Low voltage Modem Platform based on TMS320LC56

Literature Number: BPRA049
Texas Instruments Europe
March 1997

IMPORTANT NOTICE

Texas Instruments (TI) reserves the right to make changes to its products or to discontinue any semiconductor product or service without notice, and advises its customers to obtain the latest version of relevant information to verify, before placing orders, that the information being relied on is current.

TI warrants performance of its semiconductor products and related software to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are utilized to the extent TI deems necessary to support this warranty. Specific testing of all parameters of each device is not necessarily performed, except those mandated by government requirements.

Certain application using semiconductor products may involve potential risks of death, personal injury, or severe property or environmental damage ("Critical Applications").

TI SEMICONDUCTOR PRODUCTS ARE NOT DESIGNED, INTENDED, AUTHORIZED, OR WARRANTED TO BE SUITABLE FOR USE IN LIFE-SUPPORT APPLICATIONS, DEVICES OR SYSTEMS OR OTHER CRITICAL APPLICATIONS.

Inclusion of TI products in such applications is understood to be fully at the risk of the customer. Use of TI products in such applications requires the written approval of an appropriate TI officer. Questions concerning potential risk applications should be directed to TI through a local SC sales office.

In order to minimize risks associated with the customer's applications, adequate design and operating safeguards should be provided by the customer to minimize inherent or procedural hazards.

TI assumes no liability for applications assistance, customer product design, software performance, or infringement of patents or services described herein. Nor does TI warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right of TI covering or relating to any combination, machine, or process in which such semiconductor products or services might be or are used.

Contents

List of Figures

List of Tables

Low voltage Modem Platform based on TMS320LC56

ABSTRACT

This application report presents a modem reference design based on the TMS320LC56 DSP. The advanced peripherals of this device provide the features necessary for integration into complex systems optimizing access times and minimizing external logic. A software analysis at the beginning shows that the computing power of the LC56 is sufficient to support even the highest standards of voice and data transmission. The 3.3V technology of this DSP also makes it possible to integrate this solution in systems such as portable computers where low power consumption is the prime consideration. The combination of 5V with 3.3V devices is also discussed in this report. Onboard line interface, UART, large memory and expansion connectors bring a high degree of flexibility to this design, building a generic evaluation platform.

1. Introduction

This application report discusses a modem reference design based on the TMS320LC56 DSP from Texas Instruments. A software analysis in the beginning will show that the TMS320LC56 has sufficient computing power to support even the highest standards of voice and data transmissions.

The flexible memory and I/O interfaces provide the features necessary to integrate the TMS320LC56 into complex systems with fast access times and minimum external control logic.

The 3.3V technology of the DSP allows power consumption to be minimized, making this solution appropriate for portable computers where power consumption is a prime consideration. Combining 5V and 3.3V devices will also be discussed in this report.

2. DATA/PROG/MIPS analysis

The modem industry is moving away from fixed chip-set designs to a more flexible and future-proof solution based on programmable DSP technology. The benefits of DSP technology are summarized below:

- **Reduced Cost**

A single TMS320C5X can replace a 2- or 3-chipset solution, reducing board size, chip count and component interfacing. Easy upgrades can be achieved by loading revised code into an external EPROM without the need to design and replace expensive components.

- **Differentiated Product**

The programmability of the DSP enables system designers to blend standard algorithms such as Data pumps with their own in-house algorithms which will differentiate their product from others in the market.

Next, the memory and processing power requirements for a complete V.34+ solution based on the C5X family is presented. An interpolation to the C54X family can be obtained assuming 25% increased efficiency with respect to the C5X figures given in the study.

MEMORY/MIPS REQUIREMENT FOR COMPLETE V.34 SOLUTION
(Based on C5X family)

	Program	Data	Mips	
FAX				
V.21	0.5Kw	0.1Kw	2.0	
V.27ter	2.0Kw	0.4Kw	4.0	
V.29	2.5Kw	0.5Kw	4.0	
V.17	5.0Kw	0.8Kw	6.0	
MODEM				
V.23	0.6Kw	0.1Kw	4.5	
V.22/V.22bis	2.7Kw	0.3Kw	4.0	
V.32/V.32bis	8.0Kw	6.0Kw	14.5	
V.34	12.0Kw	10.0Kw	30.0	
COMPRESSION/ ERROR DETECTION				
V.42 / V.42bis	6.0Kw	32.0Kw	6.0	
AT COMMANDS				
Basic Comm. + Parser	5.5Kw	4.0Kw		(AT commands are contained in the call set-up, therefore, no
Extended AT	5.8Kw	0.5Kw		impact on MIPS figure)
DSVD				
G.729A	9.0Kw	2.0Kw	12.0	
G.MUX	4.0Kw	1.0Kw	3.0	
TOTAL PROG	**63.6Kw**			(Store in FLASH EPROM or partially masked on DSP ROM. Some extra memory should be added for Interrupt service routines, etc.)

WORST CASE SCENARIO

	Program	Data	Mips
V.34 + V.42+ V.42bis + DSVD+ GMUX	**31Kw**	**45Kw**	**51**

3. Hardware design

3.1 System Overview

The system contains the components necessary for a modem. Data transfers and signal processing will be handled only by the DSP. The TLC320AC01 provides the A/D and D/A converters for the receive and transmit channels. Its analog input and output are connected to a telephone line interface which fulfills the US standard, enabling tests in a real environment.

The JTAG port provides direct access to the DSP and optimizes test and emulation capabilities of the system. In addition, a seven segment LED display makes it possible to monitor the status of the DSP. It may be used for debug and demonstration purposes.

The UART TL16C750 enables the system to communicate with a host via an RS232 interface.

The large size of external memory provides a very flexible development environment.

An expansion connector gives the opportunity for additional peripherals.

Figure 1 shows the components of the system and the required connections of the bus signals.

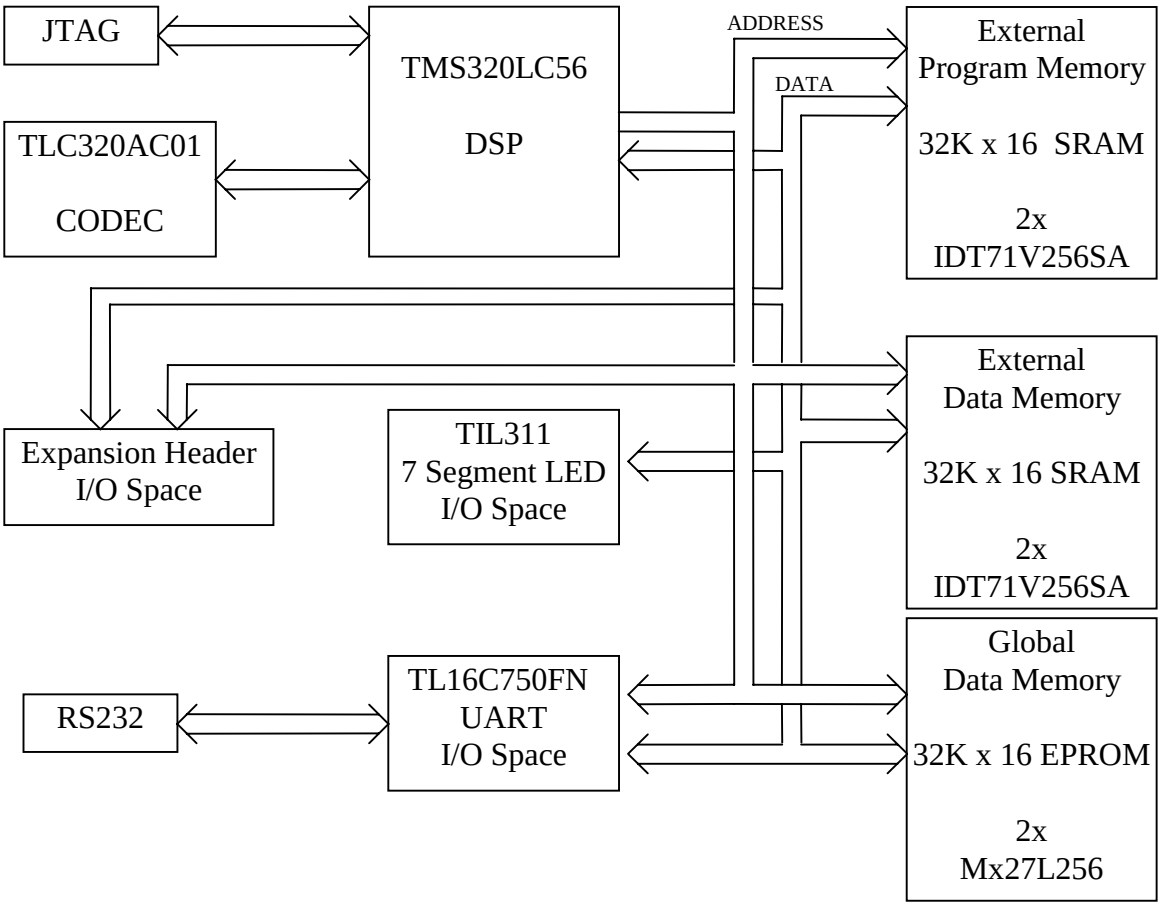


Figure 1: System Overview.

3.2 Connections to the Parallel Port

The total space accessible from the DSP by the parallel port is divided into ‘Program’, ‘Data’, ‘Global Data’ and ‘I/O’. With each access to external devices, the ‘LC56 selects one of these spaces by driving the appropriate memory select strobes (PS\, DS\, IS\ and BR\) low:

Table 1: Status of memory select signals.

Enabled Space	PS\	DS\	IS\	BR\
Program	Low	High	High	High
Data	High	Low	High	High
Global Data	High	Low	High	Low
I/O	High	High	Low	High

The address and data lines are shared by all external spaces.

The two SRAM devices U5 and U6 (compare schematics) are the only memory devices in program space. The connection of PS\ to the CS\ inputs of the SRAMs is therefore sufficient to avoid any bus conflicts.

The EPROMs U7 and U8 must be placed in the global data memory for the boot load function stored in the on-chip ROM of the ‘LC56. BR\ is connected to the chip enable of the EPROMs.

Because DS\ also goes low during global memory accesses it is not possible to use DS\ alone as chip enable for the SRAMs providing the external Data memory (U3 and U4).Bus conflicts would occur during each access to the EPROM.

One solution for avoiding this would be to generate the chip enable signal for the SRAMs with additional logic from BR\ and DS\. However, the additional delay is not acceptable when accessing the SRAMs with zero wait states in a 40MHz system.

To avoid any logic in the chip enable path it is better to use A15 as output enable of the SRAMs in addition to the connection of DS\ as chip select. Now the SRAM outputs are only enabled during accesses to the lower half (addresses 0x0000 - 0x7FFF) of the data space. EPROM is mapped in the global data space (addresses 0x8000 - 0xFFFF).

[User’s Guide TMS320C5x, p. 6-40]

The I/O space will be shared by the 7 segment LED display, U18, and the UART communication element, U20. As both devices are not time critical it is possible to insert external logic to generate the chip enable signals as needed. To lengthen the memory cycles for these slower devices, software wait states have to be implemented for all accesses to the I/O space.

With all devices connected to the data bus, the capacitive loading is too high. The output drivers of the SRAMs are specified for external loads of only 30pF. The implementation of a buffer between the DSP and the slow devices like the UART, LED and the EPROM reduces the loading seen by the SRAMs.

