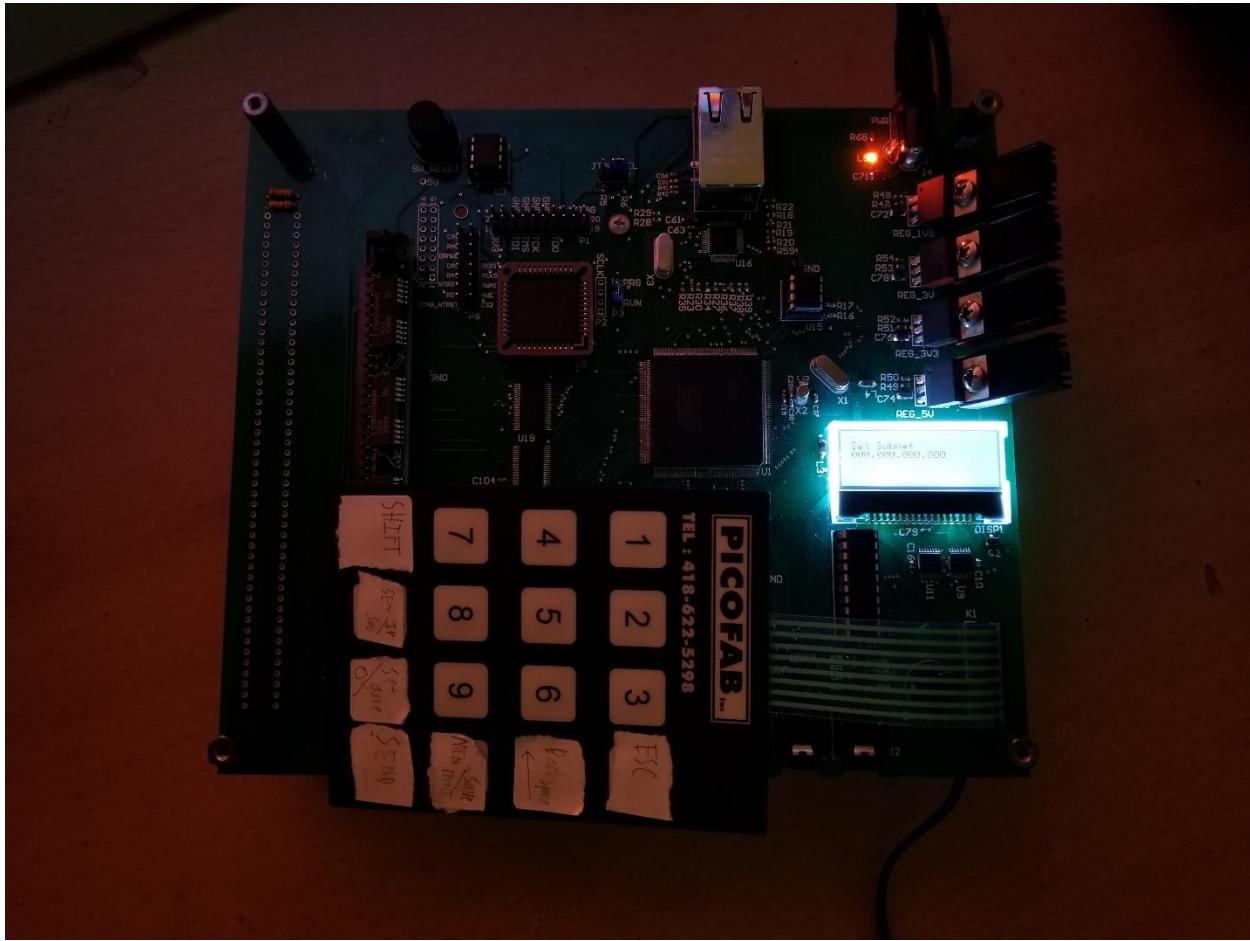


VoIP phone User Manual



The EE52 VoIP phone is a phone that can communicate with other EE52 VoIP phones. The user controls the phone by using a 128x32 display and a 4x4 keypad. There is a headphone and microphone jack that a headset can be plugged into, and there is a button for putting the phone “on-the-hook” to hangup the call.

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System Specifications

Processor	Atmel AT91RM9200
Input power	8V-12V DC 5.5mm barrel jack
Display	128x32
Headphone Jack	3.5mm mono audio jack
Microphone Jack	3.5mm
Keypad	4x4 button keypad

Startup

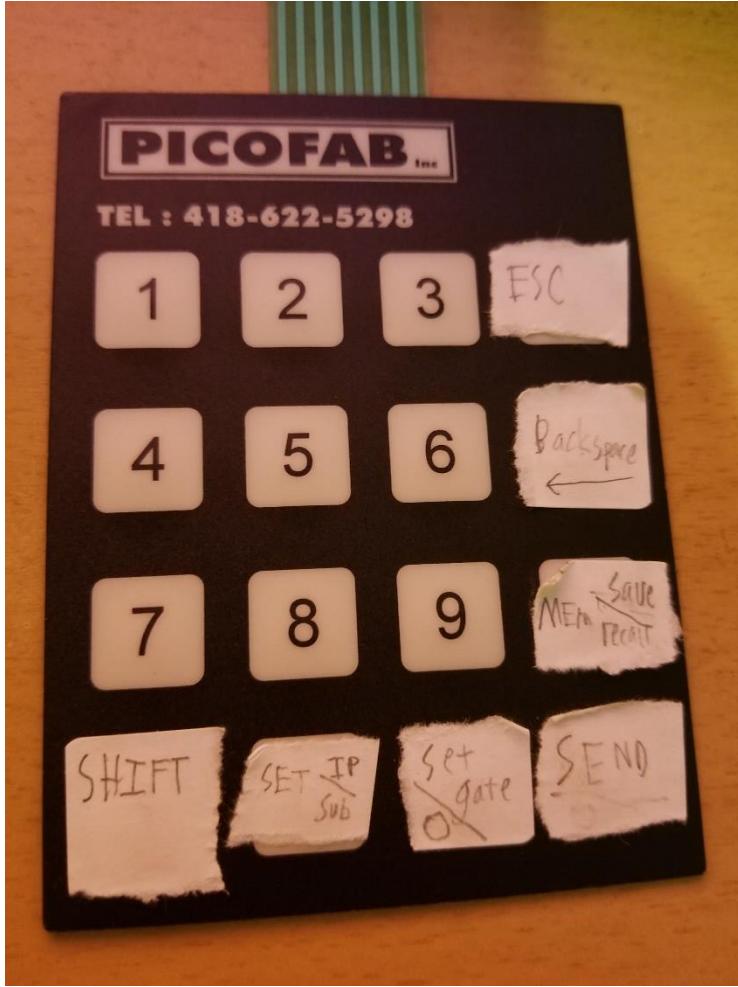
Plug the system into the wall with the provided 12V DC wall power supply. The system will initialize and run a full diagnostic test on the onboard memory. After the SRAM and DRAM have been thoroughly tested for errors, the display backlight will blink and then the status “Idle” will appear on the screen. The phone is now fully booted. Proceed to the next section “Interfacing with the phone”

