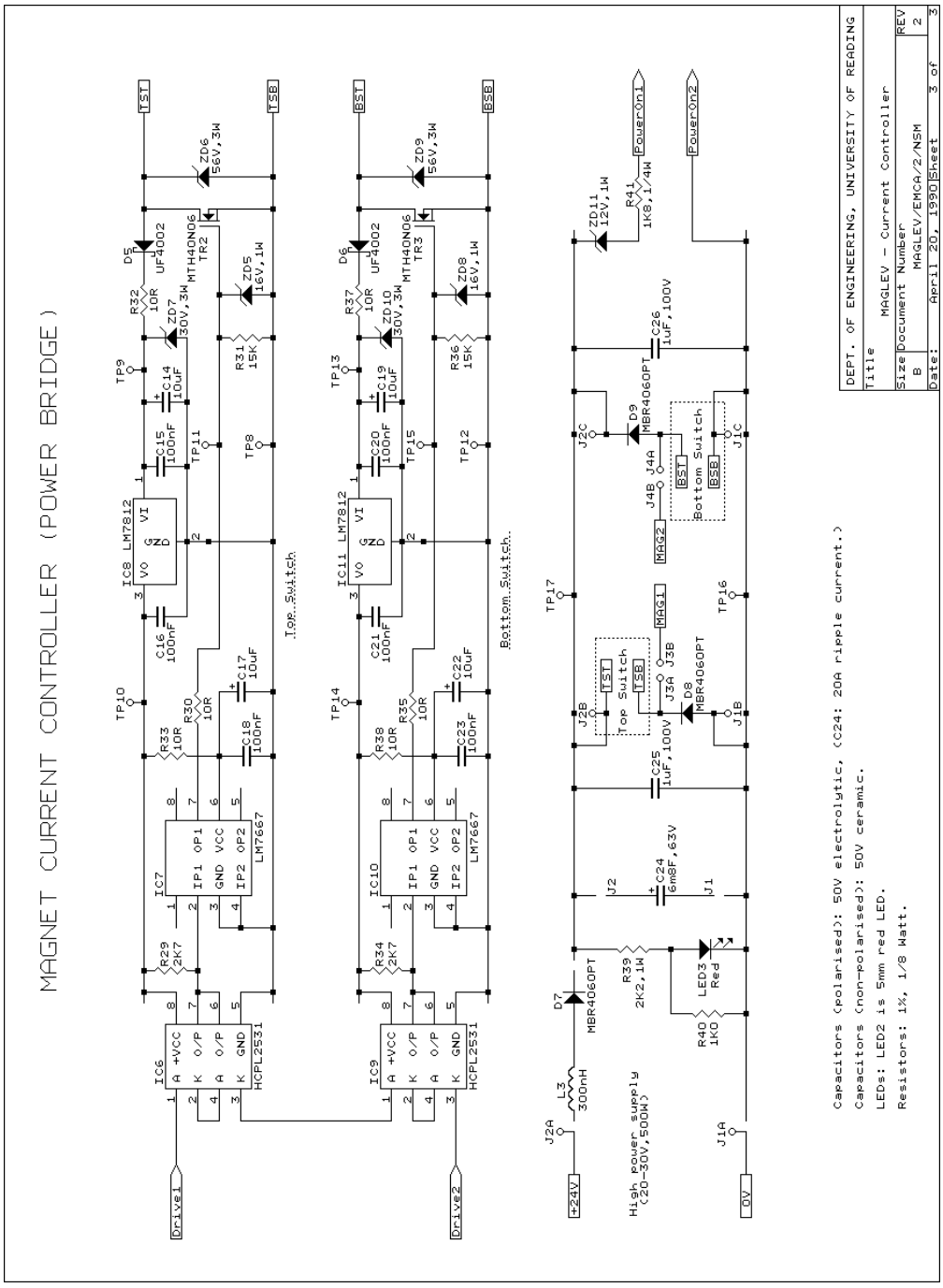
D.6 Electromagnet current controller module