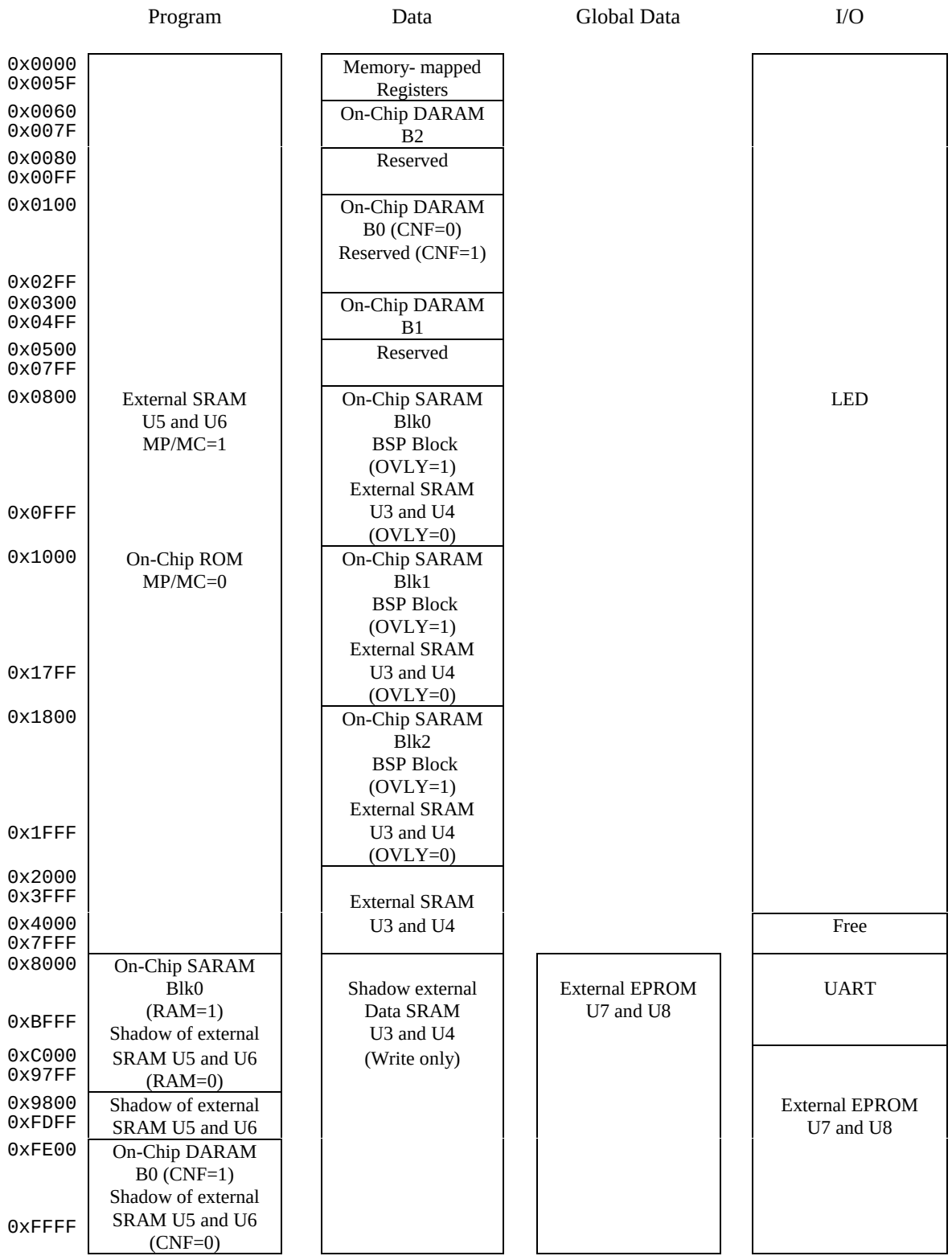


Figure 2: System Memory Map.

3.2.1 Memory Interface / Timing verification

a) SRAM

Read Cycle:

The SRAM devices used in this application are specified with an access time t_A = 15ns from address valid and CS\ low to data valid.

The 'LC56 starts any memory access cycle with the output of the valid addresses. At the same time the appropriate memory select strobe (DS\, PS\, BR\ or IS\) is driven low. After the time t_a(RDAV) the data must be valid on the bus.

For address and chip select the following equation must be fulfilled:

t_A t_a(RDAV) (1)

In our case, with a 15ns SRAM, a TMS320LC56-80 and Clock frequency of 40MHz we have:

15ns 15ns ✓

(✓ = equation fulfilled)

Before the DSP can latch the data with the rising edge of RD\ the bus has to be kept valid for the setup time t_{su}(RD-RDH). As RD\ is not connected to the SRAMs the timing is evaluated from the output of the valid address:

t_{su}(RD-RDH) < t_{wmin}(RDH) + t_{wmin}(RDL) - t_A; (2)

7ns < H - 2ns + H - 2ns -15ns;

7ns < 6ns

In our case, equation (2) is not possible to fulfill. This worst case cannot occur as t_w(RDH) and t_w(RDL) are linked together. This means that when one of them has its minimum value the other one is usually longer for that time. The sum of the two will be much closer to 2H than 2H - 4ns as calculated from equation (2) which ensures the setup time requirement, t_{su}(RD-RDH), is met.

After the DSP has latched the data with the rising edge of RD\, the bus will possibly no longer have kept valid (t_h(RDH-RD) = 0ns).

Write Cycle:

The falling edge on the WE\ input of the SRAM latches the addresses. The rising edge writes the data to the selected memory location.

The following equations must be fulfilled:

Address and CS\ valid before falling edge of WE\:

t_{AS} t_{su}(AV-WEL) (3)

0ns 8.5ns ✓

Minimum pulse duration WE\ low:

t_{WP} t_w(WEL) (4)

As OE\ of the SRAM is connected to ground permanently, the pulse duration of WE\ low must include the switching time of the SRAM's output drivers to high Z after the falling edge of WE\ and the setup time for the valid data before WE\ goes high again.

t_{WP} t_{WHZ} + t_{DW}; (5)

The combination of (4) and (5) gives the following:

t_{WHZ} + t_{DW} t_w(WEL) (6)

9ns + 7ns 21ns ✓

Before the rising edge of WE\ the data must be valid for the time t_{DW}:

t_{DW} t_{su}(WDV-WEH) (7)

7ns 11ns ✓

After the rising edge of WE\ the data has to be kept valid on the bus for the time t_{DH}:

t_{DH} t_h(WEH-WDV) (8)

0ns 8.5ns ✓

Before the write cycle can be completed with the rising edge of WE\ the addresses and the CE\ input have to be valid for the time t_{AW}:

t_{AW} t_{su}(AV-WEL) + t_{wmin}(WEL); (9)

10ns 8.5ns + 21ns ✓

b) EPROM

The EPROM devices used in this application are specified with an access time t_A = 150ns from address valid and CS\ low to data valid.

The ‘LC56 starts any memory access cycle with the output of the valid addresses. At the same time the appropriate memory select strobe (DS\, PS\, BR\ or IS\) is driven low. After the time t_a(RDAV) the data must be valid on the bus. The enable signal for the buffer (U22), driving the lower 8 bits of the data bus, is generated by a PAL device from IS\, DS\ and A15 using only one macro cell of the programmable device. During boot load 7 s/w wait states are added to each access to the global data memory. It can be assumed the buffer is enabled sufficiently before the EPROM to guarantee the output of valid data. Therefore, it is not necessary to take the buffer enable signal into account for timing verification.

For address and chip select the following equation must be fulfilled:

$t_A \quad t_a(RDAV) + 7T - t_{PHXmax}(245);$ (10)

150ns 15ns + 175ns - 4.1ns ✓

Before the DSP can latch the data with the rising edge of RD\ the bus has to be kept valid for the setup time t_{su}(RD-RDH). As RD\ is not connected to the EPROMs, the timing is evaluated from the output of the valid address:

$t_{su}(RD\text{-}RDH) < t_{wmin}(RDH) + t_{wmin}(RDL) + 7T - t_A - t_{PHXmax}(245);$ (11)

7ns < H - 2ns + H - 2ns + 175ns - 150ns - 4.1ns

7ns < 41.9ns; ✓

To make the system compatible with the TMS320LC54x DSP the chip enable for the EPROM is created by a PAL using IS\, A15 and DS\. The additional delay for this gate causes no problems as the timing evaluations (10) and (11) are fulfilled with more than 35ns of tolerance.

Note:

The EPROM used in this application has an output disable time of 50ns. This may cause problems if an EPROM read cycle is immediately followed by a zero wait state access to another external device.

The use of the on-chip boot loader guarantees enough cycles between consecutive external accesses.

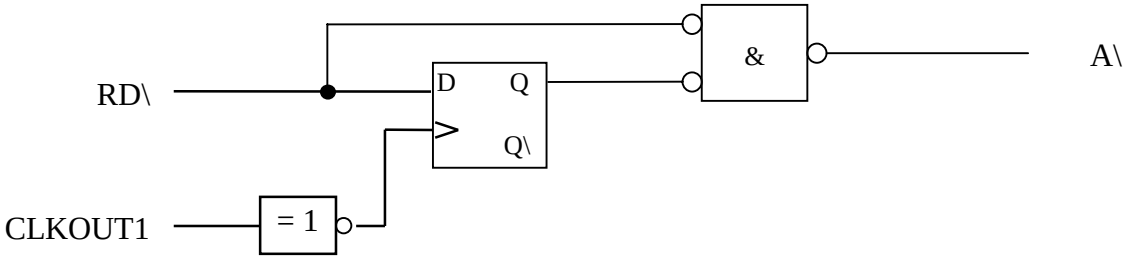
Definitions of names used in the equations above:

t_a(RDAV)	Access time, LC56 reads data from address valid
t_{su}(RD-RDH)	Setup time, data must be valid before RD high (LC56)
t_h(RDH-RD)	minimum hold time, data must be valid after RD high (LC56)
t_{wmin}(RDH)	minimum pulse duration of RD high (LC56)
t_{wmin}(RDL)	minimum pulse duration of RD low (LC56)
t_{su}(WDV-WEH)	setup time, LC56 outputs valid data before WE high
t_{su}(AV-WEL)	setup time, LC56 outputs valid addresses before WE low
t_{wmin}(WEL)	minimum pulse duration of WE low (LC56)
t_h(WEH-WDV)	minimum hold time, LC56 keeps data valid after WE high
t_A	Memory access time, data output valid after control signals valid
t_{WP}	minimum pulse duration WE low required by SRAM
t_{WHZ}	SRAM's maximum delay time, output in high Z after WE low
t_{DW}	SRAM minimum setup time, data valid before WE high
t_{DH}	SRAM minimum hold time, data valid after WE high
t_{AS}	SRAM minimum setup time, address and CE valid before WE low
t_{AW}	SRAM minimum setup time, address and CE valid before WE high
t_{PHXmax}(245)	Buffer maximum delay time, input to output valid
T	System clock cycle time
H	Half system clock cycle time T/2

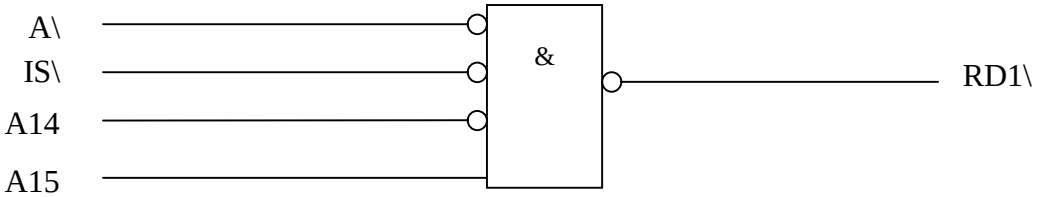
3.2.2 Host Interface (UART)

For the interface of the TL16C750 a compromise has been made. To keep the interface logic compatible with the TMS320LC54x DSPs and to avoid additional buffers in the address bus not all timing requirements of the specification for this device are met. Specifically, the read and write recovery times are not totally fulfilled. Therefore it may be necessary to implement ‘NOP’ cycles after any accesses to the UART in the software.

The following logic shifts the falling edge of RD\ for one clock cycle. This will ensure that the setup time for the addresses and CS\ is met. The NAND with RD\ ensures that the strobe goes high early enough to switch the output drivers in high impedance in time. This protects a subsequent access to another device from a bus conflict.

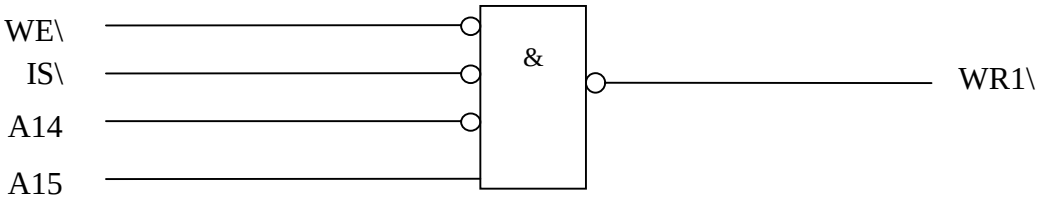


In addition the signal A\ has to be combined with the appropriate memory select signals to ensure that the output drivers are enabled only for accesses to the UART.



The two NAND gates in this logic can be merged and programmed as only one gate in the PAL.

It is not necessary to delay the falling edge of WE\. It is just combined with the memory select signals:



3.3 Connecting the Analog Interface to the Buffered Serial Port

The TLC320AC01 provides the analog-to-digital and digital-to-analog conversion for the DSP. With the help of the headers J8 to J11 it is possible to switch the analog path between the line interface with connector J5 for modem applications and the phone connectors J12 (IN) and J13 (OUT) for other general purpose applications.

The TLC320AC01 derives the sampling frequency and the bandwidth of its internal low pass filter from the master clock. To enable a sampling rate of exactly 8kHz and the typical filter specification for telecom applications it is necessary to provide 10.368 MHz as MCLK frequency.

The low voltage DSP and the ‘AC01 are connected to different power supplies. This may cause problems if one device drives the inputs of the other before it is connected to its power supply.

The connection of the voltage regulators, U13 and U14, in a chain prevents the AC01 from receiving any input signal from the DSP before its power supply voltage is applied.