Resetting the system

Should something go awry in the system, and a reset is needed, simply press the reset button located along the same side of the pcb as the ethernet jack. The system will reset, the display will blink once the memory check completes, and the system is then ready to go.

Interfacing with the phone

Keypad



The keypad is a 4x4 keypad. Some keys are multiplexed using a shift key at the bottom left of the keyboard. The shift key toggles the keyboard between shift mode and normal mode. Note, this is different than the way most keyboards operate due to a limitation in the ability to detect multiple key presses.

Pressing Set IP/Sub allows the user to set the IP address and subnet mask using the numerical keys.

Pressing Set gate allows the user to set the gateway IP address.

Pressing Mem Save/Recall allows the user to save the current address configuration to an address location, or recall the IP settings from a memory location.

Pressing Send should initiate a call.

Note, due to a bug in the LWIP library, it is not possible to set more than 3 address settings, otherwise the system will crash.

Display

The display is a 128x32 display, divided into 4 rows. Only the top two rows are used.

The top row displays the current menu the system is in, or the status of the system if a call is in progress.

State	1 st Row message
Idle	Idle
Phone off hook	Off Hook
Ringing remote user	Ringing
Connecting to remote user	Connecting
Connected to remote user	Connected
Setting IP address	Set IP
Setting subnet mask	Set Subnet
Setting gateway IP address	Set Gateway
Saving settings to memory	Memory Save
Recalling settings from memory	Memory Recall
Settings recalled from memory	Recalled Message
Error occurred in software	Illegal Message

The 2nd row displays auxiliary information for a menu, such as the IP address being set, the subnet mask, or the memory location for recall. The keyboard can be used to input data here, and save with the Send button.

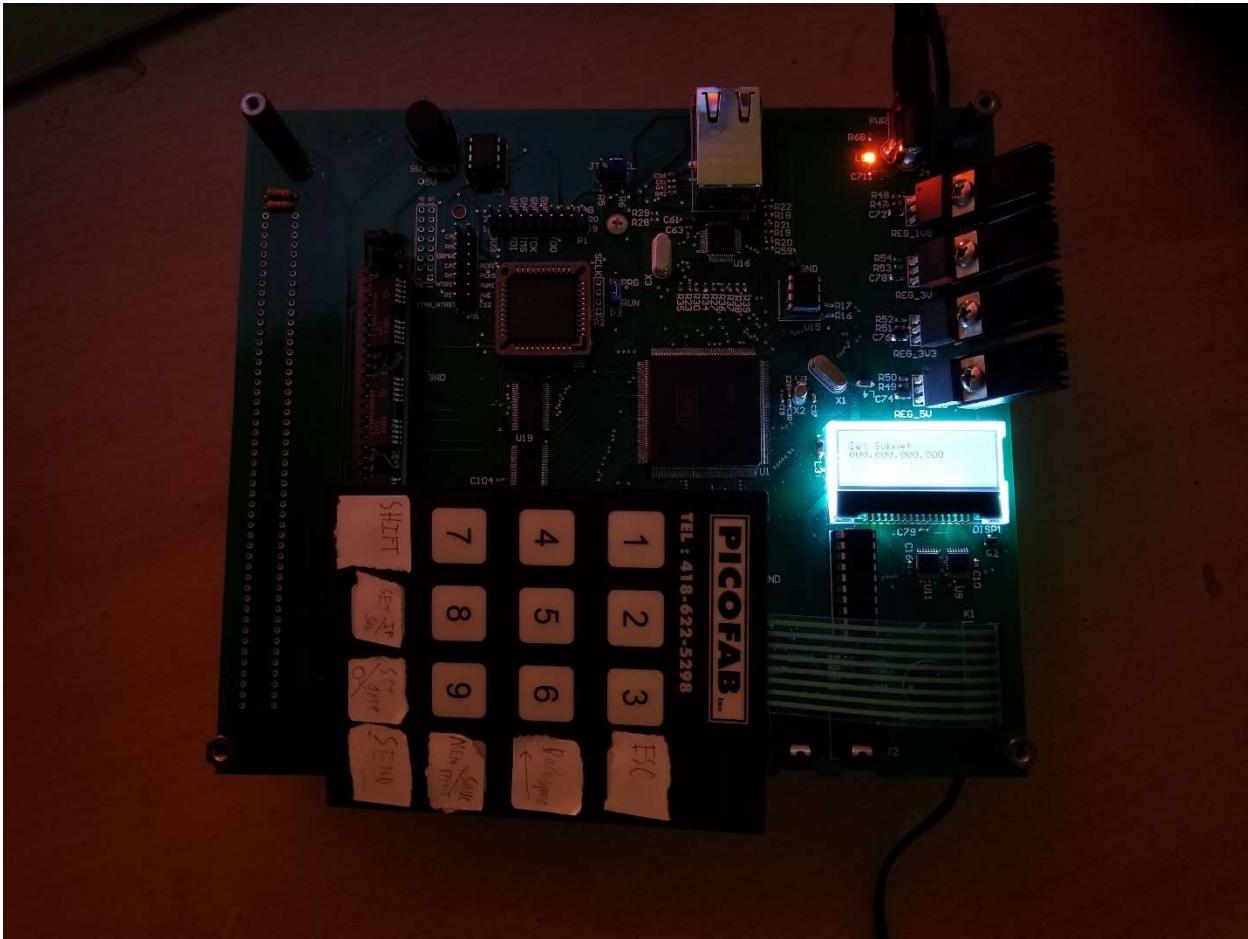
Headset

Two 3.5mm audio jacks are mounted next to the keyboard. J2 is the microphone, and J3 is the headset connection. The software has volume set capability, but the code must be recompiled to change it, so it is recommended the user use an adjustable volume headset.