D.6.1 EMCA controller logic



D.6.2 EMCA power switching bridge

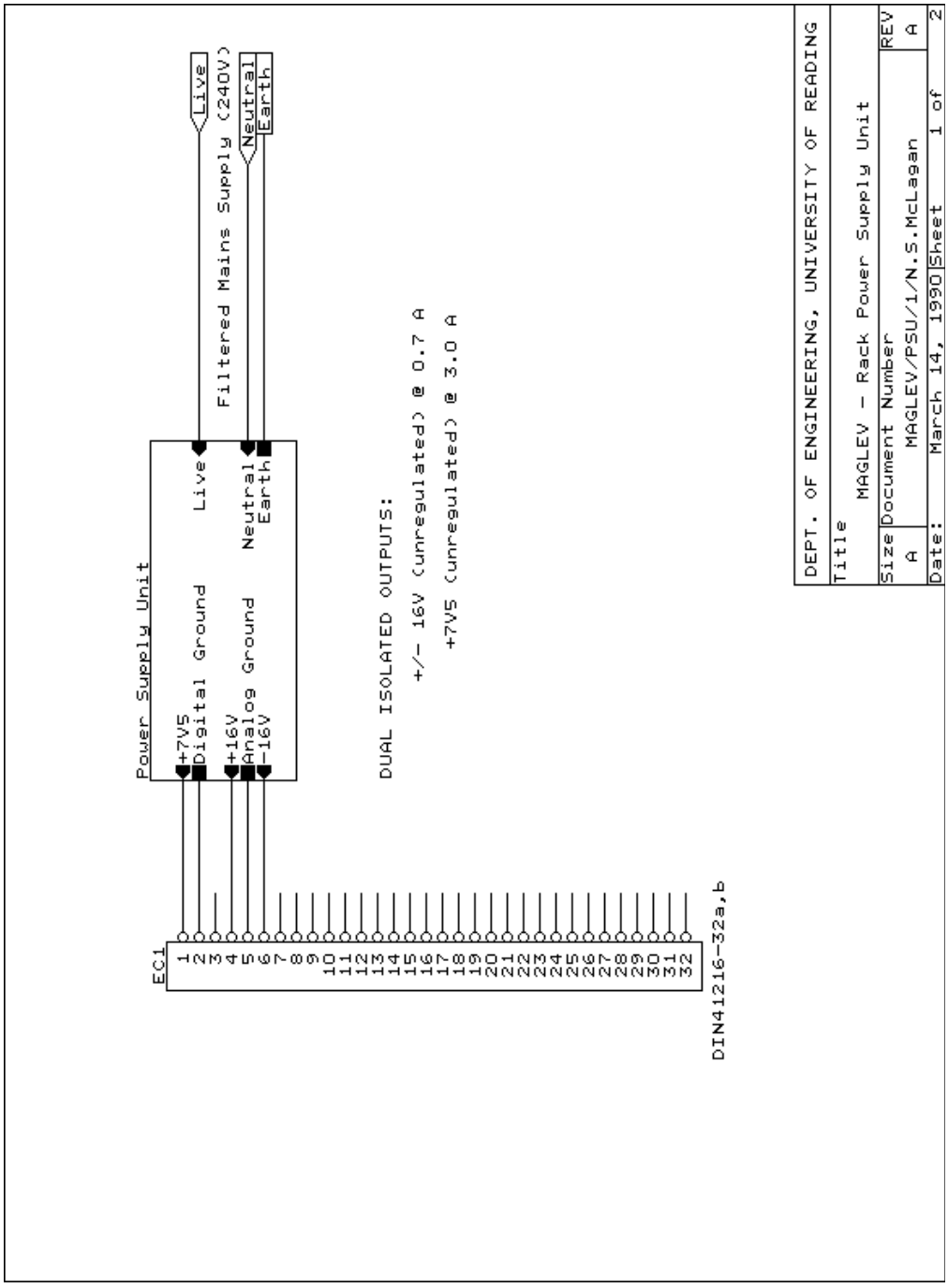


D.6.3 EMCA card component parts list

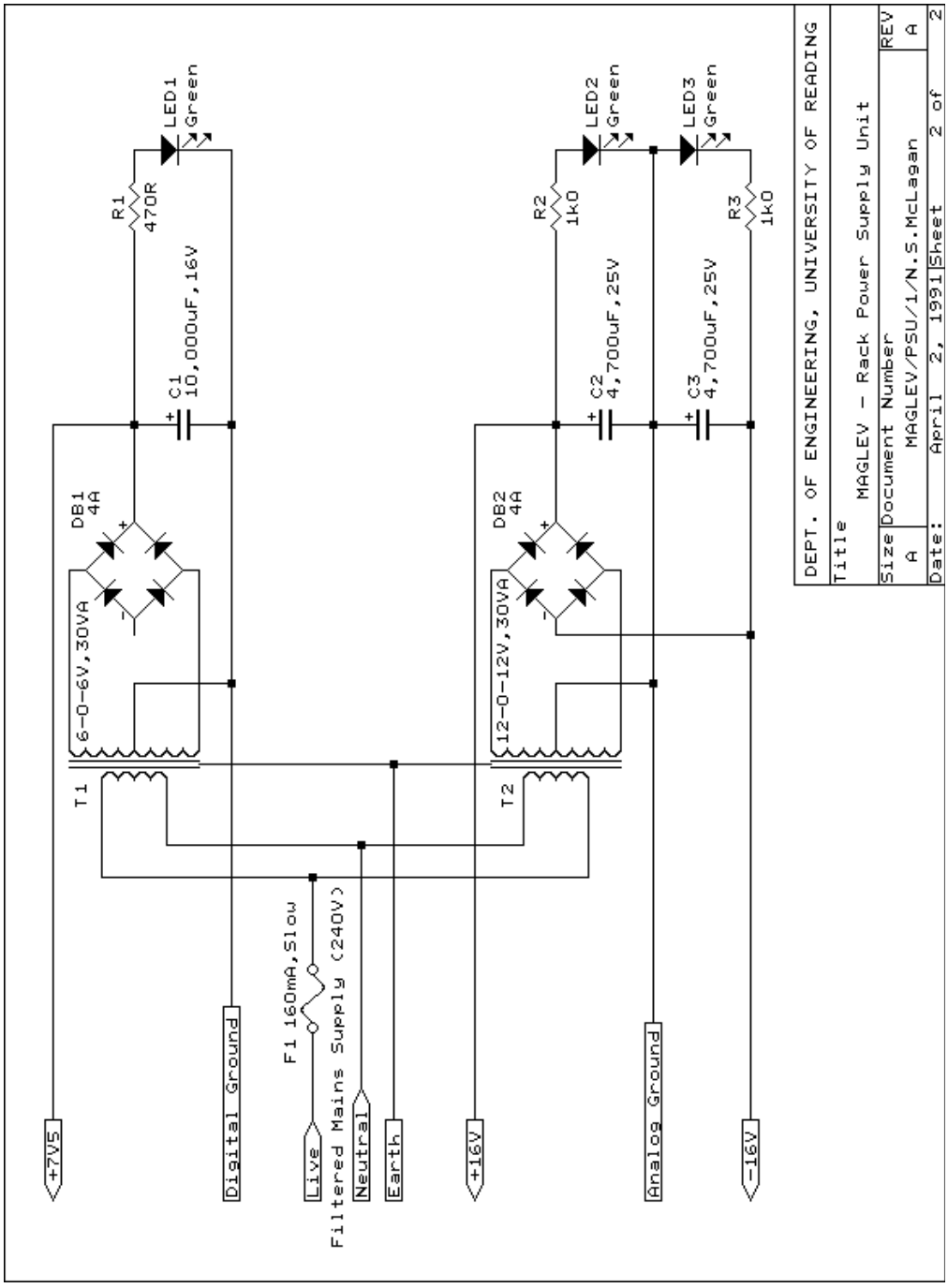
ELECTROMAGNET CURRENT AMPLIFIER **Revised: November 8, 1989**
MAGLEV/EMCA/2/N.S.McLagan **Revision: A**

Quantity	Reference	Part
1	C11	10nF
8	C14,C1,C2,C17,C19,C22 C10,C12	10uF
13	C15,C3,C4,C5,C6,C7,C9, C13,C16,C18,C20,C21,C23	100nF
1	C24	6m8F,63V
2	C25,C26	1uF,63V
1	C8	22pF
3	D2,D1,D3	1N4148
1	D4	BAT85
2	D5,D6	UF4002
3	D7,D8,D9	MBR4060PT
1	EC1	DIN41216 'MH'
1	HECT	LT100-P/SP5
1	IC2	LM7912
1	IC3	TL084
1	IC5	LM3525
3	IC6,IC4,IC9	HCPL2531
2	IC7,IC10	LM7667
3	IC8,IC1,IC11	LM7812
10	J1A,J1B,J1C,J2A,J2B,J2C, J3A,J3B,J4A,J4B	20A Jumpers
2	L1,L2	100uH
1	L3	300nH
1	LED2	Green LED
2	LED3,LED1	Red LED
1	R1	51R,1/2W
3	R10,R12,R14	100K
1	R11	2M7
1	R13	82K
6	R2,R6,R7,R8,R15,R16	10K
1	R20	470R,1/4W
3	R21,R22,R24	100R
1	R25	4K7
1	R28	330R,1/4W
2	R29,R34	2K7
6	R31,R17,R18,R19,R23,R36	15K
6	R33,R30,R32,R35,R37,R38	10R
1	R39	2K2,1W
1	R4	1M0
3	R40,R3,R27	1K0
1	R41	1K8,1/4W
1	R5	22K
2	R9,R26	47K
17	TP8,TP1,TP2,TP3,TP4,TP5, TP6,TP7,TP9,TP10,TP11, TP12,TP13,TP14,TP15,TP16,TP17	Test pins
1	TR1	BC108
2	TR2,TR3	MTH40N06
1	VR1	20K
1	VR2	5K
2	ZD1,ZD2	24V
1	ZD11	12V,1W
1	ZD3	4V7
1	ZD4	2V7
2	ZD6,ZD9	56V,3W
2	ZD7,ZD10	30V,3W
2	ZD8,ZD5	16V,1W

D.7 Chassis power supply module



D.7.1 PSU supply conditioning



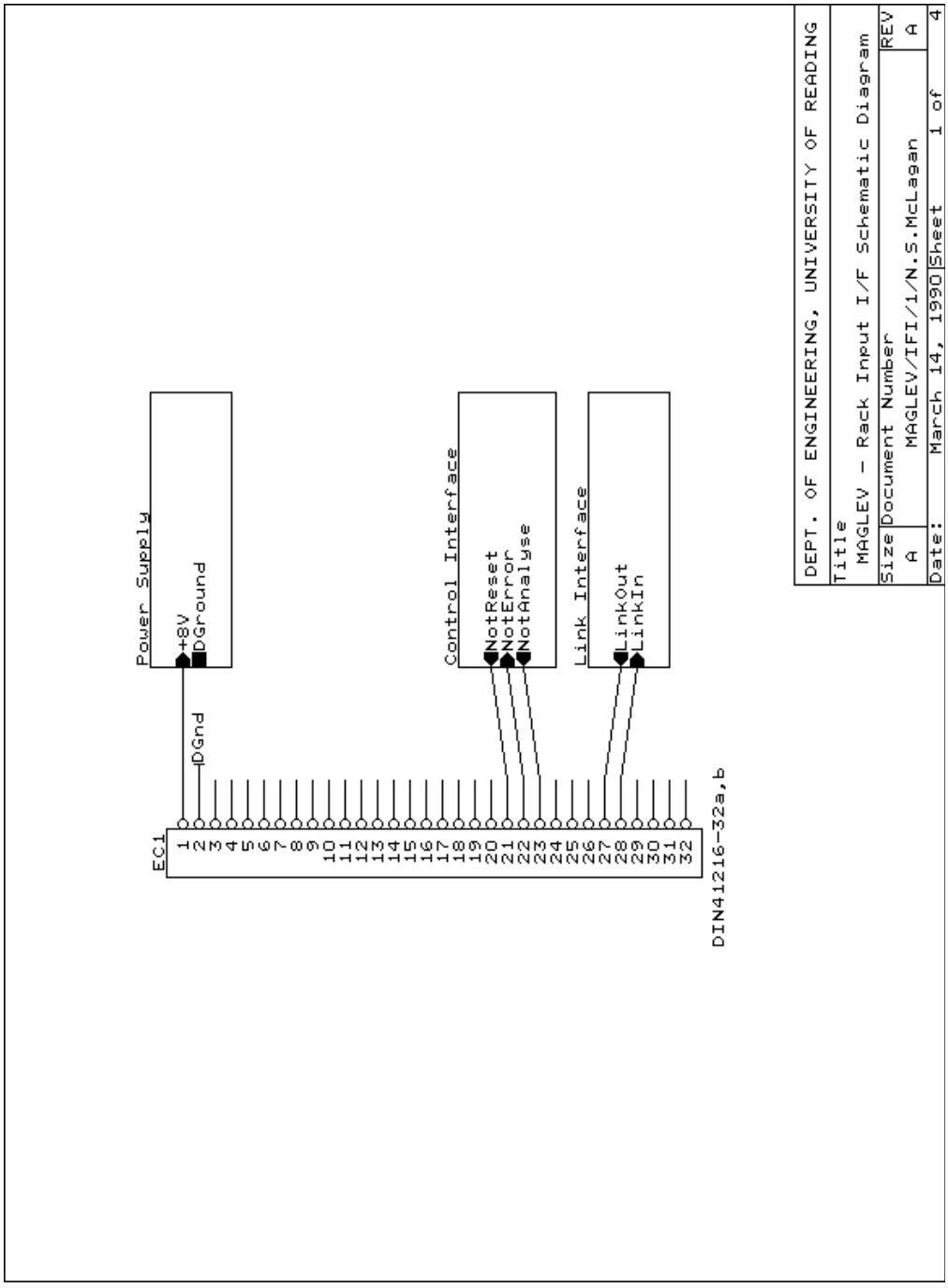
D.7.2 PSU card component parts list

MAGLEV - Rack Power Supply Unit **Revised: March 14, 1990**
MAGLEV/PSU/1/N.S.McLagan **Revision: A**