Therefore it is only necessary to protect the DSP inputs from the 5V output voltage level of the AC01. A 5.6 kΩ series resistor (R7, R8, R9) limits the current into the DSP input to 1mA. An additional capacitor (C26, C27, C28) in parallel with this resistor maintains the rise and fall times. (for details refer to TLC320AC01 Application report, p.18, SLAAE09)

3.4 Variable System Clock

The clock of the DSP is generated by a programmable oscillator. The inputs A, B and C vary its output frequency on pin #2 as shown in table 2. Pin #1 always outputs the specified frequency of the device.

Table 2: Variable frequency for CLKIN.

Inputs				Outputs	
C	B	A		D	F
SW3	SW2	SW1		pin #2	pin #1
L	L	L	F/2	10MHz	20MHz
L	L	H	F/4	(5MHz)	20MHz
L	H	L	F/8	2.5MHz	20MHz
L	H	H	F/16	(1.25MHz)	20MHz
H	L	L	F/32	625kHz	20MHz
H	L	H	F/64	(312.5kHz)	20MHz
H	H	L	F/128	156.25kHz	20MHz
H	H	H	F/256	(78.125kHz)	20MHz

The pins DIV1 and DIV2 of the DSP specify the factor between the frequency on CLKIN and the DSP clock.

Table 3: TMS320LC56 clock options.

Parameter	CLKMD1 SW6	CLKMD2 SW5	CLKMD3 SW4
PLL multiply by three	L	L	L
PLL multiply by five	H	L	L
PLL multiply by four	L	H	L
PLL multiply by nine	H	H	L
External divide-by-two, oscillator disabled	L	L	H
PLL multiply by one	H	L	H
PLL multiply by two	L	H	H
Ext./Int. divide-by-two, oscillator enabled	H	H	H

4. Enabling compatibility with TMS320LC541/3/6

To be able to use the same design with a member of the TMS320LC54x family a second ZIF socket for a DSP has been added to the PCB. As both devices are connected in parallel to the bus it must be ensured that there is only one DSP inserted at a time.

As the parallel ports of the two processor types are slightly different, a couple of changes to the control logic are necessary.

The TMS320LC56's control outputs WE\ and RD\ of the parallel port do not exist on the TMS320LC54x devices. They have to be created by external logic for the UART and the SRAMs if the 'LC54x is used.

The TMS320LC56's STRB\ signal is split into the MSTRB and the IOSTRB strobes at the 'LC54x. MSTRB is only for accesses to the program and data space activated; IOSTRB only for accesses to the I/O space. The combination of R/W and MSTRB generates the WE\ strobe for writes to the SRAM banks. The RD1\ and WE1\ UART strobes are generated with IOSTRB, R/W\, and A[14:15] performing bank select.

To switch the board from 'LC56 to either 'LC541, 'LC543 or 'LC546 the PAL device, U19, has to be programmed with the file lead.jed instead of lc56.jed.

A jumper on J14 connects the WE\ output of the PAL to the SRAMs. This connection is only allowed if a DSP of the 'LC54x family is used. It must be removed for the 'LC56.

The 'LC56 must be placed into the socket U1, all 'LC54x devices into socket U24.

The boot loader of the LC54x reads the initialization word from the address 0xffff in the I/O space, while the boot load process itself accesses the EPROM in the data memory. Therefore the logic generating the enable signal for the EPROM must be combined in addition to DS\ and A15 with the IS\ strobe.

5. Software: Initialization & Test

The following chapter describes the programs for initialization and test routines written during the development of the board. The source code is contained in the appendix to this report.

5.1 Communication between DSP and PC via RS232

The Windows '*Terminal*' software enables the DSP to use the keyboard and monitor of a PC as input and display interface directly. The board transfers its data to the PC via the RS232 interface driven by the UART communication element, U20.

The data exchange between DSP and the communication element is controlled by the interrupts RXREADY and TXREADY driven by the UART. They are connected to the DSP as INT2 and INT3.

TXREADY signals to the processor that the previous byte has been sent to the PC and it is then possible to write the next byte to its transmit buffer. RXREADY tells the DSP a new byte has been received from the PC and is ready for reading.

To avoid any loss of data, the DSP must read a new byte from the UART receive channel before the PC sends the next byte. Therefore RXREADY is connected to an interrupt with a higher priority than TXREADY.

The software described in the following is based on the communication between PC and DSP via the UART.

The user can choose a routine to run from the menu. By pressing any key, the routine activated will end and the DSP will return to the main program, giving the user a new choice.

5.2 Buffered Serial Port and TLC320AC01

The analog interface TLC320AC01 is connected to the DSP via the buffered serial port. It consists of two independent channels for transmitting and receiving. Each channel has its own memory space or buffer. From the buffer, the transmit channel will read data to be sent. After each read the transmit buffer address pointer AXR will be incremented. The size of the transmit buffer is specified in the register BKX. The port will generate the XINT interrupt each time one half of the buffer has been transmitted.

If AXR has reached the end of the buffer it will be reset to the start address.

The receive channel is similarly organized. ARR contains the actual receive buffer address and BKR the length. The RINT interrupt is generated each time one half of the buffer has been loaded with new data.

The DSP can access the buffers as memory mapped into the On-Chip SARAM Blk0 starting at address 0x0800 in the data space.

The subroutine _ac01of the program will reset the ‘AC01 via the XF pin and initializes the control registers of the analog interface. The DSP will then loop back the incoming samples to the output channel of the AC01.

The AC01 has primary communication for the data exchange from the A/D and D/A converters, and secondary communication to set its control registers. Secondary communication is activated if the two LSBs of a data word written to the DAC during primary communication are set high.

The initialization words used by the software are pre-loaded into the transmit buffer, and are sent interleaved with dummy data to activate secondary communication.

After initialization, it must be ensured that only data words are transmitted to the AC01 with bits 0 and 1 set to zero, unless secondary communication is requested to change the setup of the analog interface. The program then starts to receive samples and store them in the transmit buffer before any samples are sent to the AC01.

After the DSP has detected both interrupts, transmit and receive, it will shift the new data in the receive buffer into the inactive half of the transmit buffer.

It will continue this loop-back process until the user presses a key and an interrupt from the UART signals the process to stop.

5.3 Testing the external SRAM

If this memory test is selected, the DSP will start to write and read data to the memory space defined in the configuration file as ‘testmem’ and ‘testprg’. Each stored value will be checked for errors and any faults will increment the error counter ‘ERR’. The program will stay in this mode until the user presses any key - at which point, the memory test will stop and the actual value of ERR will be displayed.

At the start of the routine the contents of the memory locations in the data space specified by ‘testmem’ will be set to zero. The contents of the data space will then be copied to the program memory specified by ‘testprg’.

After that, the DSP reads a location in the program space, checks if the value is correct and stores a new value (0x5555) in this cell. If the value read is different from the value expected, the counter ERR is incremented. The same task is performed in data space. This procedure is repeated for the whole length of the memory defined by ‘RANGE’ by incrementing the address pointers by 1 after each store instruction.

The same test is repeated with 0xaaaa, 0xffff and 0x0000 as the new values are written to the external memory locations.

The consecutive values are chosen to maximize the number of data bits changed with each access.

The test is executed 16 times for each of the four values. The LED indicates the current number of iterations performed (0 to 16).

The program then starts a different test.

The DSP executes 8 consecutive writes to the external data space. The data written alternates between 0x5555 and 0xaaaa with each cycle. After this, the DSP reads out this data and stores the sum of the eight values in the accumulator to check it. If the result is not correct, ERR is incremented. This procedure is repeated for the following blocks of eight words until the DSP reaches the end of the external memory space, defined by RANGE.

After this, the program executes the same routine with 0x0000 and 0xffff as the values to be written.

Finally the DSP restarts the whole memory test without resetting ERR until the program detects an interrupt from the UART, signaling that a key has been pressed by the user.

References

1. Designing with the TLC320AC01 Analog Interface for DSPs, John Walliker and Julian Daley, Texas Instruments 1994, SLAAE09
2. TLC320AC01 Analog Interface circuit, Texas Instruments 1993, SLAS057A
3. TMS320C5x, TMS320LC5x data sheet, Texas Instruments 1995, SPRS030A
4. TMS320C5x User's Guide, Texas Instruments 1993, SPRU56C
5. Power Supply Circuits, Texas Instruments 1996, SLVD002
6. Low-Voltage Logic, Texas Instruments 1994, SCVDE03
7. TMS320C54x User's Guide, Texas Instruments 1995, SPRU131A
8. TMS320C54x Data Sheet, Texas Instruments 1996, SPRS039
9. TMS320C54x Serial Ports User's Guide, Texas Instruments 1995, SPRU156
10. Digital Design Workshop, E. Haseloff and P. Forstner, Texas Instruments 1995