Ethernet

Ethernet is located on the same side of PCB as the power jack. The ethernet is designed to work in 10Mbps mode with RJ-45 connector-based cables. Currently, ethernet is not supported by this phone (what a great phone, I know).

VoIP phone Technical Documentation

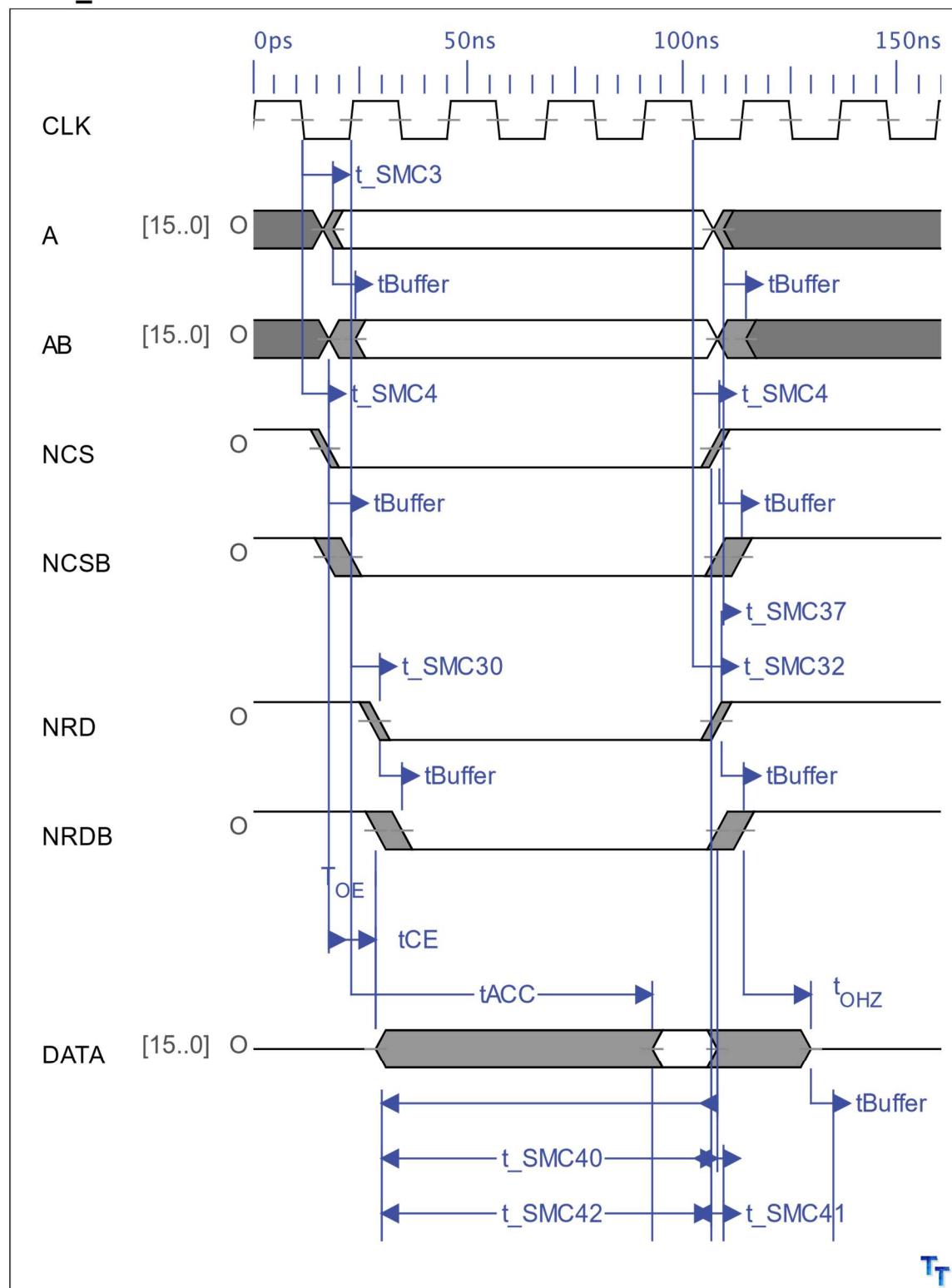


The EE52 VoIP phone is a phone that can communicate with other EE52 VoIP phones. The user controls the phone by using a 128x32 display and a 4x4 keypad. There is a headphone and microphone jack that a headset can be plugged into, and there is a button for putting the phone “on-the-hook” to hangup the call.