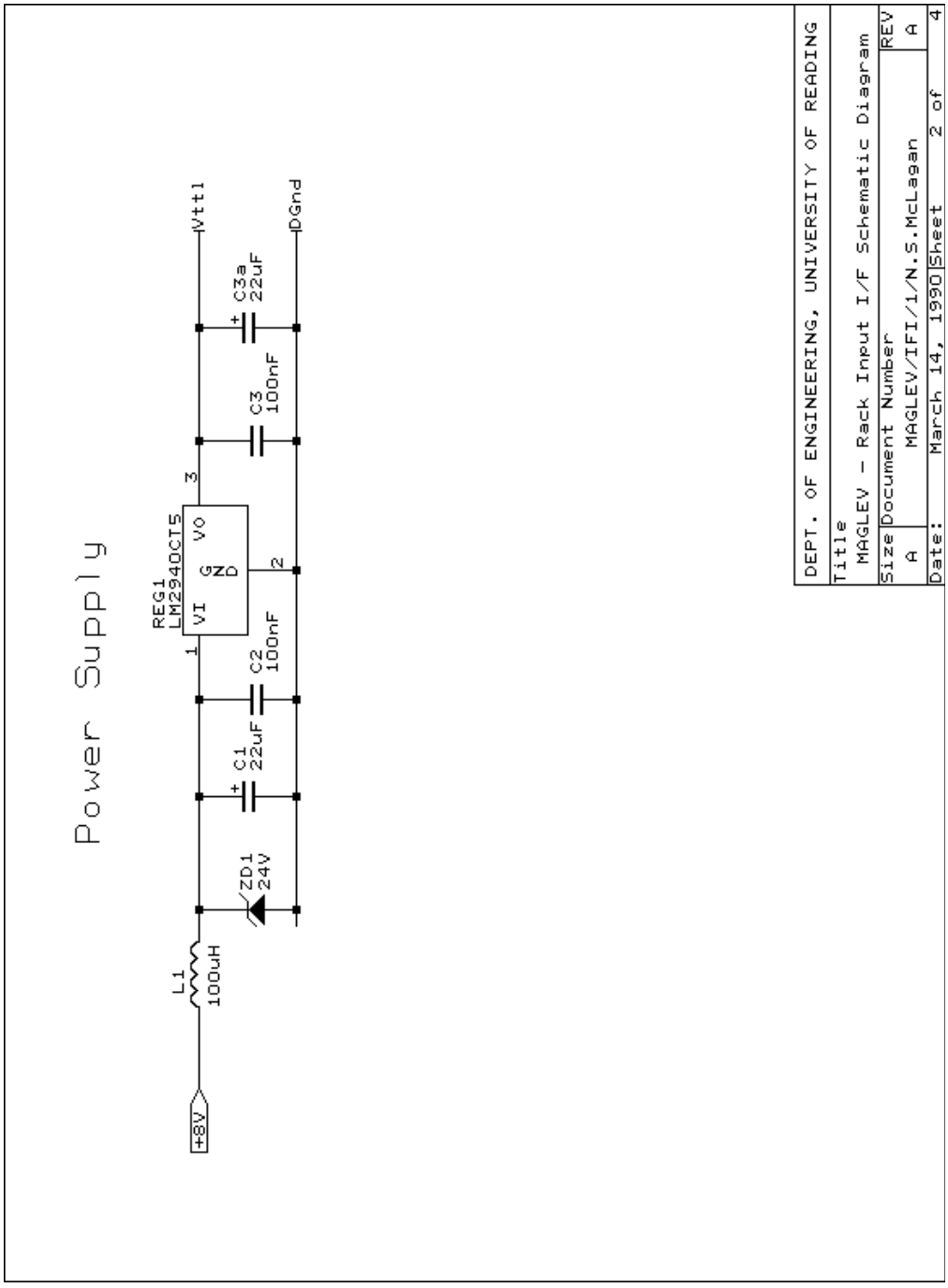
Bill Of Materials **April 2, 1991** **17:45:25** **Page 1**

Quantity	Reference	Part
1	C1	10,000uF,16V
2	C2,C3	4,700uF,25V
2	DB1,DB2	4A
1	EC1	DIN41216-32a,b
1	F1	160mA,Slow
3	LED1,LED2,LED3	Green
1	R1	470R
2	R2,R3	1k0
1	T1	6-0-6V,30VA
1	T2	12-0-12V,30VA

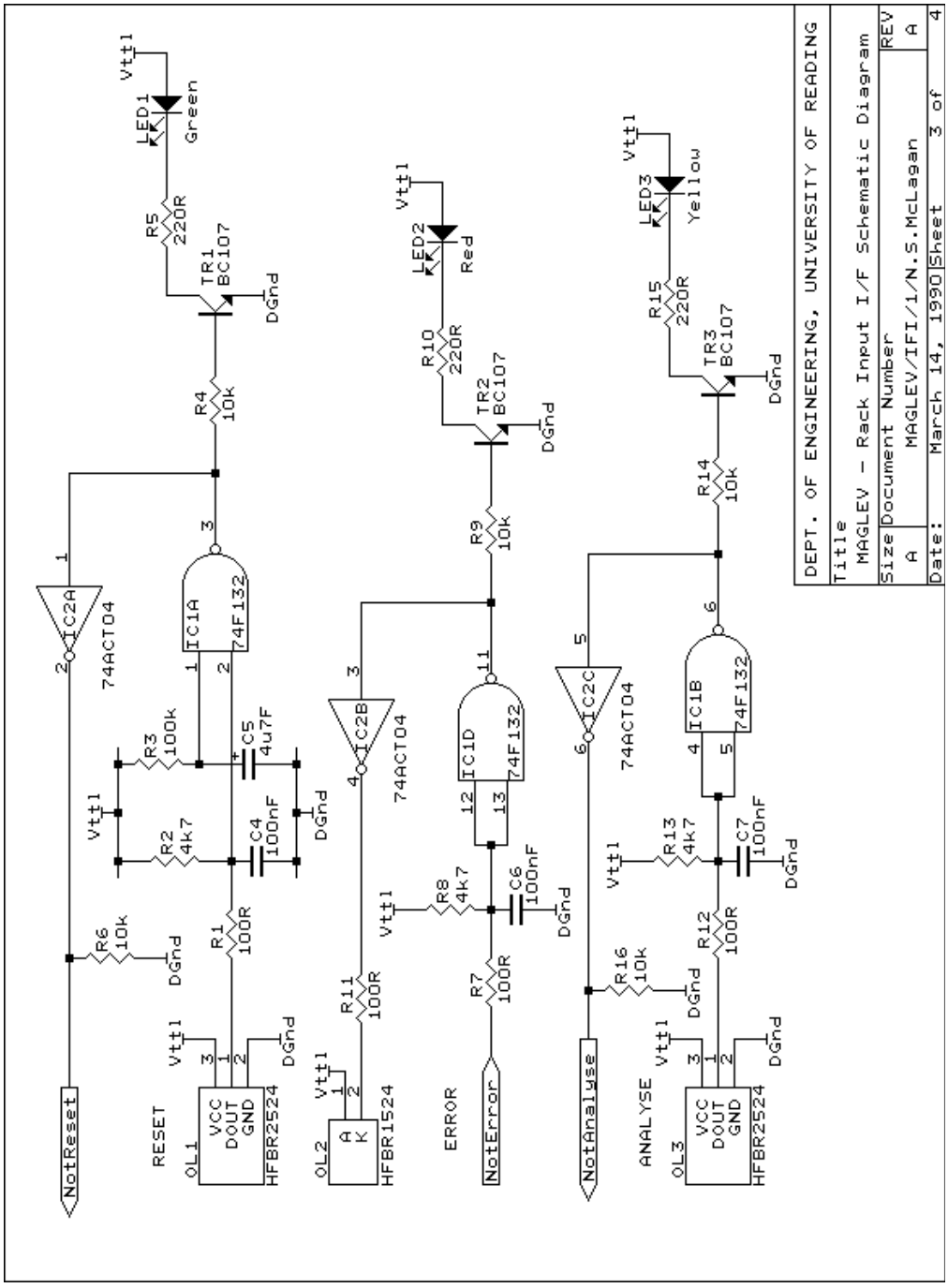
D.8 Chassis optical input interface card



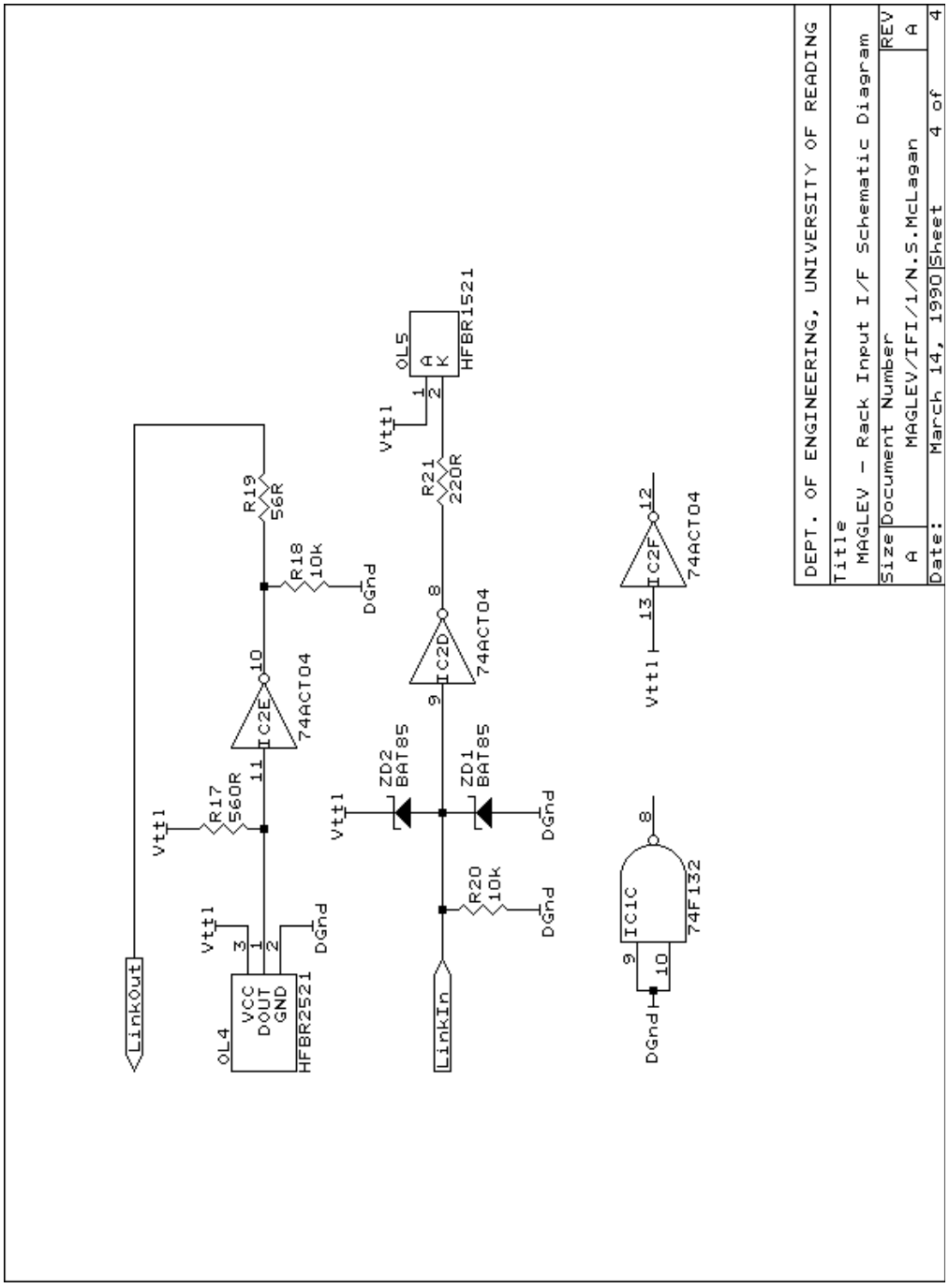
D.8.1 Chassis input interface power supply