Appendix A Source Code

```
/*************************************************************************/
/*                            FILE NAME: MAIN.C                          */
/*                  PROGRAM UART COMMUNICATION WITH TMS320LC56           */
/*                                                                       */
/*************************************************************************/

#define  clean_up receive_data(); break /* cleanup macro                 */
#define  maxstring 40
#include "main1.c"                              /* flag names, constants     */
extern void memory();
extern void ac01();
extern int ERR;                                 /* error counter of memtest  */
  int  DIMR = 6;
/*_______________________________________________________________________*/

void main(void)
{
  #define max 100
  char C, COMMAND;
  char s[max];
  int  i,n;
  int  DONE = 0;
       asm(" splk    #1000100010111000b, PMST ");
       asm(" splk    #01C0h, PDWSR");          /* reset waitstates, 7 FOR IO    */
       asm(" LMMR IMR,#_DIMR");
       asm(" splk   #0ffffh,IFR");             /* clear all pending int         */
       asm(" CLRC INTM");                      /* disable interrupts            */
       port8003 = 135;     /*load value for line cntrl reg,enable DLAB          */
/*             10000111                                                       */
/*             ||||||++--------------- word length = 8bit                     */
/*             |||||+----------------- number of stop bits = 2                */
/*             ||||+------------------ parity bit = no                        */
/*             |||+------------------- even parity select = odd               */
/*             ||+-------------------- stick parity bit = disabled            */
/*             |+--------------------- break control bit = disabled           */
/*             +---------------------- divisor latch bit = enabled            */
       port8000 = 16;      /* load divisor with 16 -> 9600 Baud                */
       port8101 = 0;/* clear upper byte of divisor                           */
       port8003 = 7;/* disable DLAB bit                                      */
       C = '\n';           /* load C with a character                       */
       port8000 = C;/* send this character to UART to activate a             */
                           /* transmit interrupt                            */
       C = port8000;/* read received word from the UART to claer it          */

sendinteger(0xa);          /* reset cursor                                  */
sendinteger(0xd);          /* line feed                                     */
sendinteger(0xa);          /* reset cursor                                  */
sendinteger(0xd);          /* line feed                                     */
sendstring(" *** LC56 test platform ***",27);
sendinteger(0xa);          /* reset cursor                                  */
sendinteger(0xd);          /* line feed                                     */
sendinteger(0xa);          /* reset cursor                                  */
sendinteger(0xd);          /* line feed                                     */
sendstring("Please make your choice... ",27);
sendinteger(0xa);          /* reset cursor                                  */
sendinteger(0xd);          /* line feed                                     */
sendinteger(0xa);          /* reset cursor                                  */
sendinteger(0xd);          /* line feed                                     */
sendstring("Memorytest        (m)",21);
sendinteger(0xa);          /* reset cursor                                  */
sendinteger(0xd);          /* line feed                                     */
sendstring("AC01 in Loop Back (a)",21);
sendinteger(0xa);          /* reset cursor                                  */
sendinteger(0xd);          /* line feed                                     */
sendstring("Stop              (s)",21);
sendinteger(0xa);          /* reset cursor                                  */
sendinteger(0xd);          /* line feed                                     */
```

```
while(!DONE)              /* stay in following loop while DONE = 0             */
   {
   COMMAND = receivechar();      /* load COMMAND with character received f. UART*/
   sendchar(COMMAND);            /* write character received on the monitor     */
   sendinteger(0xa);             /* reset cursor                                */
   sendinteger(0xd);             /* line feed                                   */
    switch (COMMAND)                   /* execute the command...               */
      {

       case 'M': case 'm': memory();                 /* run function memory     */
                           printresult(ERR);         /* print error counter     */
                           sendinteger(0xa);         /* reset cursor            */
                           sendinteger(0xd);         /* line feed               */
                           sendstring("New choice? (m,a or s)",22);
                           break;                    /* return from 'switch'    */

       case 'a': case 'A': sendstring("ac01 in loop back mode",22);
                           sendinteger(0xa);         /* reset cursor            */
                           sendinteger(0xd);         /* line feed               */
                           sendstring("press any key to stop",21);
                           sendinteger(0xa);         /* reset cursor            */
                           sendinteger(0xd);         /* line feed               */
                           ac01();                   /* run function ac01       */
                           sendstring("New choice? (m,a or s)",22);
                           break;                    /* return from 'switch'    */

       case 'S': case 's': sendstring("program completed",17);
                           sendinteger(0xa);         /* reset cursor            */
                           sendinteger(0xd);         /* line feed               */
                           DONE = 1;                 /* set DONE to 1           */
                           break;                    /* return from 'switch'    */

      }
   }
}

/*_____________________________________________________________________________*/
```

```
/*************************************************************************/
/*                            FILE NAME: main1.C                         */
/*             LC56 UART COMMUNICATION FUNCTIONS                         */
/*                                                                       */
/*  clear_messages()  receive_data()     send_data()     send_file_data()  */
/*  initialize_evm()  receive_command()  send_command()  receive_file_data()  */
/*  printresult()                                                        */
/*************************************************************************/
#include <string.h>
/*#include "evm1.h"              /* flag names, constants                */
#include <ioports.h>
extern int RXREADY;              /* indicator for UART receive intrpt    */
extern int TXREADY;              /* indicator for UART transmit intrpt   */
unsigned char reply;
ioport char port8000;                  /* UART transmit & receive buffer  */
ioport int  port8003;                  /* UART Line Control Register      */
ioport int  port8100;                  /* UART Divisor lower byte         */
ioport int  port8101;                  /* UART Divisor upper byte         */
/*_______________________________________________________________________*/

void sendstring(char s[], int lim)
     {
       int c,i;
       i = 0;
       while(--lim >= 0)               /* send lim characeters of string s   */
             sendchar(s[i++]);
     }
/*_______________________________________________________________________*/

void sendchar(char c)
       {
       while(!TXREADY);                /* wait for txready interrupt      */
       port8000 = c;                   /* write char to UART's TX register   */
       TXREADY = 0;                    /* Clear ready to transmit bit     */
       }
/*_______________________________________________________________________*/
char receivechar()
       {
       RXREADY = 0;
       reply = port8000;               /* read char from UART's RX register  */
       while(!RXREADY);                /* wait for txready interrupt      */
       reply = port8000;               /* read char from UART's RX register  */
       RXREADY = 0;                    /* Clear ready to receive bit      */
         return(reply);                /* return the received value       */
       }
/*_______________________________________________________________________*/

void sendinteger(int i)
       {
       while(!TXREADY);                /* wait for txready interrupt      */
       port8100 = i;                   /* write char to UART's TX register   */
       TXREADY = 0;                    /* Clear ready to transmit bit     */
       }
/*_______________________________________________________________________*/
```

```
void itoa(int n,char s[])              /* transform the integer value n into   */
      {                                /* the ASCII string s                   */
      int i, sign;
      if ((sign = n) < 0)
         n = -n;
      i = 0;
      do {
         s[i++] = n % 10 + '0';
      }
      while ((n /= 10) > 0);
      if (sign < 0)
         s[i++] = '-';
      s[i] = '\0';
      reverse(s);
      }
/*_____________________________________________________________________________*/

void reverse(char s[])           /* reverses the string e.g. 'abc' -> 'cba'   */
      {
      int c, i, j;
      for (i = 0, j = strlen(s)-1; i < j; i++, j--)
         {
         c = s[i];
         s[i] = s[j];
         s[j] = c;
         }
      }
/*_____________________________________________________________________________*/

void printresult(int E)
      {
      int n, i;
      long L;
      char s[10];
      sendstring("Memorytest identified ",22);
      L = E;                       /* load E in an long value                 */
      n = ltoa(L,s);               /* transform L in ASCII string, n=length of s */
      for(i=0;i<n;i++)             /* send this string                        */
         {
         sendchar(s[i]);
         }
      sendstring(" errors",7);
      sendinteger(0xa);            /* line feed                               */
      }
```

```
*******************************************************************************
*                   Texas Instruments ltd. 1996                               *
*      Function test of external memory and buffered seial port               *
*                   TMS320LC56          TLC320AC01                            *
*******************************************************************************

       .title "MEMORY AND AC01 TEST"
       .version 50
       .mmregs
        .def  _memory
       .def   _ac01
       .global      _ERR
       .global      _RXREADY
       .global _TXREADY
       .ref   _c_int0
BDRR   .set 30h
BXDR   .set 31h
BSPC   .set 32h
BSPCE  .set 33h
AXR    .set 34h
BKX    .set 35h
ARR    .set 36h
BKR    .set 37h
RANGE  .set 5fffh
XSIZE  .set 4        ; tx buffersize = 4 = rxbuffersize
HSIZE  .set 2        ; half buffer size

; This part initializes the LC56 processor and buffered serial port.
; then initializes the AC01 and starts the main signal
; processing loop. In this example, a data sample is read from
; the adc and written back to the dac unchanged.


XTOP   .sect "txbuff"
       .word  11b                  ; request secondary comms
       .word  0000000101000101b    ; reg1 36-> 8kHz @10.368MhZ
                                   ; 35-> 7.937kHz @10Mhz

       .word  11b                  ; request secondary comms
       .word  0000001000010010b    ; reg2 = B register
;             ||||||||||||||||
;             ||||||||++++++++--------- data = 18
;             |||+++++------------------ address = 2
;             ||+----------------------- write =0
;             ++------------------------ phase shif
;
;      reg 3 = A' stays as default

;      reg 4
       .word  11b                  ; request secondary comms
       .word  0000010000011001b
;             ||||||||||||||||
;             ||||||||||||||++--------- output 0=sq 1=0dB 2=-6dB 3=-12dB
;             ||||||||||||++----------- intput 0=sq 1=0dB 2=-6dB 3=-12dB
;             ||||||||||++------------- monitor 0=sq 1=0dB 2=-6dB 3=-12dB
;             ||||||||++--------------- not used
;             |||+++++------------------ address = 4
;             ||+----------------------- write  = 0
;             ++------------------------ phase shift
```

```
;      reg 5
       .word  11b                ; request secondary comms
       .word  0000010100000101b
;             ||||||||||||||||
;             ||||||||||||||++--------- 0=loopback 1 =norm 2 =aux 3 = both
;             |||||||||||||+----------- 0=hp on, 1=hp off
;             ||||||||||||+------------ 0=echo on , 1=echo off
;             |||||||++++------------- not used
;             |||+++++----------------- address = 5
;             ||+----------------------- write  = 0
;             ++------------------------ phase shift

;      reg6 = digital configuration
;      reg7 = frame synch delay
;      reg8 = frame sync number
       .word 9,10,11,12,13,14,15,16

RTOP   .sect "rxbuff"
       .word 10h,20h,30h,40h,50h,60h,70h,80h
       .word 90h,0a0h,0b0h,0c0h,0d0h,0e0h,0f0h,100h

       .data
CLOCK: .word  0,1,2,3,4     ; Clock Values
       .word  5,6,7,8,9     ; Clock Values
       .word  10,11,12,13,14,15

testmem      .usect  "test_d",RANGE
tstprg .usect  "test_p",RANGE

gotxflag     .usect "b2",1 ; used to signal int from serial
                           ; output port
gotrflag     .usect "b2",1 ; used to signal int from serial
                           ; input port
TEMP1        .usect "b2",1 ; used store buffaddr
TEMP         .usect "b2",1
ADDR         .usect "b2",1
_ERR         .usect "b2",1
_RXREADY     .usect  "b2",1
_TXREADY     .usect  "b2",1


; Macro definitions

; The following macro waits for an interrupt from the serial
; port before it continous with program execution

waitxint     .macro
waitxint?
       lacc   gotxflag      ; load flag into acc
       bz     waitxint?     ; wait for int
       splk   #0,gotxflag   ; reset the flag
       .endm
waitrint     .macro
waitrint?
       lacc   gotrflag      ; load flag into acc
       bz     waitrint?     ; wait for int
       splk   #0,gotrflag   ; reset the flag
       .endm
       .sect "vectors"
rs     b      _c_int0
int1   b      int1
int2   b      rxr           ; UART receive  interrupt
int3   b      txr           ; UART transmit interrupt
tint   b      tint
rint   b      rint
xint   b      xint
brint  b      getrdata      ; bufferred serial port receive  interrupt
bxint  b      getxdata      ; bufferred serial port transmit interrupt
int4   b      int4
rsvd14 b      rsvd14
rsvd16 b      rsvd16
rsvd18 b      rsvd18
rsvd1A b      rsvd1A
```

```
rsvd1C b      rsvd1C
rsvd1E b      rsvd1E
rsvd20 b      rsvd20
trap   b      trap
nmi    b      nmi
rsvd26 b      rsvd26
rsvd28 b      rsvd28

       .text
       .include "ac01.asm"
       .include "memory.asm"

; interrupt handlers

getxdata:     splk   #1,gotxflag  ; set flag
              rete                ; return form interrupt restoring
getrdata:     splk   #1,gotrflag  ; set flag
              rete                ; return form interrupt restoring

rxr:          LACC   #1           ; set RXREADY if
              SAMM   _RXREADY     ; int2 occurs
              RETE

txr:          LACC   #1           ; set TXREADY if
              SAMM   _TXREADY     ; int3 occurs
              RETE

.end
```

```
*******************************************************************************
*                          TMS320CL56                                         *
*                    function memory test                                     *
*                    include file of mem.asm                                  *