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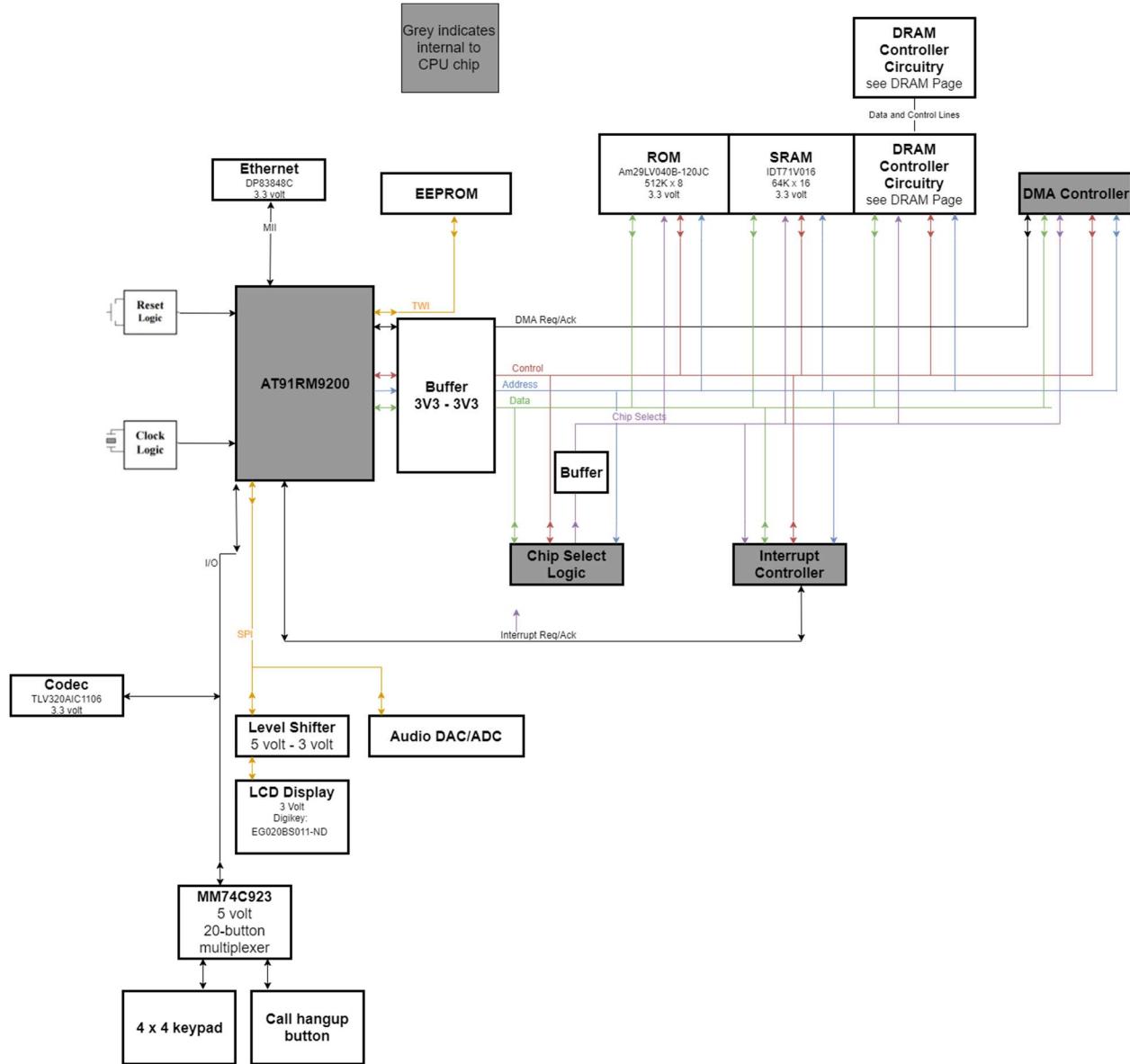


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Overview

Processor	Atmel AT91RM9200
Input power	8V-12V DC 5.5mm barrel jack
Display	128x32
Headphone Jack	3.5mm mono audio jack
Microphone Jack	3.5mm
Keypad	4x4 button keypad

Block Diagram



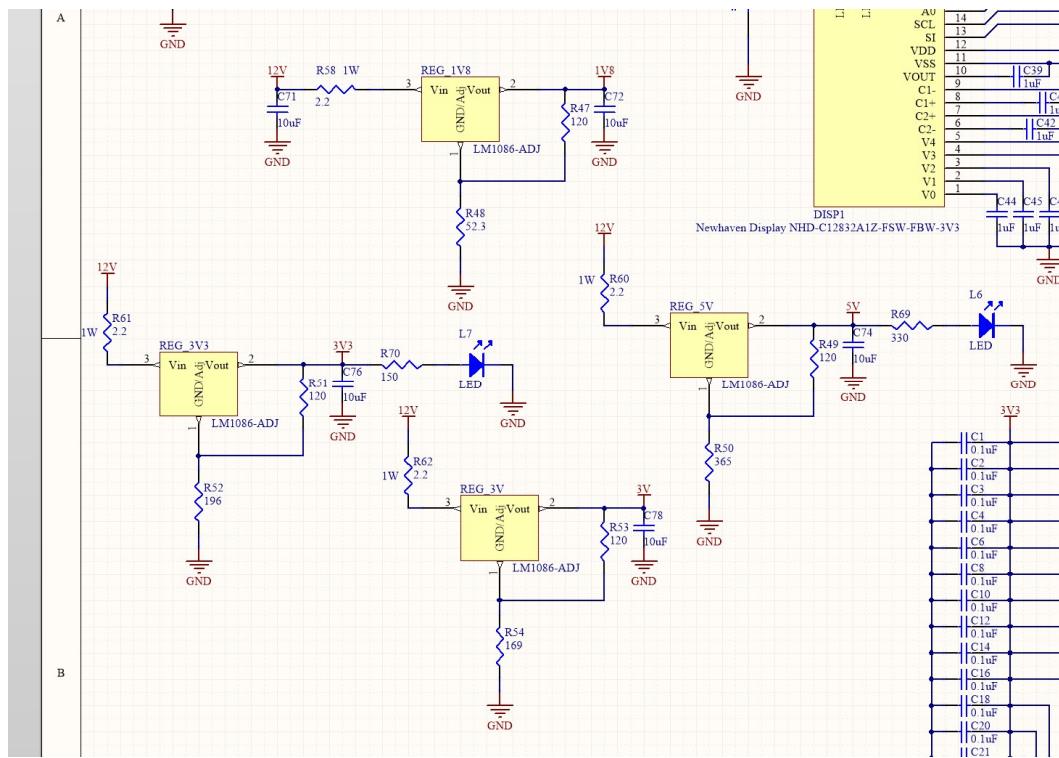
Power Circuitry

The system takes ~8V-12V DC input. The upper bound is due to thermal dissipation constraints of the linear regulator heatsinks. There are four power rails on this board.

Rail	Uses
5V	Reset circuit, DRAM, CPLD
3V3	Audio, SRAM, ROM, CPU
3V	Display
1V8	CPU Core logic

Linear Regulators

The system uses LM1086 linear regulators with heatsinks attached.