D.8.2 Chassis input interface control signals



D.8.3 Chassis input interface data signals

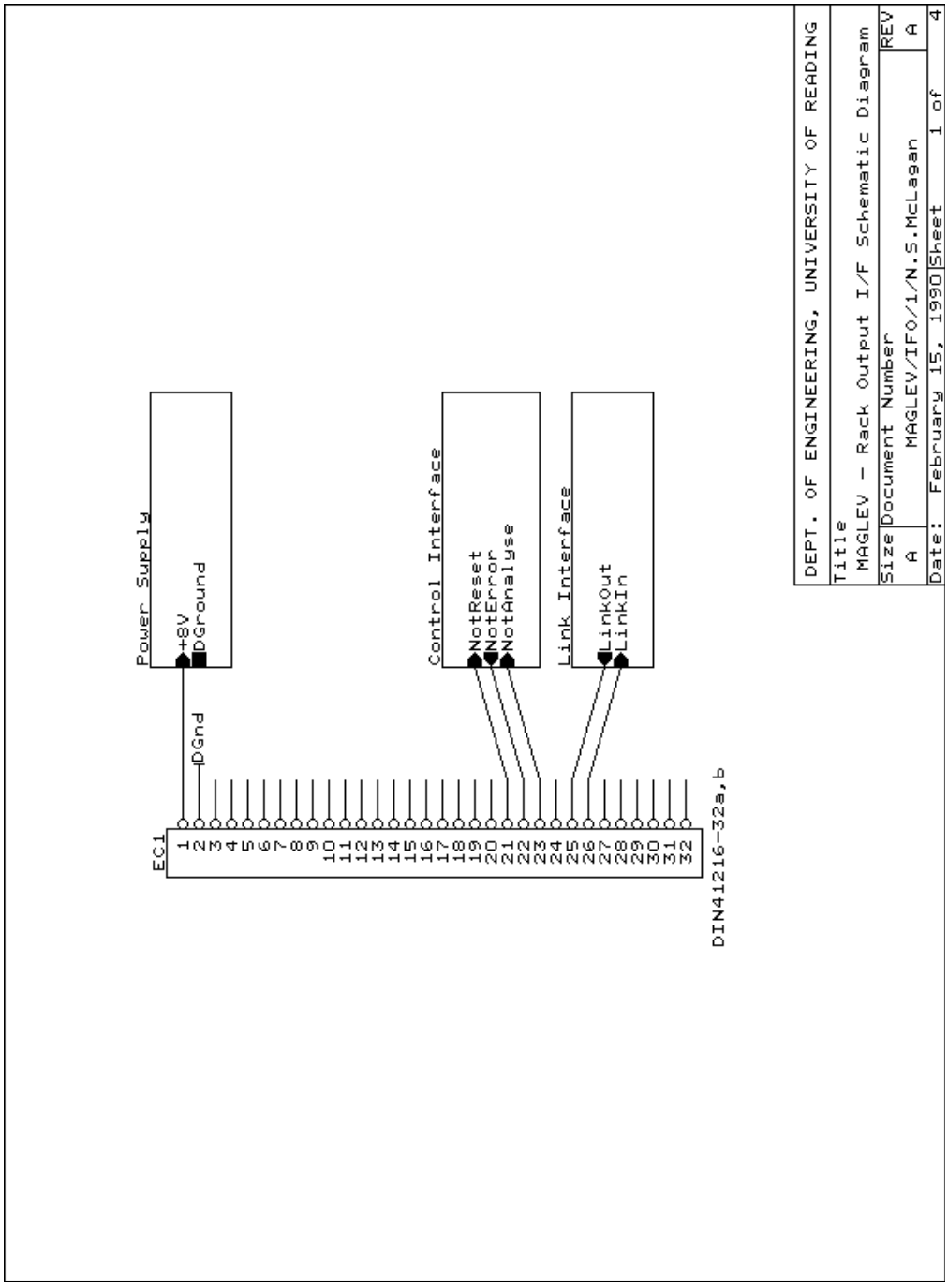


D.8.4 Chassis input interface card component parts list

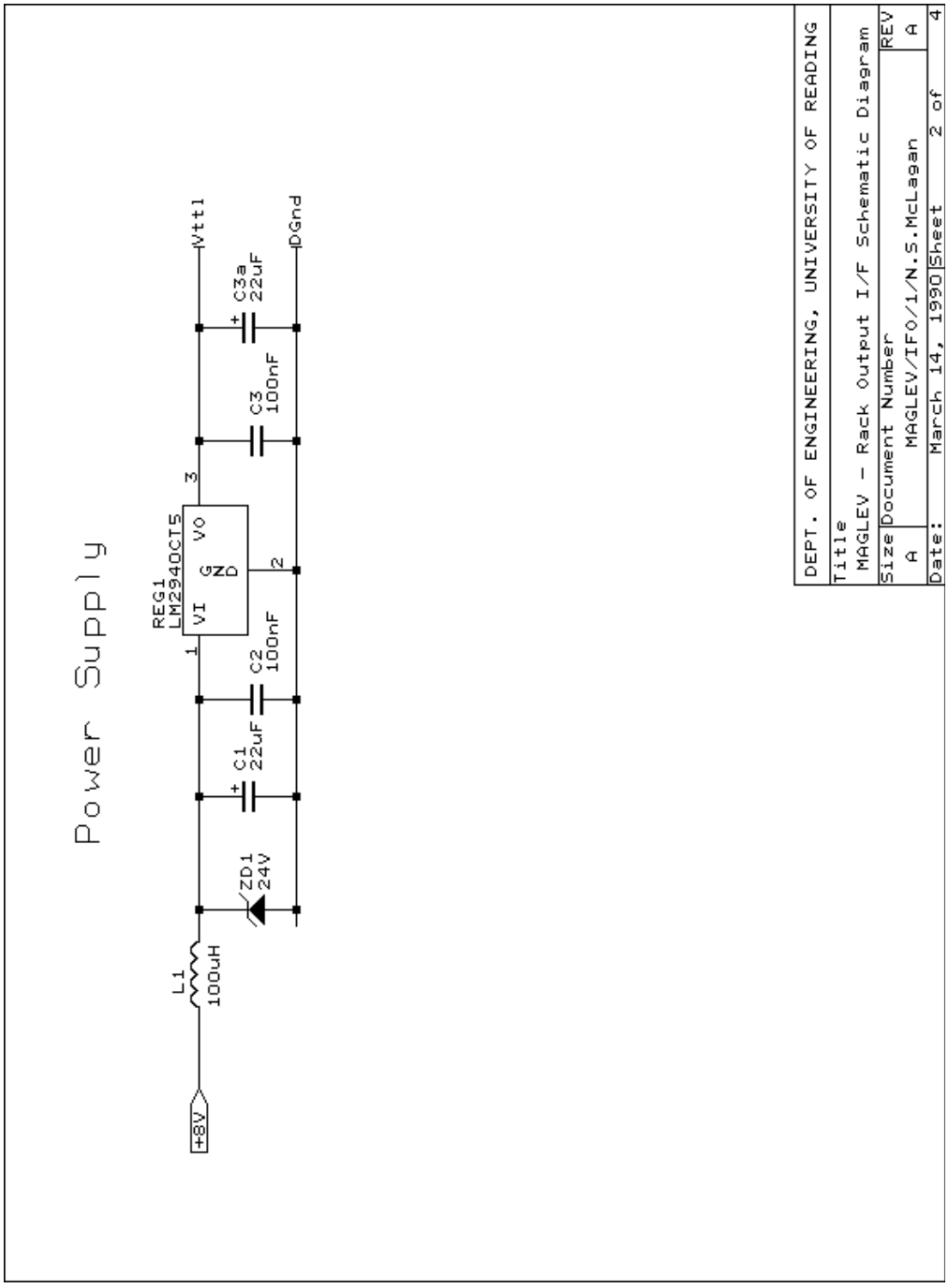
```
MAGLEV - Rack Input I/F Schematic Diagram         Revised:     March 14, 1990
MAGLEV/IFI/1/N.S.McLagan                          Revision: A

Bill Of Materials              April  2, 1991     17:27:12          Page    1
```

Quantity	Reference	Part
2	C1,C3a	22uF
5	C2,C3,C4,C6,C7	100nF
1	C5	4u7F
1	EC1	DIN41216-32a,b
1	IC1	74F132
1	IC2	74ACT04
1	L1	100uH
1	LED1	Green
1	LED2	Red
1	LED3	Yellow
2	OL1,OL3	HFBR2524
1	OL2	HFBR1524
1	OL4	HFBR2521
1	OL5	HFBR1521
3	R2,R8,R13	4k7
1	R3	100k
7	R4,R6,R9,R14,R16,R18,R20	10k
4	R1,R7,R11,R12	100R
4	R5,R10,R15,R21	220R
1	R17	560R
1	R19	56R
1	REG1	LM2940CT5
3	TR1,TR2,TR3	BC107
1	ZD1	24V
2	ZD1,ZD2	BAT85