*******************************************************************************
       .text                       ; start of main program
_ac01:
       POPD   *+                   ; save stack pointer
       SAR    AR0,*+               ; to be compatible with
       SAR    AR1,*                ; routines written in C
       LARK   AR0,1
       LAR    AR0,*0+

       ldp    #0                   ; set dp to first page
       setc   INTM                 ; disable interrupts
       setc   SXM                  ; set sign ext mode
       setc   OVM                  ; set Overflow mode

; The code below does the following: disables visibility of address
; bus, on chip single access ram is mapped into prog space,sets the IPTR
; to point to 8000h  and selects MICROPROCESSOR mode
       clrc   xf
       splk   #1000100010111000b, PMST
       clrc   CNF                  ; B0 mapped in data space

; Set the interrupt mask to respond to buffered serial interrupt
       splk   #0c6h,IMR            ; only respond to buffered serial rx & tx int and
                                   ; uart
       splk   #08h,BSPC            ; reset and configure BSPC
       splk   #0b400h,BSPCE        ; configure BSPCE, buf for tx/rx enabled
                                   ; 16bits ext frame & clk
       splk   #XTOP, AXR           ; load startaddress of buffer in AXR
       splk   #RTOP, ARR           ; load startaddress of buffer in ARR
       splk   #16, BKX             ; load buf size in BKX (only for initialisation)
       splk   #XSIZE, BKR          ; load buf size in BKR
       splk   #0c0h, IFR           ; clear any pending interupt

       setc   xf                   ; release codec
       rpt    #20
       nop
; Reset the codec and release it again to make it ignore first garbage
; word generated by serial port
       clrc   xf                   ; reset codec
       rpt    #20                  ; wait for 20 cycles
       nop
       setc   xf                   ; release codec
       splk   #048h, BSPC          ; start SPI transmit part
       CLRC   INTM                 ; enable interrupts

; Serial interface and AC01 are now in stable state
; set up AC01
       waitxint                    ; wait for xint, ac01 has received initialization
       splk   XTOP, AXR            ; reset tx buffer address
       splk   #088h, BSPC          ; start SPI receive part
       splk   #XSIZE, BKX          ; enable full size of tx buffer
       waitrint                    ; wait for rint     after half buffer is full
       splk   RTOP, ARR            ; reset rx buffer address

       LAR    AR4, #0              ; Loop counter for debugging
LOOP   LAR    AR3, #HSIZE          ; load loop counter with 'half buffersize' - 1
       MAR    *,AR3
       splk   #RTOP, TEMP1
       LACL   TEMP1                ; load address of lower half of receive buffer
       BIT    BSPCE,1              ; check RH flag in BSPCE register
       BCND   LRBP, NTC            ; branch if RH = 0
       ADD    #HSIZE               ; add half buffer size if RH = 1
LRBP   SACL   TEMP1
       LAR    AR5, TEMP1           ; load receive buffer pointer
       splk   #XTOP, TEMP1
       LACL   TEMP1                ; load address of lower half of transmit buffer
       BIT    BSPCE,4              ; check XH flag in BSPCE register
       BCND   LXBP, NTC            ; branch if XH = 0
       ADD    #HSIZE               ; add half buffer size if RH = 1
LXBP   SACL   TEMP1
```

```
       LAR    AR2, TEMP1          ; load transmit buffer pointer
       MAR    *-,AR5              ; substract 1 from loop counter AR3

SHIFT  LACL   *+, AR2             ; activate tx buffer pointer
       SACL   *+, AR3             ; store 1st rsample as 1st txsample
       BANZ   SHIFT,*-,AR5        ; repeat 'half buffer size' times
       NOP
       NOP
       splk   #0b400h, BSPCE      ; reload SPCE and set BXE again
       splk   #0c8h, BSPC         ; start SPI rx and tx part

       waitxint                   ; wait for last samples transmited
       waitrint                   ; wait for new samples received

       LACC   ARR
       LACC   AXR
       LACC   BKR
       LACC   BKX
       MAR    *, AR4              ; increment loop counter for
       MAR    *+, AR5             ; debugging
       LACC   _RXREADY            ; check if interrupt from the UART
       BCND   LOOP,EQ             ; occured. If not stay in the loop

       NOP
       nop

       LARP   AR1                 ; reload stack pointer
       SBRK   2
       LAR    AR0,*-
       PSHD   *
       RET
```

```
*******************************************************************************
*                          TMS320CL56                                         *
*                    function memory test                                     *
*                    include file of mem.asm                                  *
*******************************************************************************
        .text
_memory:
       POPD   *+                  ; save stack pointer
       SAR    AR0,*+              ; to be compatible with
       SAR    AR1,*               ; routines written in C
       LARK   AR0,1
       LAR    AR0,*0+

       ldp    #0
       splk   #0, greg
       splk   #1000100010111000b, PMST
       splk   #111000000b, PDWSR         ; set software wait states
;              ||||||+++----------------------  program:  0 wait states
;              |||+++-------------------------   data:    0 wait states
;               +++--------------------------   i/o:     7 wait states

       CLRC   INTM                ; enable intetrrupts
       MAR    *,AR3               ; activate AR3
       CLRC   CNF                 ; map on-chip RAM into data space
       LACL   #0                  ; reset the
       SACL   _ERR                ; Error counter
       LAR    AR3,#CLOCK          ; preload counter values
       SACL   *+                  ; in data space locations
       LACL   #1
       SACL   *+
       LACL   #2
       SACL   *+
       LACL   #3
       SACL   *+
       LACL   #4
       SACL   *+
       LACL   #5
       SACL   *+
       LACL   #6
       SACL   *+
       LACL   #7
       SACL   *+
       LACL   #8
       SACL   *+
       LACL   #9
       SACL   *+
       LACL   #10
       SACL   *+
       LACL   #11
       SACL   *+
       LACL   #12
       SACL   *+
       LACL   #13
       SACL   *+
       LACL   #14
       SACL   *+
       LACL   #15
       SACL   *+


       ldp    #0                  ; set dp to first page
       CLRC   SXM                 ; suppress sign extension



START  LAR    AR6,#testmem        ; load start address of
       MAR    *, AR6              ; data memory to test
       RPTZ   #RANGE              ; load 0 in all memory
        SACL  *+                  ; locations within RANGE
       LAR    AR6,#testmem        ; reset also program space
       LACC   #tstprg             ; while copy data to program
       RPT    #RANGE
        TBLW  *+
```

```
       MAR    *,AR3              ; ARP points to AR3
       LAR    AR3,#CLOCK         ; Load AR3 with start value
       LAR    AR2,#15            ; AR2 is the loop counter
       LAR    AR5,#0

LOOPM:
       OUT     *+,0001h          ; Output value of AR3



       LACC   #0h
       LAR    AR6,#testmem       ; load start address of
       MAR    *,AR6              ; data memory to test
       LAR    AR7,#RANGE         ; load counter with the length
                                 ; of memory to test
       LACC   #tstprg            ; store the start address or
       SACL   ADDR               ; program memory to test in ADDR

OTOA:  LACC   ADDR               ; read first program memory
       TBLR   TEMP               ; location
       LACC   #0h
       XOR    TEMP               ; check if value is correct
       BCND   ERR_P1,NEQ         ; if not correct then ERR_P1
       NOP
       NOP
P1:    LACC   #0AAAAh            ; load new value to store in
       SACL   TEMP               ; program memory location
       LACC   ADDR               ; store this value in prog
       TBLW   TEMP
       ADD    #1                 ; increment ADDR
       SACL   ADDR
       LACC   #0h
       XOR    *                  ; read data memory location
                                 ; and check value
       BCND   ERR_D1,NEQ         ; if not correct ERR_P1
       NOP
       NOP
D1:    LACC   #0AAAAh            ; store new value in
       SACL   *+,AR7             ; data memory location
       BANZ   OTOA,*-,AR6        ; stay in loop if loop counter
                                 ; AR7 is not 0. Post decrement AR7
       NOP
       NOP



       LACC   #tstprg            ; same as OTOA but change values
       LAR    AR7,#RANGE         ; from A to 5
       LAR    AR6,#testmem
       SACL   ADDR
ATO5:  LACC   ADDR
       TBLR   TEMP
       LACC   #0AAAAh
       XOR    TEMP
       BCND   ERR_P2,NEQ
       NOP
       NOP
P2:    LACC   #5555h
       SACL   TEMP
       LACC   ADDR
       TBLW   TEMP
       ADD    #1
       SACL   ADDR
       LACC   #0Ah
       XOR    *
       BCND   ERR_D2,NEQ
       NOP
       NOP
D2:    LACC   #5555h
       SACL   *+,AR7
       BANZ   ATO5,*-,AR6
       NOP
       NOP
```

```
       LAR    AR6,#testmem        ; same as OTOA but change values
       LACC   #tstprg             ; from 5 to F
       LAR    AR7,#RANGE
       SACL   ADDR
f5TOF:  LACC   ADDR
       TBLR   TEMP
       LACC   #5555h
       XOR    TEMP
       BCND   ERR_P3,NEQ
       NOP
       NOP
P3:    LACC   #0FFFFh
       SACL   TEMP
       LACC   ADDR
       TBLW   TEMP
       ADD    #1
       SACL   ADDR
       LACC   #5555h
       XOR    *
       BCND   ERR_D3,NEQ
       NOP
       NOP
D3:    LACC   #0FFFFh
       SACL   *+,AR7
       BANZ   f5TOF,*-,AR6
       NOP
       NOP



       LAR    AR6,#testmem        ; same as OTOA but change values
       LACC   #tstprg             ; from F to 0
       LAR    AR7,#RANGE
       SACL   ADDR
FTOO:  LACC   ADDR
       TBLR   TEMP
       LACC   #0FFFFh
       XOR    TEMP
       BCND   ERR_P4,NEQ
       NOP
       NOP
P4:    LACC   #0h
       SACL   TEMP
       LACC   ADDR
       TBLW   TEMP
       ADD    #1
       SACL   ADDR
       LACC   #0FFFFh
       XOR    *
       BCND   ERR_D4,NEQ
       NOP
       NOP
D4:    LACC   #0h
       SACL   *+,AR7
       BANZ   FTOO,*-,AR6
       NOP
       NOP

       MAR    *,AR2
       BANZ   LOOPM,*-,AR3        ; Branch to start of loop
       NOP
;Start this part after 16 times LOOPM

; The following test will generate consecutive writes and reads
; to the external memory
       LACC   #RANGE, 13          ; load range divided by 8 in AR3
       SACH   TEMP
       LAR    AR3, TEMP
       LAR    AR4, #testmem       ; load start address of datamem
       MAR    *,AR4               ; to test in AR4
CONS1: LACC   #05555h             ; load accumulator with
       SACL   TEMP                ; 5555aaaah
       LACC   TEMP, 16
       OR     #0aaaah
```

```
        SACL   *+                ; store aaaah in external data
        SACH   *+                ; store 5555h in external data
        SACL   *+                ; store aaaah in external data
        SACH   *+                ; store 5555h in external data
        SACL   *+                ; store aaaah in external data
        SACH   *+                ; store 5555h in external data
        SACL   *+                ; store aaaah in external data
        SACH   *+                ; store 5555h in external data
        SAR    AR4,ADDR          ; reset the address pointer
        LACL   ADDR
        SUB    #8
        SACL   ADDR
        LAR    AR4, ADDR
        LACC   *+                ; read and accumulate the values
        ADD    *+                ; written before
        ADD    *+
        ADD    *+
        ADD    *+
        ADD    *+
        ADD    *+
        ADD    *+
        ADD    #4                ; add 4 to the accumulator
        AND    #0ffffh           ; if all reads and writes are ok
        BCND   ERR_CONS1, NEQ    ; ACCU = 0. If not ERR_CONS1
C1:     MAR    *, AR3            ; stay in loop until AR3 = 0
        BANZ   CONS1,*-,AR4      ; post increment loop counter AR3

        LACC   #RANGE, 13        ; same as above
        SACH   TEMP              ; this time with 0000 and ffffh
        LAR    AR3, TEMP         ; as values to be written to
        LAR    AR4, #testmem     ; external memory
        MAR    *,AR4
CONS2:  LACC   #0ffffh
        SACL   TEMP
        LACC   TEMP, 16
        SACL   *+
        SACH   *+
        SACL   *+
        SACH   *+
        SACL   *+
        SACH   *+
        SACL   *+
        SACH   *+
        SAR    AR4,ADDR
        LACL   ADDR
        SUB    #8
        SACL   ADDR
        LAR    AR4, ADDR
        LACC   *+
        ADD    *+
        ADD    *+
        ADD    *+
        ADD    *+
        ADD    *+
        ADD    *+
        ADD    *+
        ADD    #4
        AND    #0ffffh
        BCND   ERR_CONS2, NEQ
C2:     MAR    *, AR3
        BANZ   CONS2,*-,AR4

        LACC   _RXREADY          ; check if interrupt occurred
        BCND   START,EQ          ; from UART. If not start again
        NOP                      ; with memory test
        NOP
        LARP   AR1               ; reload stack pointer
        SBRK   2
        LAR    AR0,*-
        PSHD   *
        RET
```

```
ERR_D1 LACC _ERR                ; add 1 to the
       ADD #1                   ; error counter
       SACL _ERR                ; and continue
       B      D1                ; program execution
ERR_D2 LACC _ERR
       ADD #1
       SACL _ERR
       B      D2
ERR_D3  LACC _ERR
       ADD #1
       SACL _ERR
       B      D3
ERR_D4  LACC _ERR
       ADD #1
       SACL _ERR
       B      D4
ERR_P1  LACC _ERR
       ADD #1
       SACL _ERR
       B      P1
ERR_P2  LACC _ERR
       ADD #1
       SACL _ERR
       B      P2
ERR_P3  LACC _ERR
       ADD #1
       SACL _ERR
       B      P3
ERR_P4  LACC _ERR
       ADD #1
       SACL _ERR
       B      P4
ERR_CONS1      LACC _ERR
       ADD #1
       SACL _ERR
       B      C1
ERR_CONS2      LACC _ERR
       ADD #1
       SACL _ERR
       B      C2
```

```
/*************************************************************************/
/* Test Program for EMU5X running on a LC56                              */
/* Configurations of processor:                                          */
/*     1) Microprocessor mode (MP/MC=1)                                  */
/*     2) B0 DARAM configure on data space (CNF=0)                       */
/*     3) 6K Single Access Ram configure in Program space                */
/*************************************************************************/

 main.obj
 mem.obj
-stack 512
-cr
-i c:\dsp\c5x\lib
-l rts50.lib

-m main.map
-o main.out
-v0

MEMORY
{
    PAGE 0 :
       EXT_PROG : origin =  555h ,length =  7000h     /* 32K ext RAM      */
       PROG_RAM : origin =  8800h ,length =  1000h    /* 6K RAM           */

    PAGE 1 :

       REGS   :   origin = 0000h ,length = 0060h      /* MEM REG          */
       DARAM_B2: origin = 0060h ,length = 0020h       /* Always Data      */
       RAM_B0B1: origin = 0100h ,length = 0400h       /* CNF=0            */
       EXT_DATA: origin = 2000h ,length = 6000h       /* 24K ext RAM      */
       BLK0   :  origin = 0800h ,length = 0800h       /* OVLY=1           */
}

/*-------------------------------------------------------------------------*/
/* SECTIONS ALLOCATION                                                     */
/*-------------------------------------------------------------------------*/

SECTIONS
{
       test_p : { } > EXT_PROG  PAGE 0
       vectors: { } > PROG_RAM  PAGE 0
       .text  : { } > PROG_RAM  PAGE 0         /* CODE                    */
       .bss   : { } > RAM_B0B1  PAGE 1         /* GLOBAL VARS,STACK,HEAP  */
       .data  : { } > RAM_B0B1  PAGE 1         /* Initialized var         */
       test_d : { } > EXT_DATA  PAGE 1
       b2     : { } > DARAM_B2  PAGE 1         /* DARAM_B2                */
       .cinit : { } > PROG_RAM  PAGE 0
       .const : { } > RAM_B0B1  PAGE 1
       .stack : { } > RAM_B0B1  PAGE 1
       txbuff : { } > BLK0      PAGE 1         /* Transmit Buffer         */
       rxbuff : { } > BLK0      PAGE 1         /* Receive Buffer          */
}
```