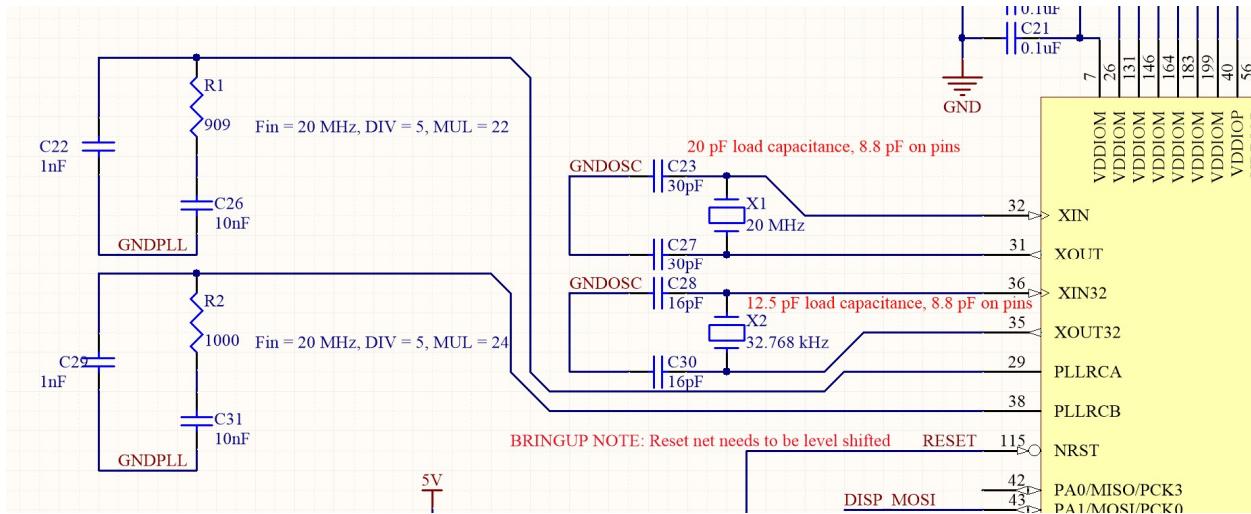


Linear regulators

CPU Support Circuitry

Clocks

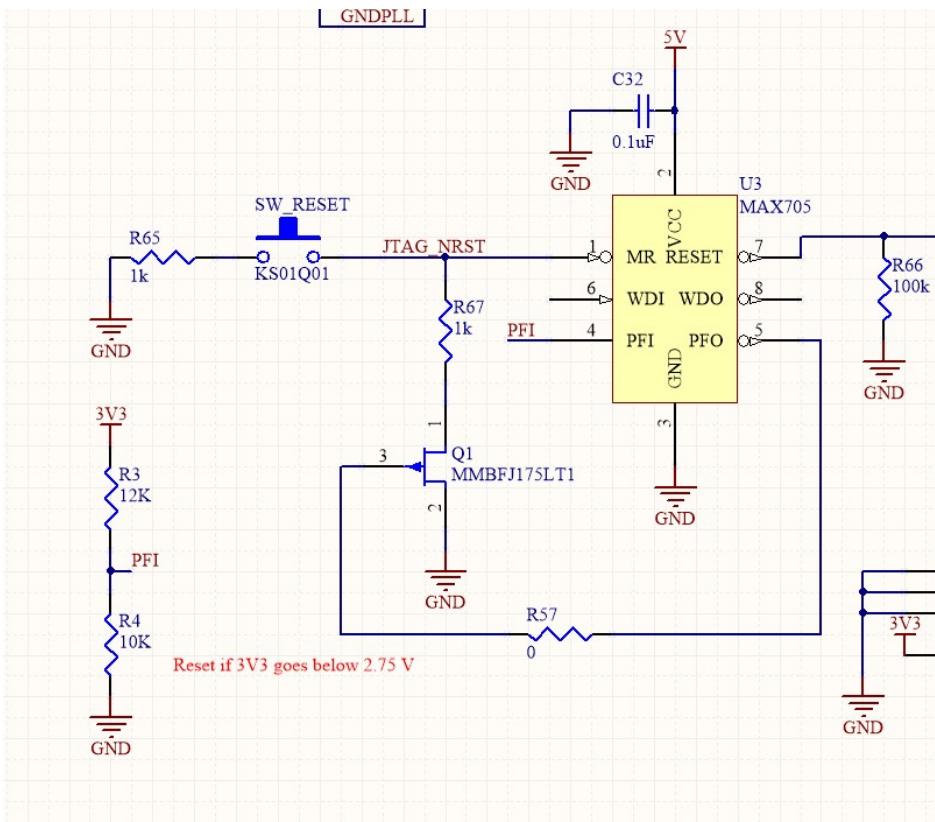
The CPU uses a 32.768 kHz slow clock and a 20 MHz main clock crystal. The main clock is scaled using a PLL to 44 MHz.



Clocks and PLL circuits

Reset

The reset circuitry uses a MAX705 chip in the standard configuration. The 5-volt reset line output is scaled using a resistor divider for devices that need 3.3V input.



JTAG

This board has a JTAG interface routed and populated for the purposes of debugging. It is a 20-pin legacy ARM IDC 0.1" pitch JTAG connector with the following pinout (see

http://infocenter.arm.com/help/topic/com.arm.doc.faqs/attached/13634/cortex_debug_connectors.pdf):

	1	2	
VCC	•	•	VCC (optional)
TRST	•	•	GND
NC/TDI	•	•	GND
SWDIO / TMS	•	•	GND
SWDCLK / TCK	•	•	GND
RTCK	•	•	GND
SWO / TDO	•	•	GND
nRESET	•	•	GND
NC/DBGRQ	•	•	GND
NC/DBACK	•	•	GND
	19	20	