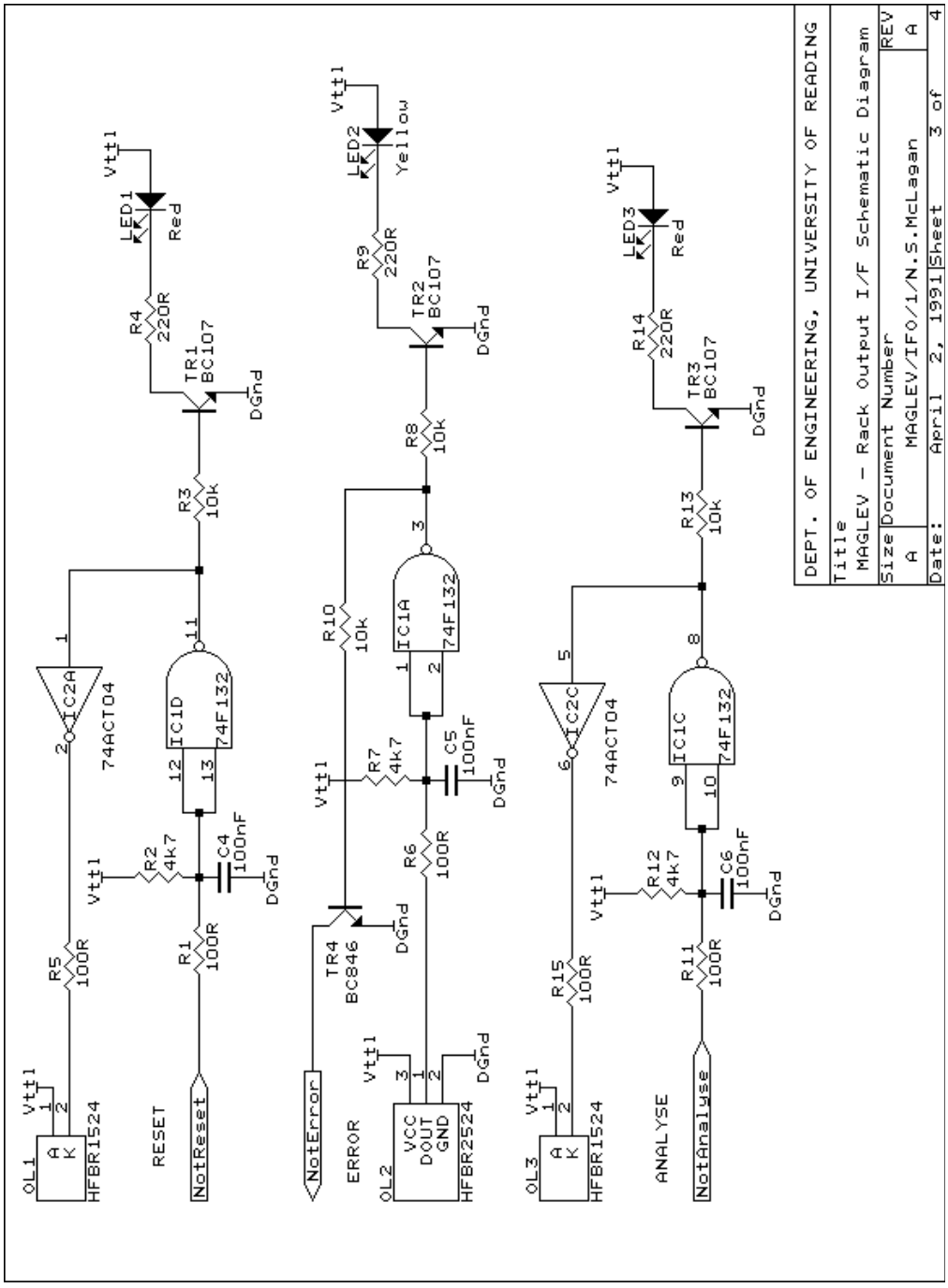
D.9 Chassis optical output interface card



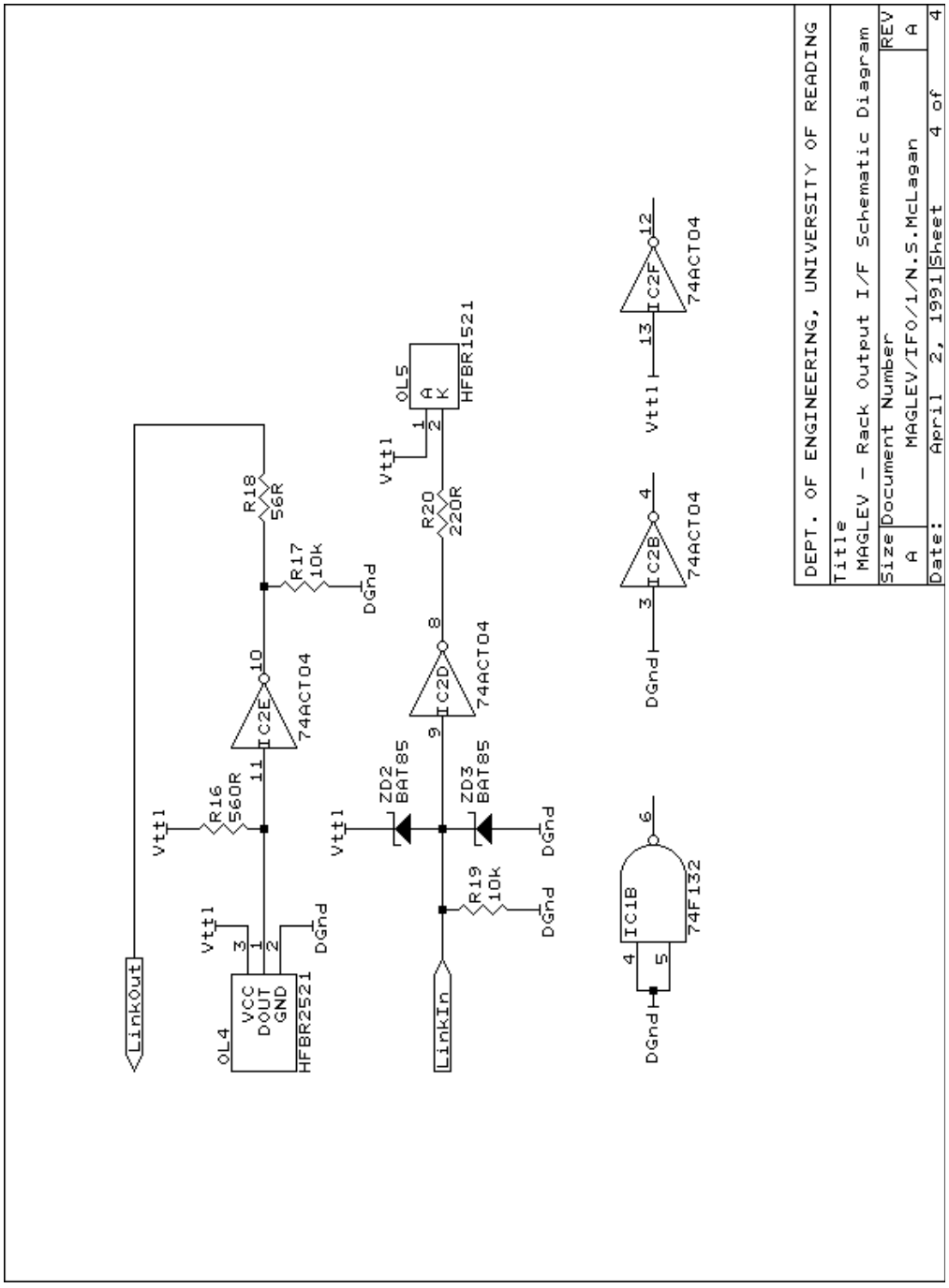
D.9.1 Chassis output interface power supply



D.9.2 Chassis output interface control signals



D.9.3 Chassis output interface data signals



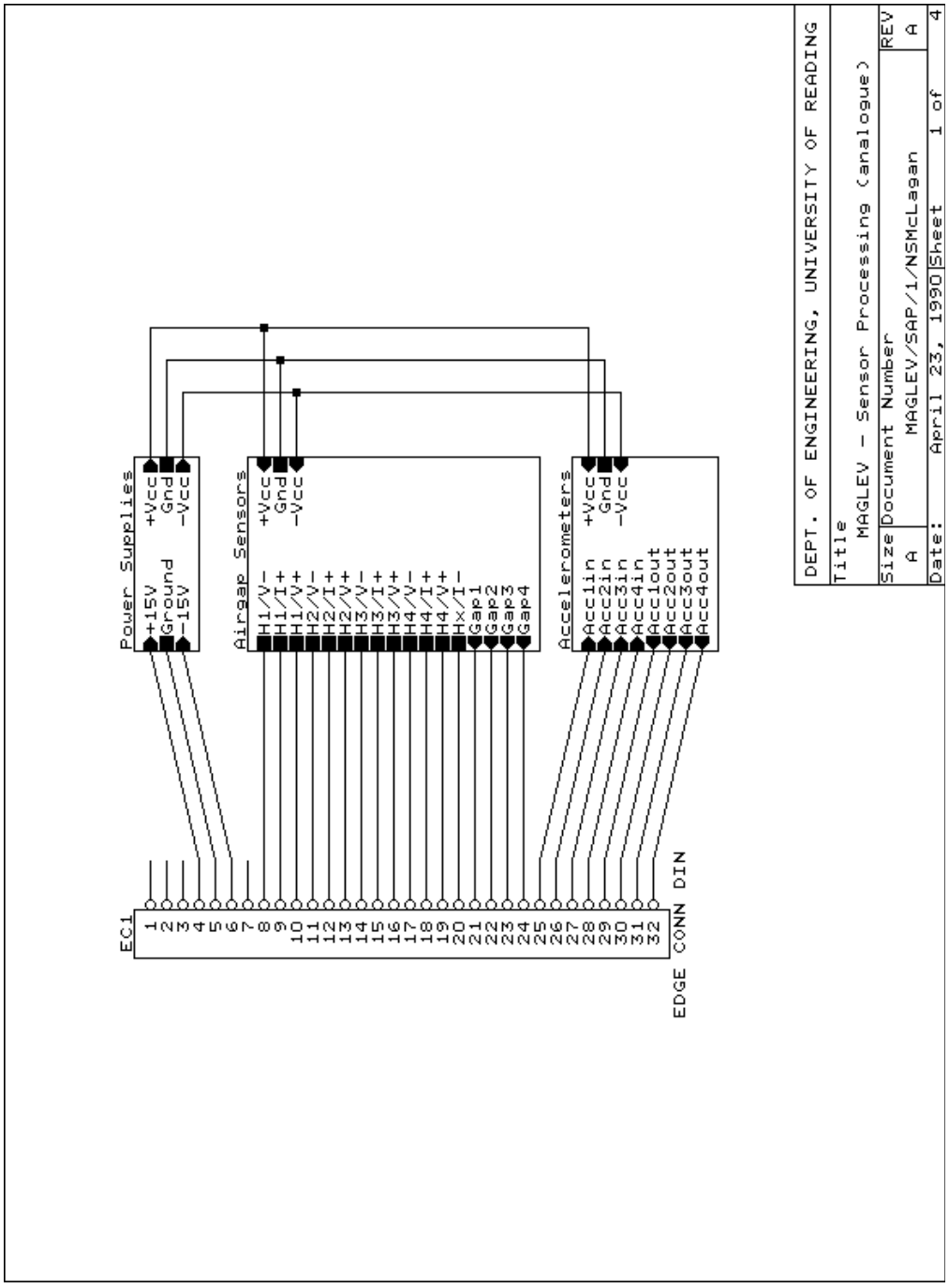
D.9.4 Chassis output interface card component parts list