Appendix B PAL Programming

" EVM used for TMS320LC56

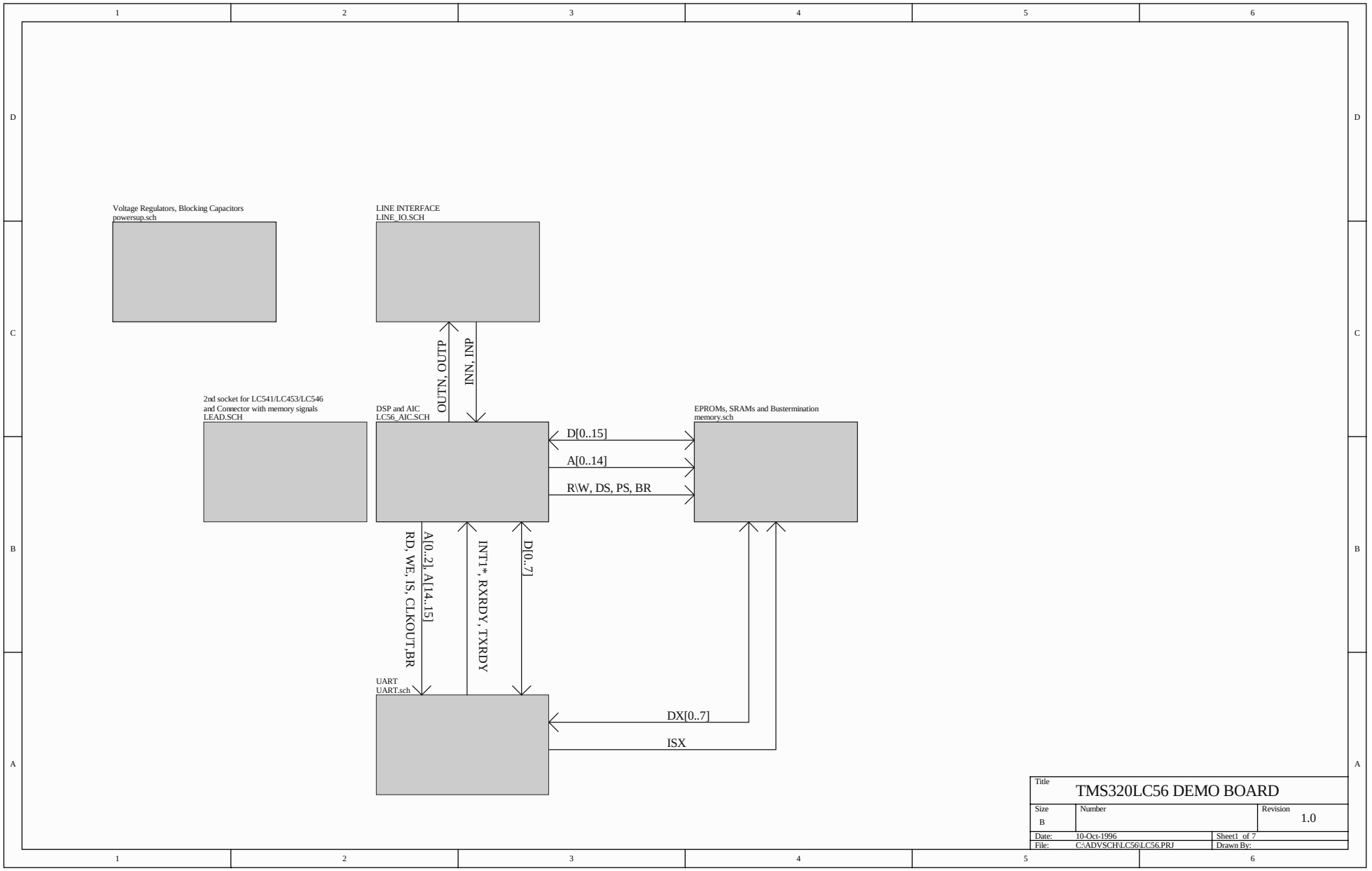
```
MODULE module_name
    lc56_2 DEVICE 'p16v8r';

"INPUTS
    CLK,A15,A14,RW,IS          PIN 1,2,3,4,5;
    DS,CLKOUT,STRB,RD          PIN 6,7,8,9;

    OE                          PIN 11;

"OUTPUTS
    CLK_A                       PIN 19;
    WEX                         PIN 18;
    BE                          PIN 17;
    ISX                         PIN 16;
    A                           PIN 14;
    RDX                         PIN 13;
    EX                          PIN 12;
    X,C,Z=.X.,.C.,.Z.;

EQUATIONS

"UART READ & WRITE ACCESS

!CLK_A  = CLKOUT;

!A  := !RD;

!RDX    = !IS & !STRB & RW & !A & !A14 & A15;

!WEX    = !IS & !STRB & !RW & !A14 & A15;

"LED STROBE

!ISX    = !A15 & !A14 & !IS & !STRB;

"BUFFER ENABLE

!BE     = !IS # !DS & A15;

"EPROM ENABLE

!EX     = !IS & A15 & A14 # !DS & A15;
```

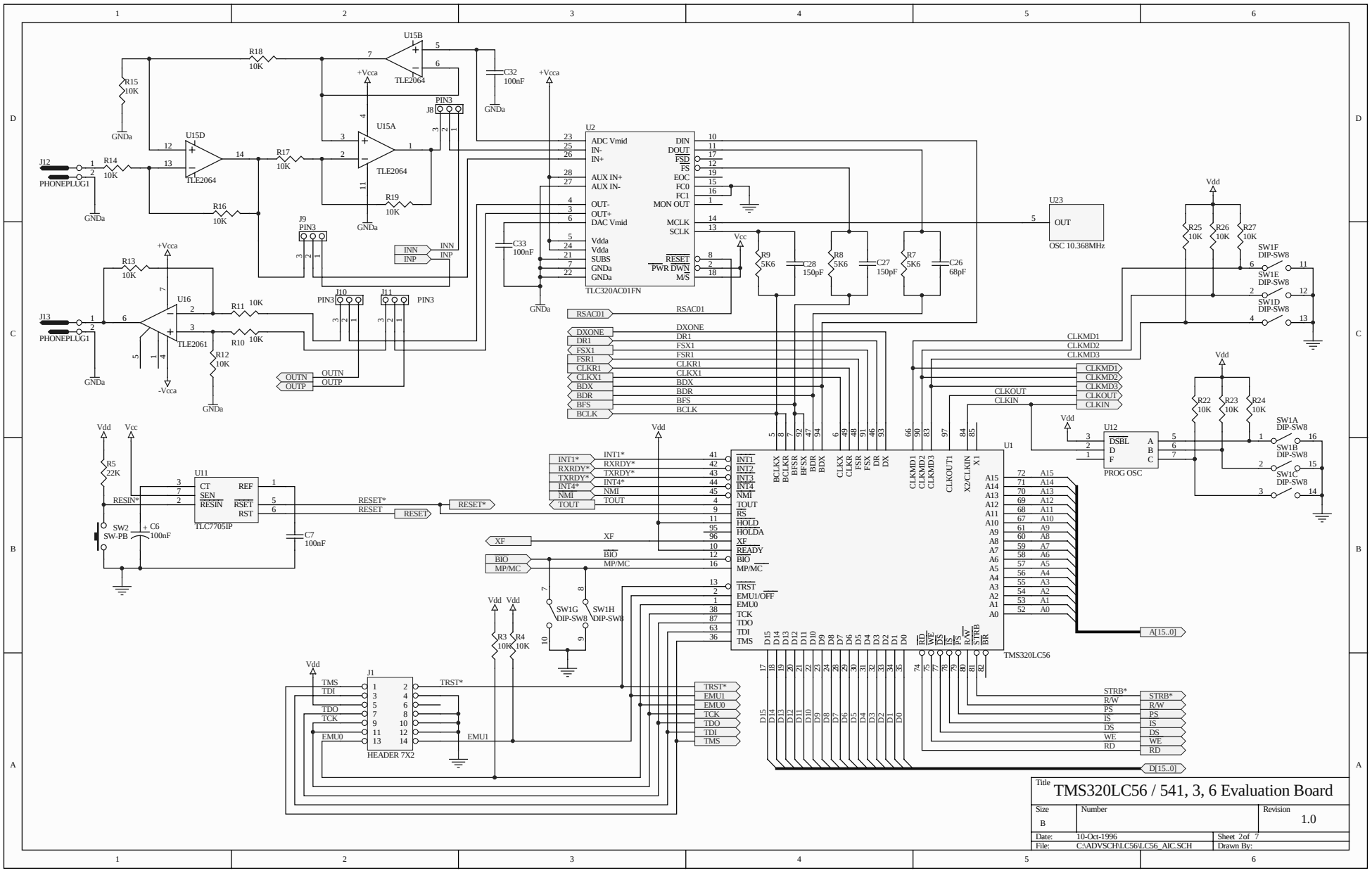
```
TEST_VECTORS ([CLK,RD,CLKOUT] -> [CLK_A,A])

              [C,  0,   0]    -> [ 1,   0];
              [C,  1,   1]    -> [ 0,   1];

TEST_VECTORS ([CLK,RD,IS,STRB,RW,A14,A15] -> [A,RDX])

              [C,  0, 0,   0,  0,  0, 1]  -> [0, 1 ];
              [C,  0, 0,   0,  1,  0, 1]  -> [0, 0 ];
              [C,  1, 0,   0,  1,  0, 1]  -> [1, 1 ];
              [C,  0, 0,   1,  1,  0, 1]  -> [0, 1 ];
              [C,  0, 0,   0,  1,  0, 0]  -> [0, 1 ];

TEST_VECTORS ([CLK,IS,STRB,RW,A14,A15] -> [WEX])

              [C,   0,  0,  0,  0, 1]  -> [ 0 ];
              [C,   1,  0,  0,  0, 1]  -> [ 1 ];
              [C,   0,  1,  0,  0, 1]  -> [ 1 ];
              [C,   0,  0,  1,  0, 1]  -> [ 1 ];
              [C,   0,  0,  0,  1, 1]  -> [ 1 ];

TEST_VECTORS ([CLK,IS,A15,A14,STRB] -> [ISX])

              [C,  1,  0,  0,   0 ] -> [ 1 ];
              [C,  0,  0,  0,   0 ] -> [ 0 ];
              [C,  0,  0,  1,   0 ] -> [ 1 ];
              [C,  0,  1,  0,   0 ] -> [ 1 ];
              [C,  0,  1,  1,   0 ] -> [ 1 ];
              [C,  0,  0,  0,   1 ] -> [ 1 ];
TEST_VECTORS ([CLK,IS,A15,DS] -> [BE])

              [C,  1,  1,  0] -> [ 0];
              [C,  0,  0,  0] -> [ 0];
              [C,  1,  0,  0] -> [ 1];
              [C,  1,  0,  1] -> [ 1];

TEST_VECTORS ([CLK,A15,A14,IS,DS] -> [EX])

              [C,   1,  1,  0, 1] -> [ 0 ];
              [C,   1,  0,  0, 0] -> [ 0 ];
              [C,   0,  1,  0, 0] -> [ 1 ];
              [C,   0,  0,  1, 0] -> [ 1 ];
              [C,   0,  0,  0, 1] -> [ 1 ];

END module_name
```