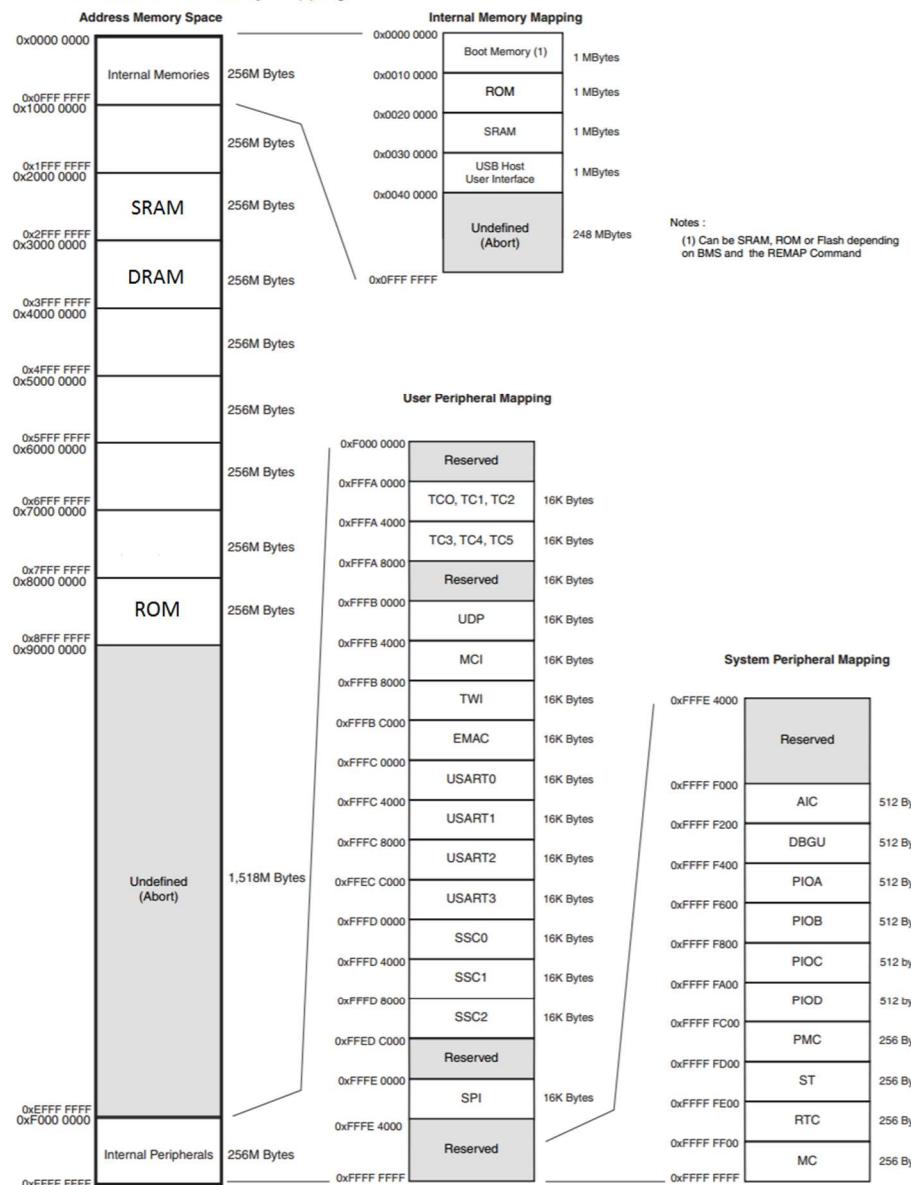
Memory

All memory access is done through 74LVT16245 buffers.

AT91RM9200

8. Memories

Figure 8-1. AT91RM9200 Memory Mapping

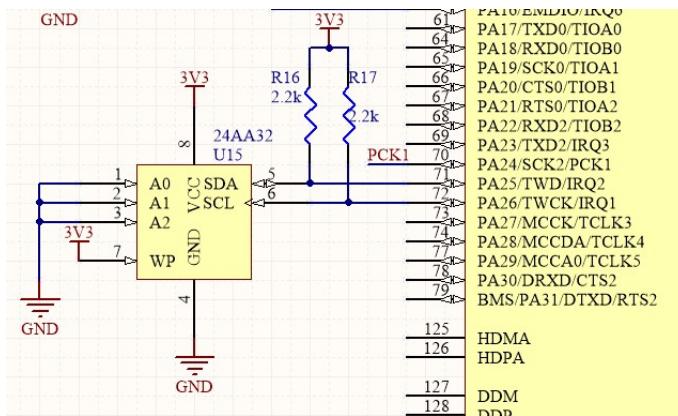


Memory Testing

When the system boots, all of the memory in the SRAM and DRAM is checked for errors before the code is copied from ROM to SRAM for program operation. This is done in the memtest.s file. The test works by writing a few sequences of numbers that do not repeat with any 2^n periodicity, and reading back the data and comparing it against the expected sequence. This test seems to do a good job at detecting rare memory integrity issues, but it does not test for DRAM refresh being fast enough to prevent DRAM bit rot.

EEPROM Bootloader

The system uses a 24AA32 over TWI for the bootloader. This bootloader initializes the ARM CPU modes, checks for SRAM and DRAM integrity, and then copies ROM to SRAM. Future possible improvements could be to check a hash of the ROM values against a hash stored in ROM to verify ROM integrity.



ROM

This board uses a 29LV040 chip for ROM. This chip has an address bus width of 19 bits, and a data bus width of 8 bits. It is on chip select 7. See schematic in Appendix.

SRAM

This board uses a IDT71V016 chip for SRAM. This chip has an address bus width of 16 bits, and a data bus width of 16 bits. It is on chip select 1. See schematic in Appendix.