MAGLEV - Rack Output I/F Schematic Diagram Revised: February 15, 1990
MAGLEV/IFO/1/N.S.McLagan Revision: A

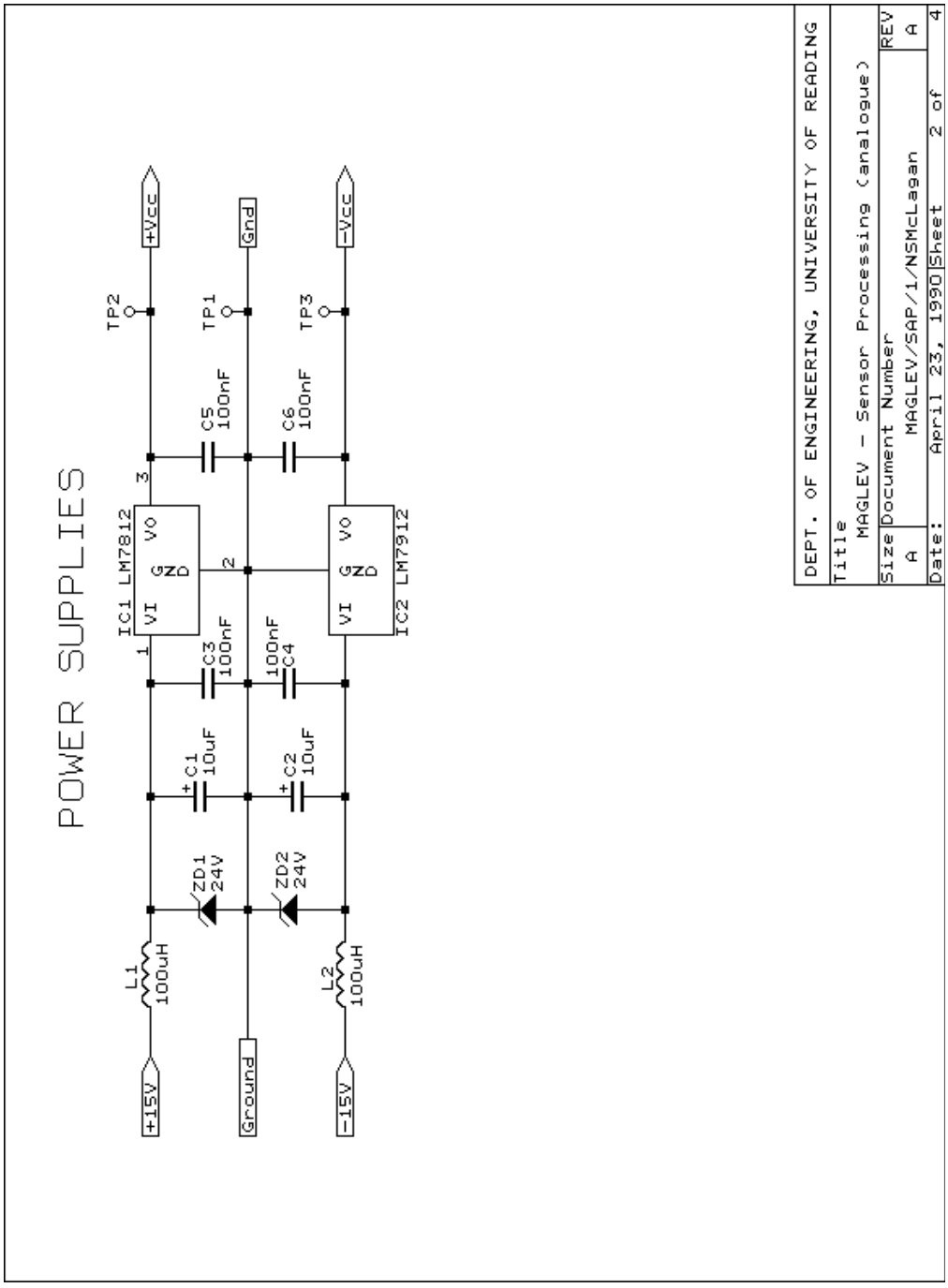
Bill Of Materials April 2, 1991 17:45:09 Page 1

Quantity	Reference	Part
2	C1,C3a	22uF
5	C2,C3,C4,C5,C6	100nF
1	EC1	DIN41216-32a,b
1	IC1	74F132
1	IC2	74ACT04
1	L1	100uH
2	LED1,LED3	Red
1	LED2	Yellow
2	OL1,OL3	HFBR1524
1	OL2	HFBR2524
1	OL4	HFBR2521
1	OL5	HFBR1521
3	R2,R7,R12	4k7
6	R3,R8,R10,R13,R17,R19	10k
5	R1,R5,R6,R11,R15	100R
4	R4,R9,R14,R20	220R
1	R16	560R
1	R18	56R
1	REG1	LM2940CT5
3	TR1,TR2,TR3	BC107
1	TR4	BC846
1	ZD1	24V
2	ZD2,ZD3	BAT85