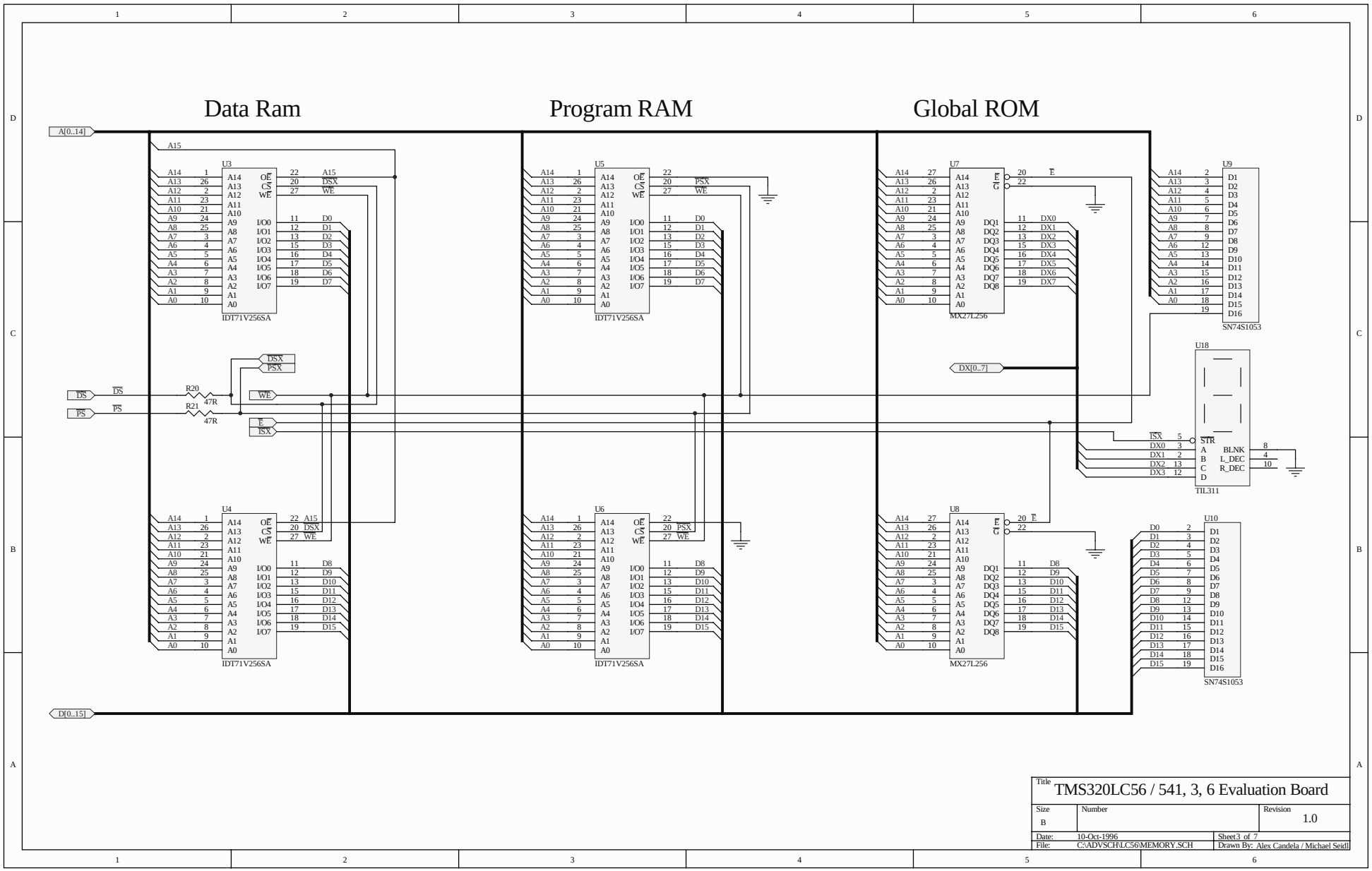
```
" EVM used for TMS320LC541,3,6


MODULE module_name
    lead_1 DEVICE 'p16v8r';

"INPUTS
    CLK,A15,A14,RW,IS           PIN 1,2,3,4,5;
    DS,CLKOUT,STRB              PIN 6,7,8;
    MSTRB                       PIN 15;
    OE                          PIN 11;

"OUTPUTS
    CLK_A                       PIN 19;
    WEX                         PIN 18;
    BE                          PIN 17;
    ISX                         PIN 16;
    WE                          PIN 14;
    RDX                         PIN 13;
    EX                          PIN 12;
    X,C,Z=.X.,.C.,.Z.;


EQUATIONS

"UART READ & WRITE ACCESS

!CLK_A  = CLKOUT;

!WE     = !MSTRB & !RW;

!RDX    = !IS & !STRB & RW & !A14 & A15;

!WEX    = !IS & !STRB & !RW & !A14 & A15;


"LED STROBE

!ISX    = !A15 & !A14 & !IS & !STRB;


"BUFFER ENABLE

!BE     = !IS # !DS & A15;


"EPROM ENABLE

!EX     = !IS & A15 & A14 # !DS & A15;
```

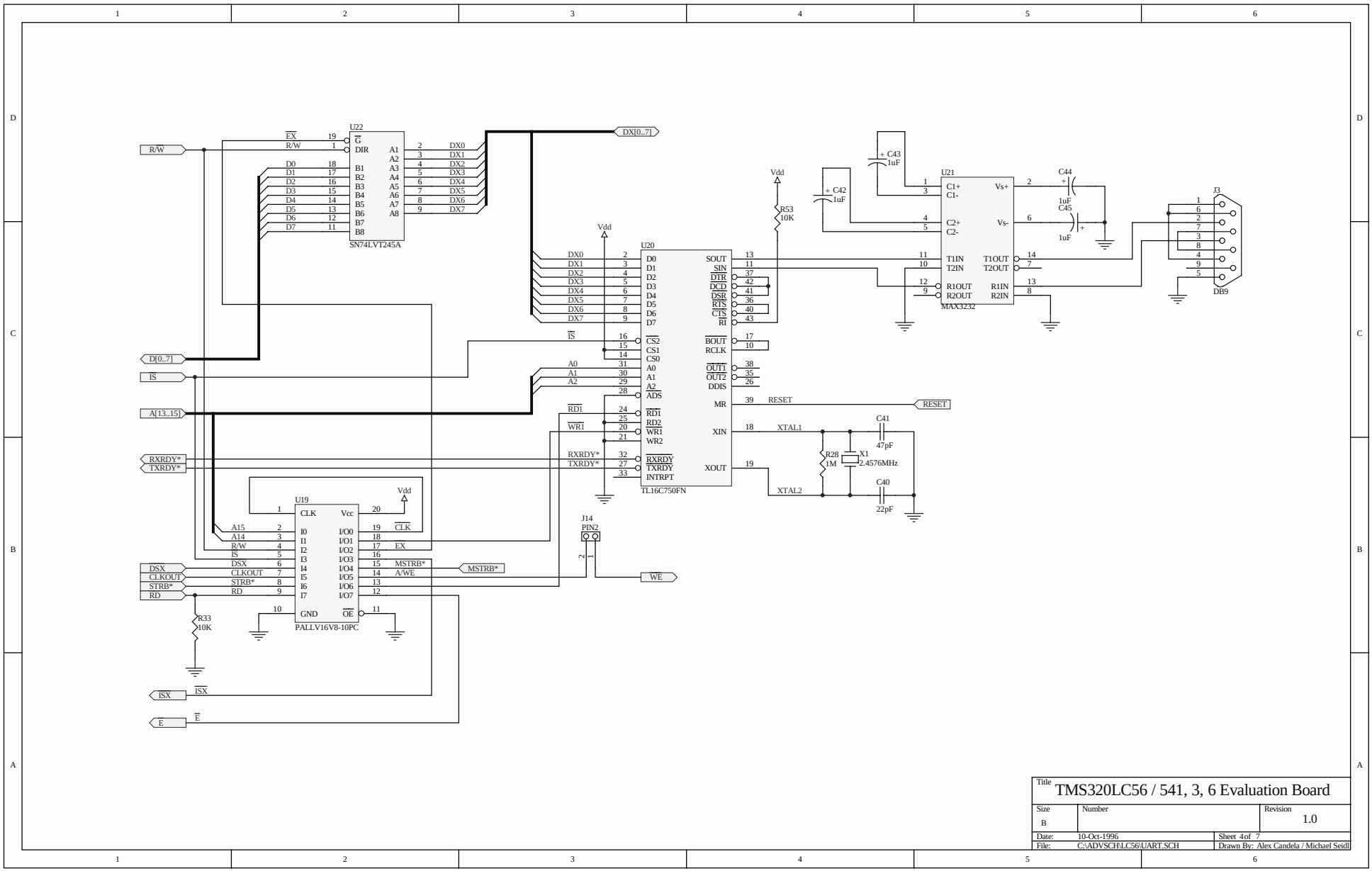
```
TEST_VECTORS ([CLK,CLKOUT] -> [CLK_A])

              [C,     0]   -> [ 1];
              [C,     1]   -> [ 0];

TEST_VECTORS ([CLK,MSTRB, RW] -> [WE])

              [C,    0  ,  1] -> [ 1];
              [C,    1  ,  1] -> [ 1];
              [C,    1  ,  1] -> [ 1];
              [C,    0  ,  0] -> [ 0];

TEST_VECTORS ([CLK,IS,STRB,RW,A14,A15] -> [RDX])

              [C,  0,   0,  0,  0, 1]  -> [ 1 ];
              [C,  0,   0,  1,  0, 1]  -> [ 0 ];
              [C,  0,   0,  1,  0, 1]  -> [ 0 ];
              [C,  0,   1,  1,  0, 1]  -> [ 1 ];
              [C,  0,   0,  1,  0, 0]  -> [ 1 ];

TEST_VECTORS ([CLK,IS,STRB,RW,A14,A15] -> [WEX])

              [C,   0,  0,  0,  0, 1]  -> [ 0 ];
              [C,   1,  0,  0,  0, 1]  -> [ 1 ];
              [C,   0,  1,  0,  0, 1]  -> [ 1 ];
              [C,   0,  0,  1,  0, 1]  -> [ 1 ];
              [C,   0,  0,  0,  1, 1]  -> [ 1 ];

TEST_VECTORS ([CLK,IS,A15,A14,STRB] -> [ISX])

              [C,  1,  0,  0,   0 ] -> [ 1 ];
              [C,  0,  0,  0,   0 ] -> [ 0 ];
              [C,  0,  0,  1,   0 ] -> [ 1 ];
              [C,  0,  1,  0,   0 ] -> [ 1 ];
              [C,  0,  1,  1,   0 ] -> [ 1 ];
              [C,  0,  0,  0,   1 ] -> [ 1 ];

TEST_VECTORS ([CLK,IS,A15,DS] -> [BE])

              [C,  1,  1,  0] -> [ 0];
              [C,  0,  0,  0] -> [ 0];
              [C,  1,  0,  0] -> [ 1];
              [C,  1,  0,  1] -> [ 1];

TEST_VECTORS ([CLK,A15,A14,IS,DS] -> [EX])

              [C,   1,  1,  0, 1] -> [ 0 ];
              [C,   1,  0,  0, 0] -> [ 0 ];
              [C,   0,  1,  0, 0] -> [ 1 ];
              [C,   0,  0,  1, 0] -> [ 1 ];
              [C,   0,  0,  0, 1] -> [ 1 ];

END module_name
```