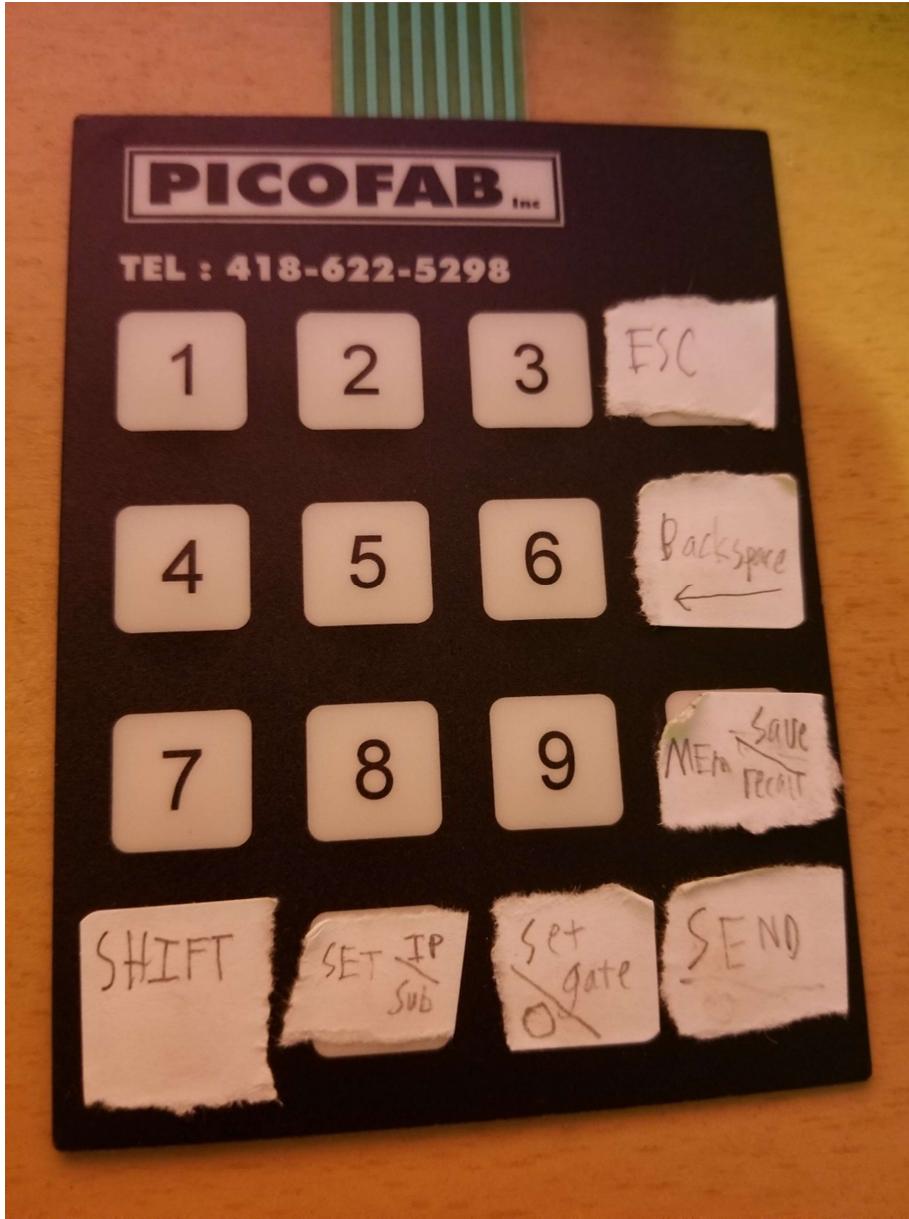
DRAM

This board uses a socket mount DRAM module. The DRAM controller is implemented in a CPLD. The address lines are multiplexed to the DRAM via U19 and U21, which are two buffers that can be toggle high-Z and enabled by the CPLD DRAM controller. The data lines are connected to the CPU data bus via a bidirectional buffer that is enabled when the DRAM chip select goes low. The directionality of the buffer is set by the NRD signal.

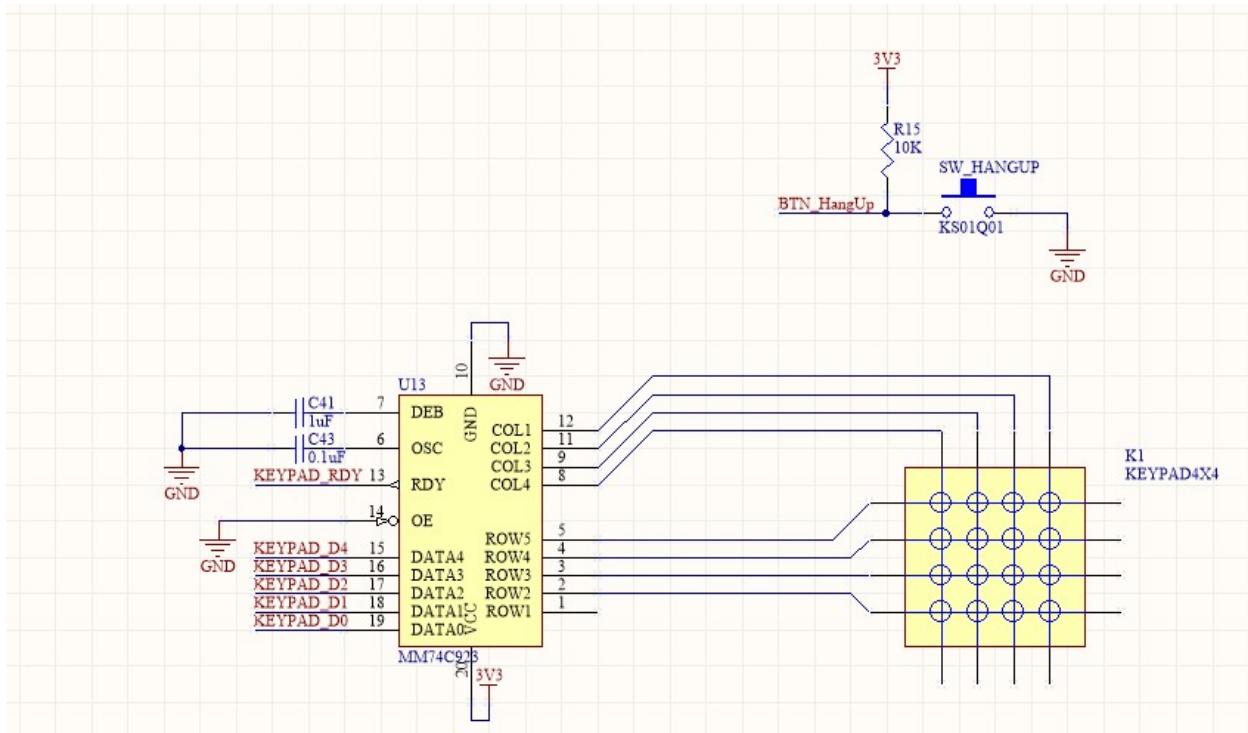
The DRAM has an effective address bus width of 20 bits, and a data bus width of 8 bits. The DRAM is on chip select 2. See Schematic in Appendix.