D.10 Sensor analogue preprocessor (4 channel) card

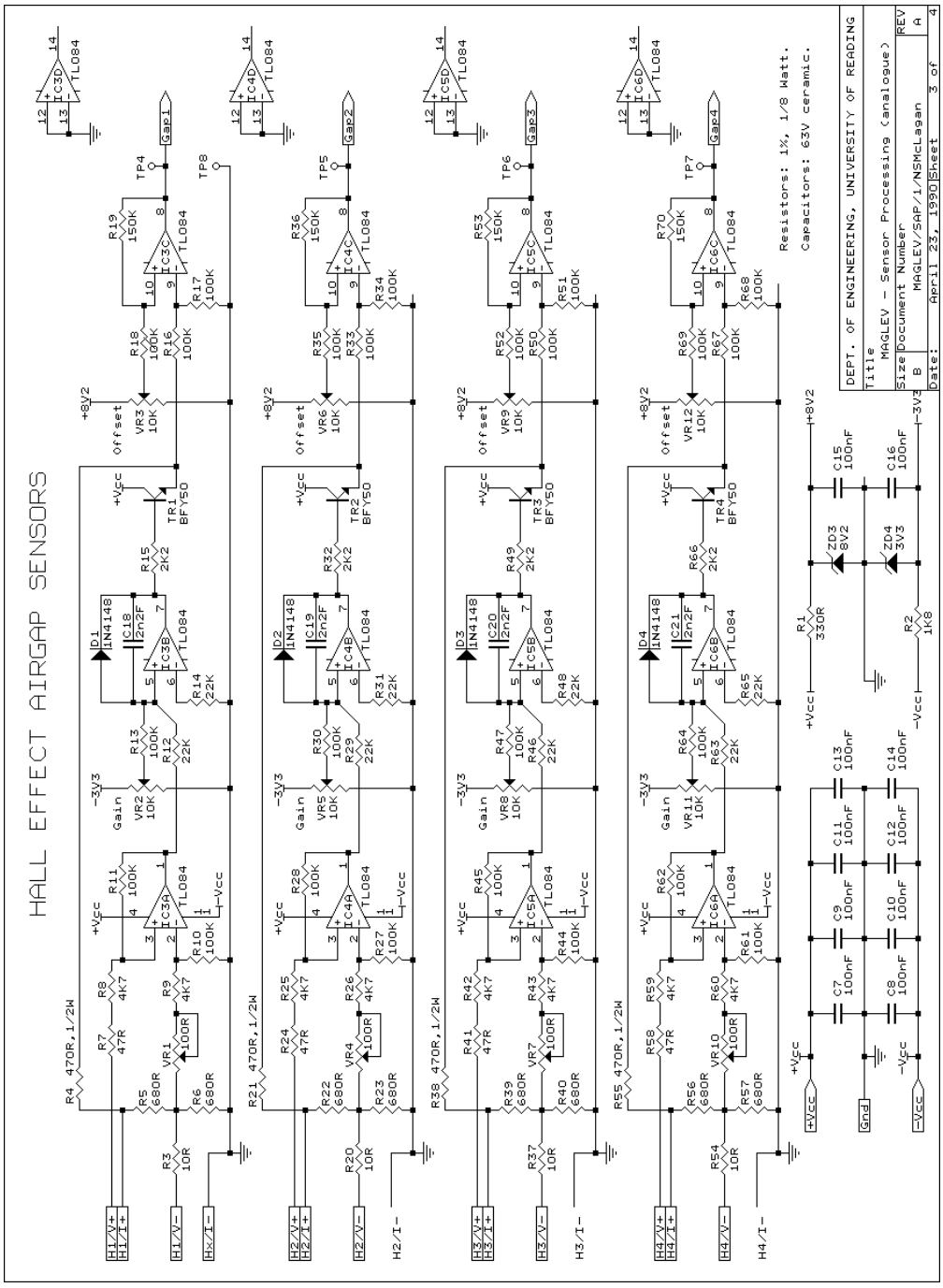


D.10.1 SAP card power supplies

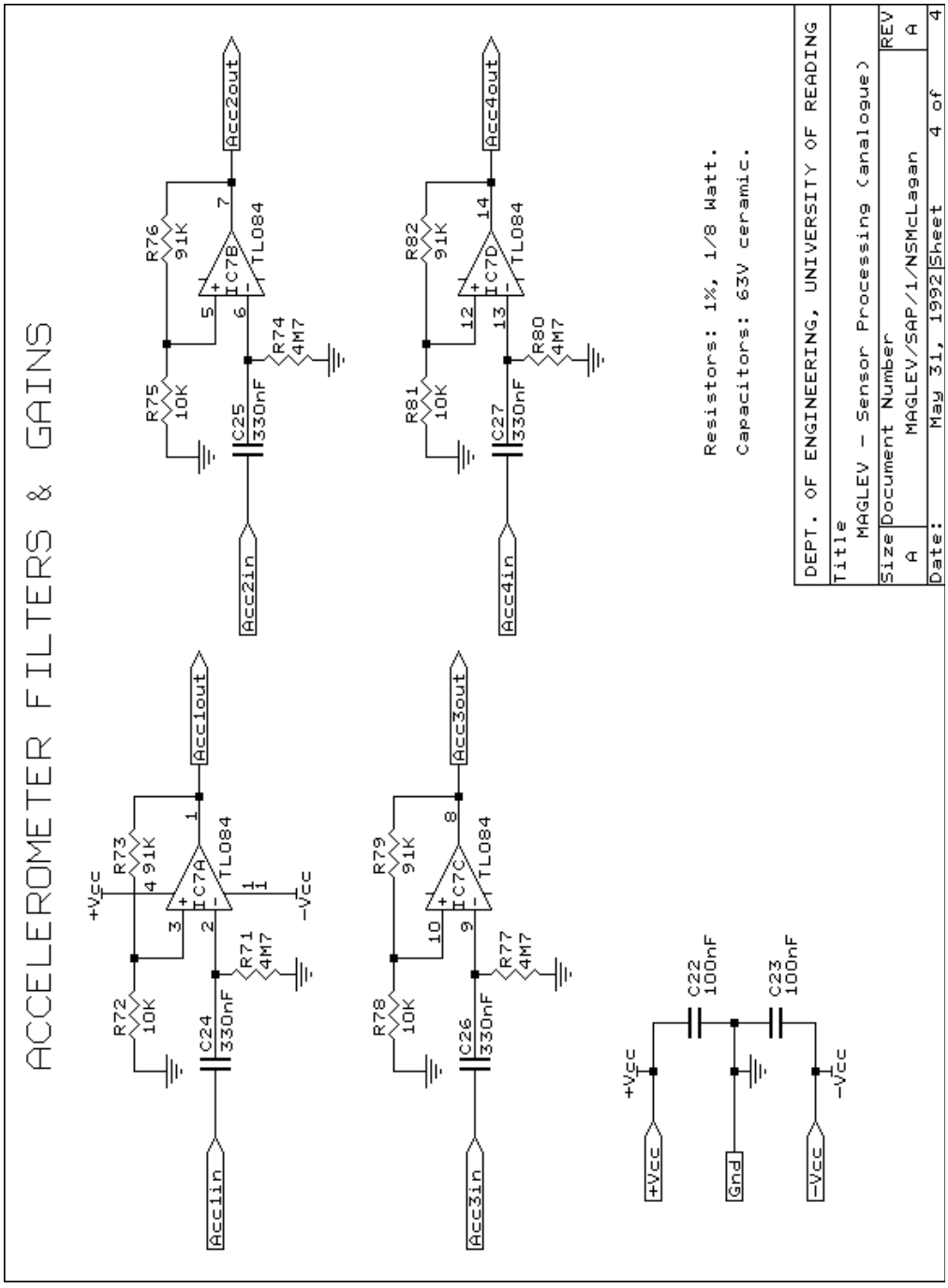


D.10.2 SAP Hall-effect air gap sensor controllers

Note: This circuitry is not implemented because commercial air gap sensors have been used instead. It is included here in case it is used in future systems.



D.10.3 SAP sensor filters and amplifiers



D.10.4 SAP card component parts list

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MAGLEV - Sensor Processing (analogue)            Revised:  November  2, 1989
MAGLEV/SAP/1/N.S.McLagan                         Revision: A

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Quantity  Reference                Part

     2    C1,C2                    10uF
    16    C15,C3,C4,C5,C6,C7,C8,C9,
          C10,C11,C12,C13,C14,C16,
          C22,C23                  100nF
     4    C18,C19,C20,C21          2n2F
     4    C24,C25,C26,C27          330nF

     4    D1,D2,D3,D4              1N4148

     1    EC1                      DIN41216-32a,c

     1    IC1                      LM7812
     1    IC2                      LM7912
     5    IC3,IC4,IC5,IC6,IC7      TL084

     2    L1,L2                    100uH

     1    R1                       330R
    24    R10,R11,R13,R16,R17,R18,
          R27,R28,R30,R33,R34,R35,
          R44,R45,R47,R50,R51,R52,
          R61,R62,R64,R67,R68,R69  100k
     8    R12,R14,R29,R31,R46,R48,
          R63,R65                  22k
     4    R15,R32,R49,R66          2K2
     4    R19,R36,R53,R70          150K
     1    R2                       1K8
     4    R3,R20,R37,R54           10R
     4    R4,R21,R38,R55           470R,1/2W
     8    R6,R5,R22,R23,R39,R40,
          R56,R57                  680R
     4    R7,R24,R41,R58           47R
     4    R71,R74,R77,R80          4M7
     4    R72,R75,R78,R81          10K
     4    R73,R76,R79,R82          91K
     8    R9,R8,R25,R26,R42,R43,
          R59,R60                  4k7

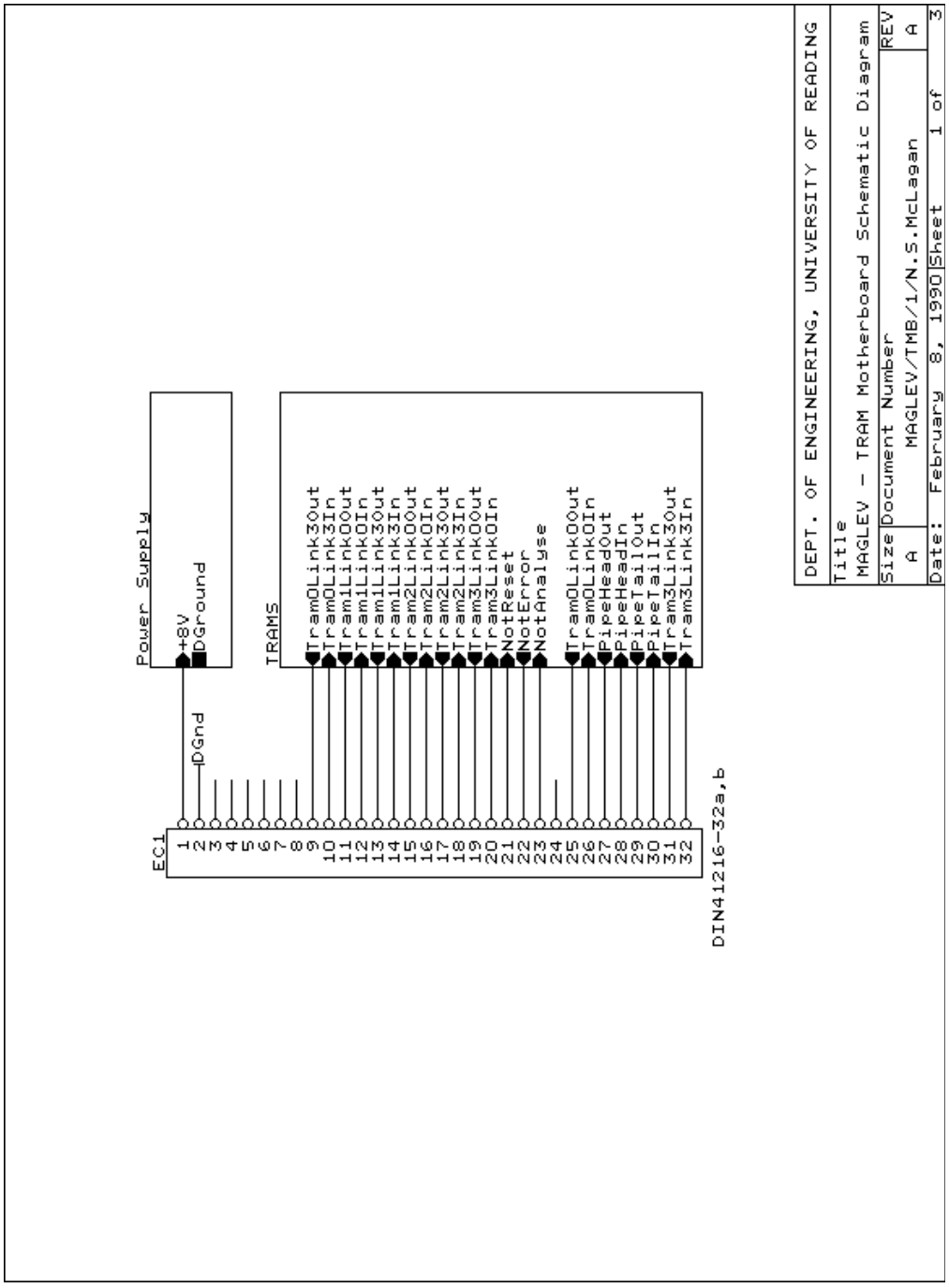
     8    TP4,TP1,TP2,TP3,TP5,TP6,
          TP7,TP8                  Test pins