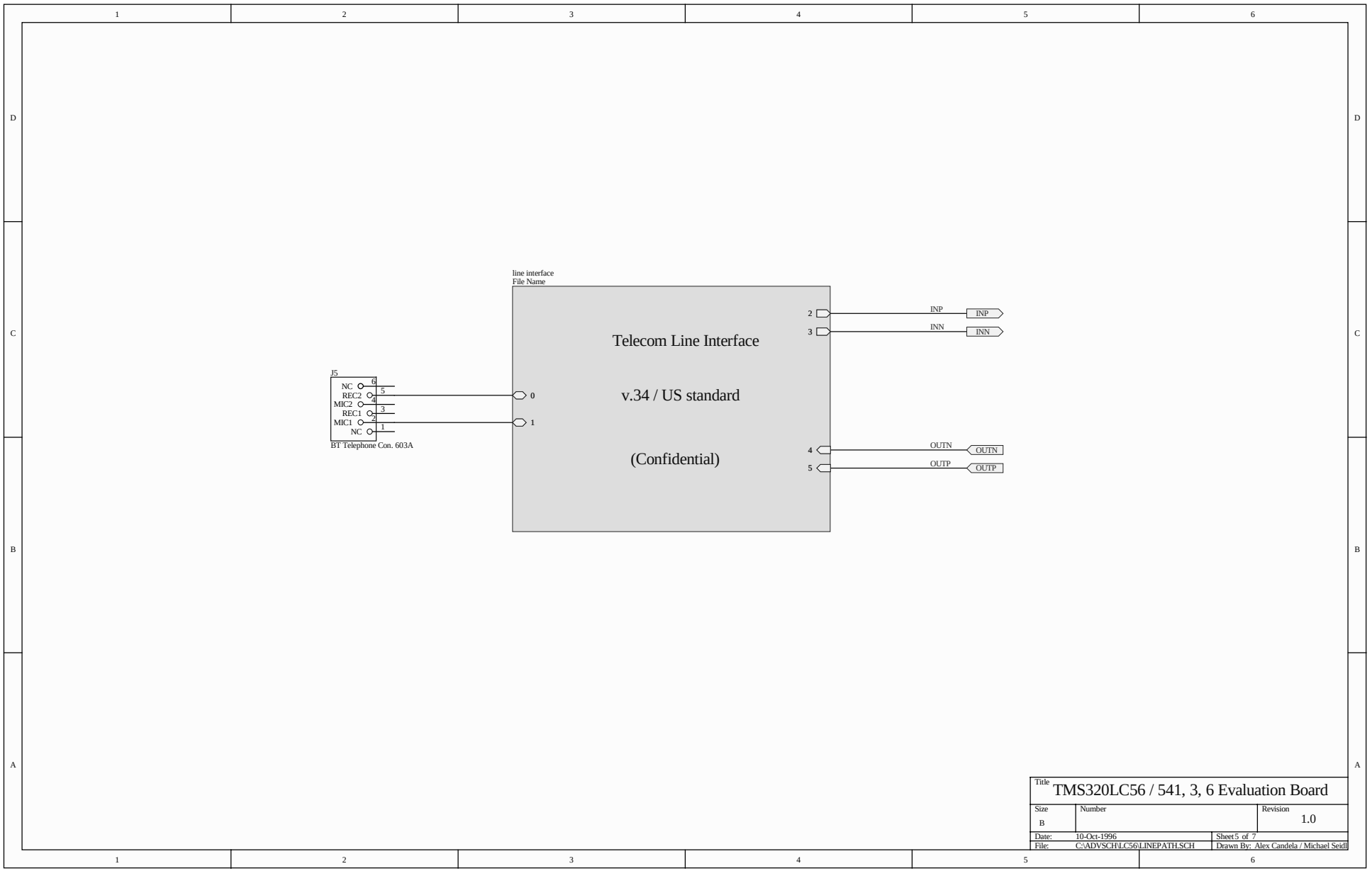
Appendix C Schematics

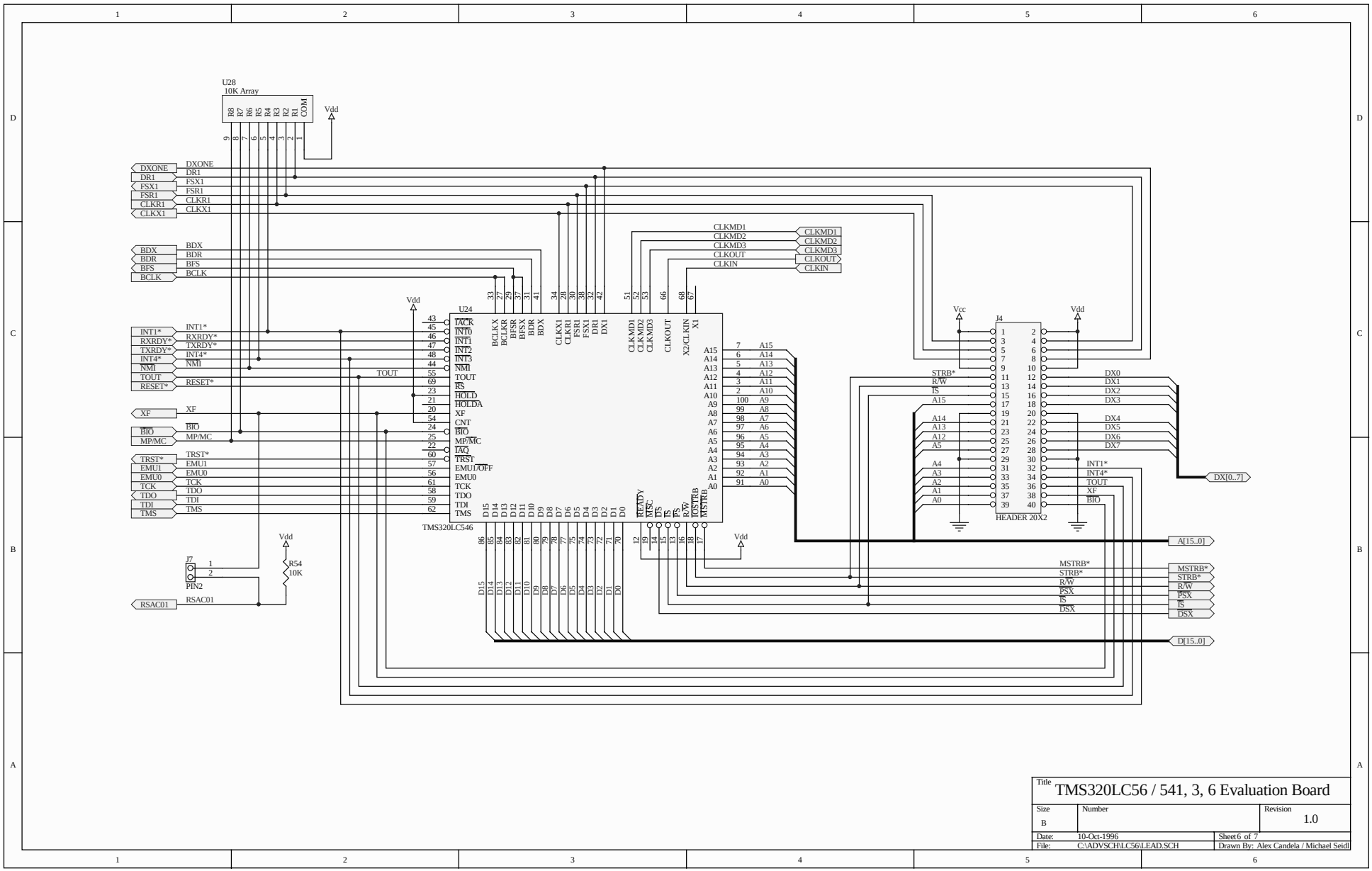

Voltage Regulators, Blocking Capacitors
powersup.sch
LINE INTERFACE
LINE_IO.SCH
OUTN, OUTP
INN, INP
2nd socket for LC541/LC453/LC546
and Connector with memory signals
LEAD.SCH
DSP and AIC
LC56_AIC.SCH
EPROMs, SRAMs and Bustermination
memory.sch
D[0..15]
A[0..14]
R\W, DS, PS, BR
RD, WE, IS, CLKOUT,BR
A[0..2], A[14..15]
INT1*, RXRDY, TXRDY
D[0..7]
UART
UART.sch
DX[0..7]
ISX
Title
TMS320LC56 DEMO BOARD
Size
B
Number
Revision
1.0
Date: 10-Oct-1996
Sheet1 of 7
File: C:\ADVSCH\LC56\LC56.PRJ
Drawn By:

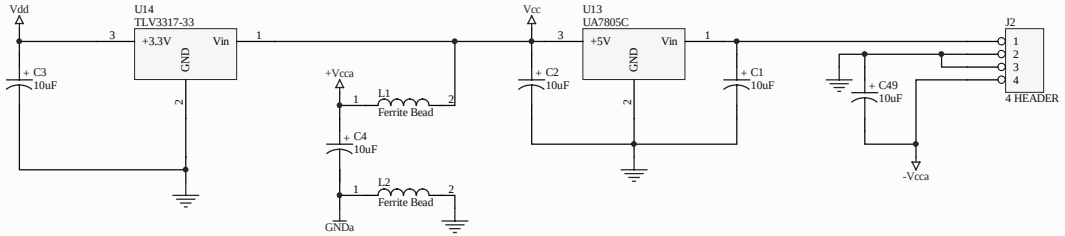

TMS320LC56 / 541, 3, 6 Evaluation Board
Size B
Number
Revision 1.0
Date: 10-Oct-1996
Sheet 2of 7
File: C:\ADVSCH\LC56\LC56_AIC.SCH
Drawn By:
U1
TMS320LC56
U2
TLC320AC01FN
U11
TLC7705IP
U12
PROG OSC
U23
OSC 10.368MHz
U15A
U15B
U15D
TLE2064
U16
TLE2061
J1
HEADER 7X2
J8
J9
J10
J11
J12
J13
PHONEPLUG1
SW1A DIP-SW8
SW1B DIP-SW8
SW1C DIP-SW8
SW1D DIP-SW8
SW1E DIP-SW8
SW1F DIP-SW8
SW1G DIP-SW8
SW1H DIP-SW8
SW2 SW-PB
A[15..0]
D[15..0]
RSAC01
DXONE
DR1
FSX1
FSR1
CLKR1
CLKX1
BDX
BDR
BFS
BCLK
CLKMD1
CLKMD2
CLKMD3
CLKOUT
CLKIN
INT1*
RXRDY*
TXRDY*
INT4*
NMI
TOUT
XF
BIO
MP/MC
TRST*
EMU1
EMU0
TCK
TDO
TDI
TMS
RESET*
RESIN*
INN
INP
OUTN
OUTP
STRB*
R/W
PS
IS
DS
WE
RD
+Vcca
-Vcca
Vcc
Vdd
GNDa


Data Ram
Program RAM
Global ROM
A[0..14]
D[0..15]
DX[0..7]
U3
U4
U5
U6
U7
U8
U9
U10
U18
IDT71V256SA
MX27L256
SN74S1053
TIL311
R20
R21
47R
DS
PS
WE
DSX
PSX
ISX
STR
BLNK
L_DEC
R_DEC
Title
TMS320LC56 / 541, 3, 6 Evaluation Board
Size
B
Number
Revision
1.0
Date:
10-Oct-1996
File:
C:\ADVSCH\LC56\MEMORY.SCH
Sheet3 of 7
Drawn By:
Alex Candela / Michael Seidl

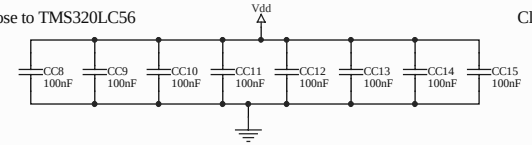

U22
SN74LVT245A
U20
TL16C750FN
U21
MAX3232
U19
PALLV16V8-10PC
J3
DB9
J14
PIN2
DX[0..7]
D[0..7]
R/W
IS
A[13..15]
RXRDY*
TXRDY*
DSX
CLKOUT
STRB*
RD
ISX
E
WE
MSTRB*
A/WE
RESET
XTAL1
XTAL2
Vdd
R53 10K
R33 10K
R28 1M
X1 2.4576MHz
C41 47pF
C40 22pF
C42 1uF
C43 1uF
C44 1uF
C45 1uF
Title TMS320LC56 / 541, 3, 6 Evaluation Board
Size B
Number
Revision 1.0
Date: 10-Oct-1996
Sheet 4of 7
File: C:\ADVSCH\LC56\UART.SCH
Drawn By: Alex Candela / Michael Seidl


line interface
File Name
Telecom Line Interface
v.34 / US standard
(Confidential)
J5
NC
REC2
MIC2
REC1
MIC1
NC
BT Telephone Con. 603A
INP
INN
OUTN
OUTP
Title
TMS320LC56 / 541, 3, 6 Evaluation Board
Size
B
Number
Revision
1.0
Date: 10-Oct-1996
Sheet 5 of 7
File: C:\ADVSCH\LC56\LINEPATH.SCH
Drawn By: Alex Candela / Michael Seidl

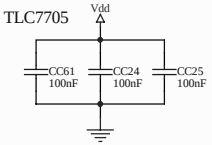

U28
10K Array
R8 R7 R6 R5 R4 R3 R2 R1 COM
Vdd
DXONE
DR1
FSX1
FSR1
CLKR1
CLKX1
BDX
BDR
BFS
BCLK
INT1*
RXRDY*
TXRDY*
INT4*
NMI
TOUT
RESET*
XF
BIO
MP/MC
TRST*
EMU1
EMU0
TCK
TDO
TDI
TMS
U24
TMS320LC546
CLKMD1
CLKMD2
CLKMD3
CLKOUT
CLKIN
J4
HEADER 20X2
STRB*
R/W
IS
DS
PS
DX0
DX1
DX2
DX3
DX4
DX5
DX6
DX7
DX[0..7]
A[15..0]
D[15..0]
MSTRB*
J7
PIN2
R54
10K
RSAC01
Vcc
Title
TMS320LC56 / 541, 3, 6 Evaluation Board
Size
B
Number
Revision
1.0
Date:
10-Oct-1996
Sheet 6 of 7
File:
C:\ADVSCH\LC56\LEAD.SCH
Drawn By: Alex Candela / Michael Seidl



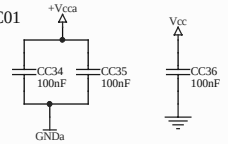
Close to TMS320LC56



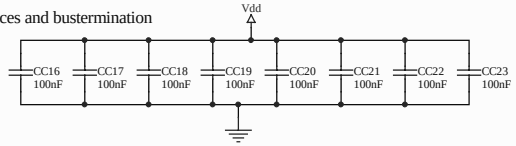
Close to Osc. and TLC7705



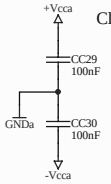
Close to AC01



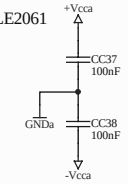
Close to memory devices and bustermination



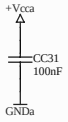
Close to TL082



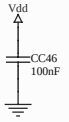
Close to TLE2061



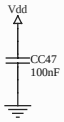
Close to TLE2064



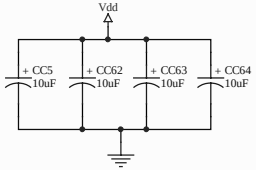
Close to PAL



Close to UART



Close to MAX3232



Title: TMS320LC56 / 541, 3, 6 Evaluation Board		
Size: B	Number:	Revision: 1.0
Date: 10-Oct-1996	Sheet7 of 7	
File: C:\ADVSCH\LC56\POWERSUP.SCH	Drawn By: Alex Candela / Michael Seidl	