     4    TR1,TR2,TR3,TR4          BFY50

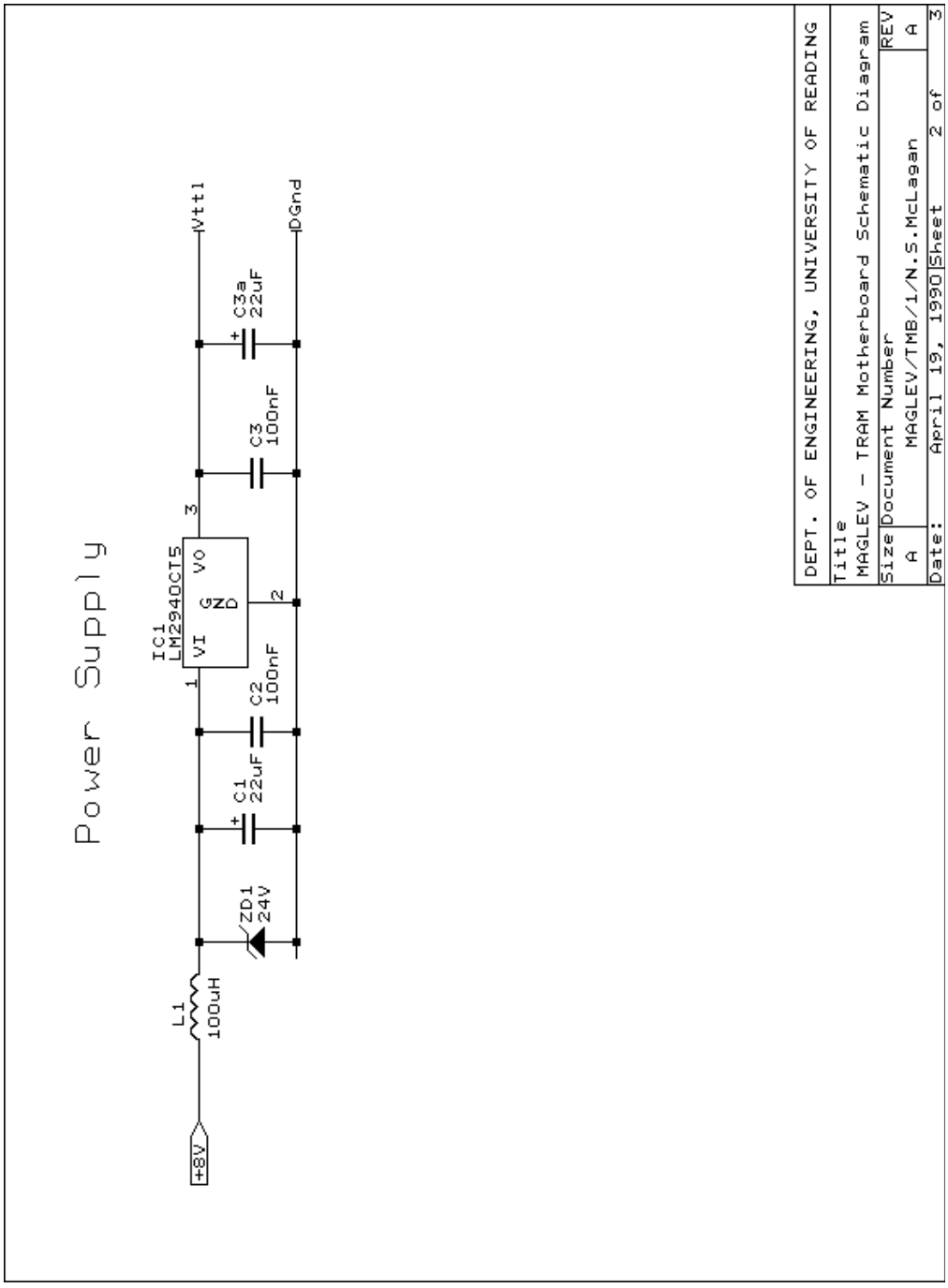
     4    VR1,VR4,VR7,VR10         100R
     9    VR3,VR2,VR5,VR6,VR8,VR9,
          VR11,VR12                10k

     2    ZD1,ZD2                  24V
     1    ZD3                      8V2
     1    ZD4                      3V3
```

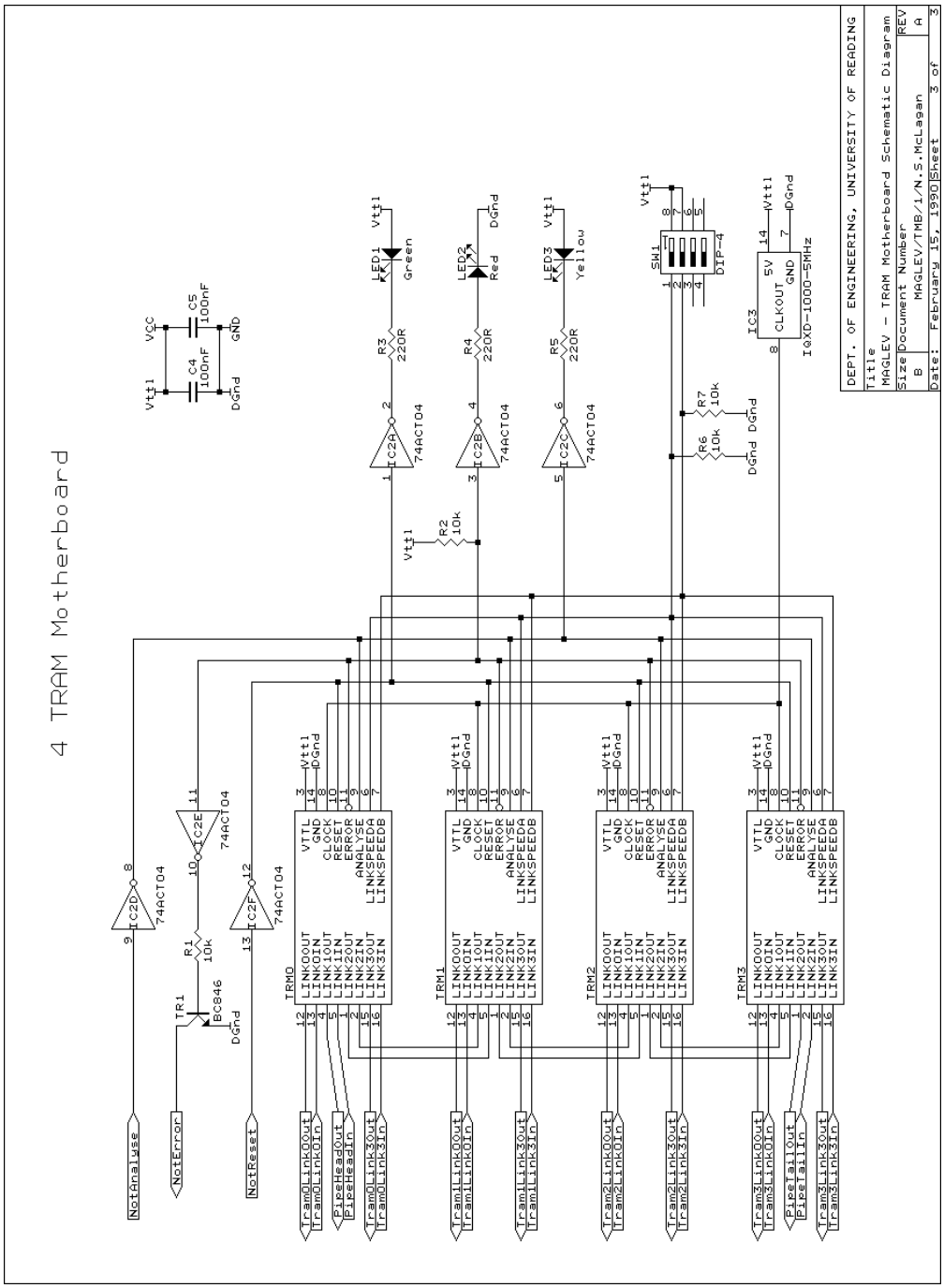
D.11 Transputer motherboard (4 tram) card



D.11.1 TMB card power supply



D.11.2 TMB TRAM connectivity



D.11.3 TMB card component parts list

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MAGLEV - TRAM Motherboard Schematic Diagram   Revised:  February  7, 1990
MAGLEV/TMB/1/N.S.McLagan                      Revision: A

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Quantity  Reference                Part

    1     C1                       22uF
    4     C2,C3,C4,C5              100nF

    1     EC1                      DIN41216-32a,b

    1     IC1                      LM2940CT5
    1     IC2                      74ACT04
    1     IC3                      IQXD-1000-5MHz Oscillator

    1     L1                       100uH

    1     LED1                     Green LED
    1     LED2                     Red LED
    1     LED3                     Yellow LED

    4     R1,R2,R6,R7              10k
    3     R3,R4,R5                 220R

    1     SW1                      DIP 4-way SPST

    1     TR1                      BC107

    1     ZD1                      24V
```