User Interface Components

Keypad



The keypad is used for user input into the device. It is a 4x4 keypad, and since more inputs are needed than are available, a shift key is used to toggle the function of a few keys. The keypad uses a MM74C923 chip for debouncing key presses. Also, on the test board, the hangup button was connected into the ROW1 channel of the chip, to simplify code. The design implemented in schematic works as well, but if the hangup button remains a button that is pressed when it is needed, rather than being a button that is always pressed when the phone is on the hook, then the hangup button can be connected to the debouncer chip. The debouncer chip can only debounce one key at a time, so if the hangup button is pressed while the user wants to press other buttons, the system would not respond to the new button presses, hence why the hangup button was kept separate in the schematic right now.



The above schematic shows the design as routed on the PCB. This design is fully functional, but on the test board, the hangup button was wired into row 1 of debouncer chip for code simplicity.

Display



The display is a NHDC12832 128x32 display. In software, the display is divided into 4 rows. Only the top two rows are used.

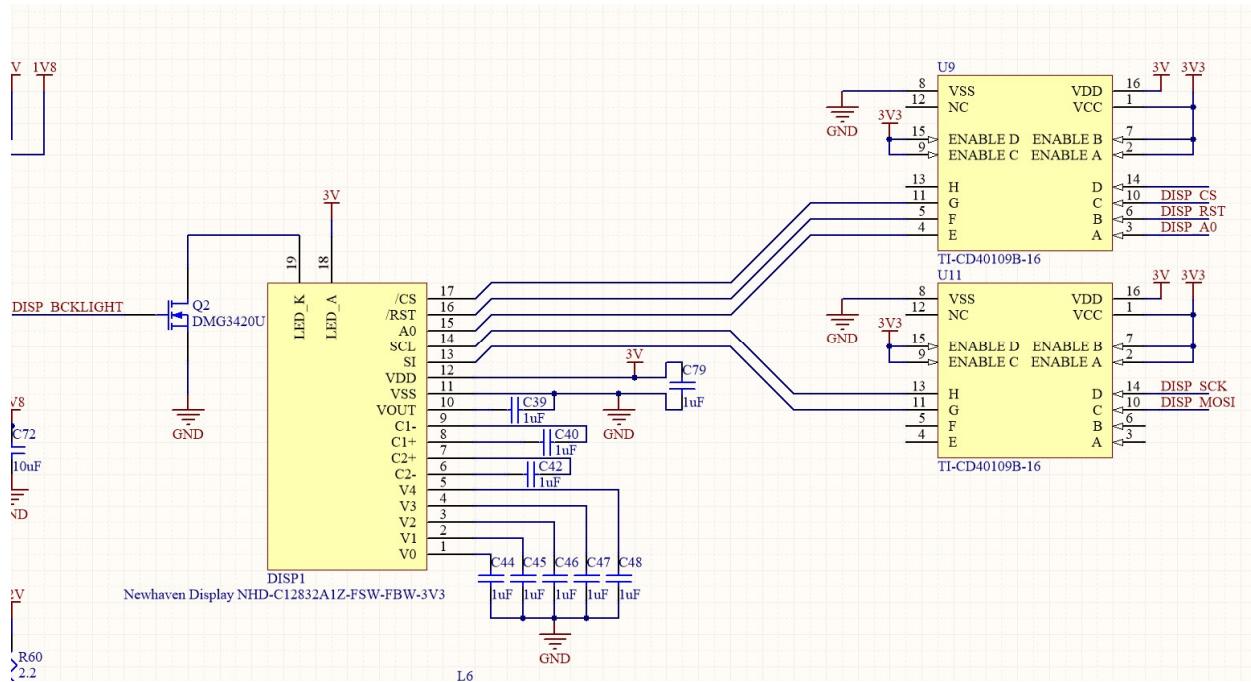
The top row displays the current menu the system is in, or the status of the system if a call is in progress.

The 2nd row displays auxiliary information for a menu, such as the IP address being set, the subnet mask, or the memory location for recall.

Data is streamed to the display using SPI, with the data transfer to the SPI peripheral done using DMA.

The display uses 3 volt power, while the CPU uses 3.3 volt, so level shifters are used.

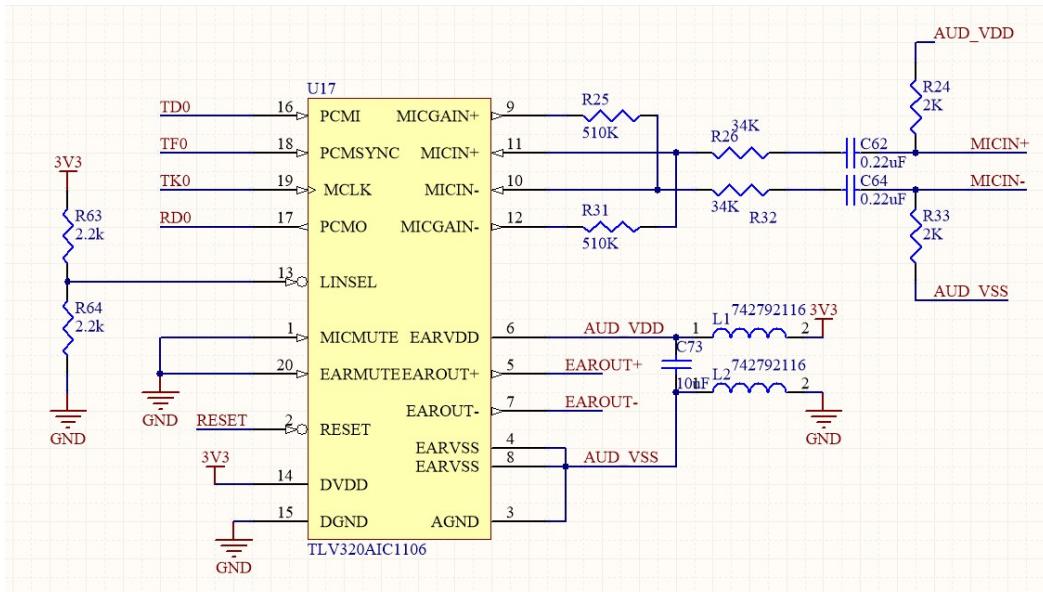
A backlight is available on the display, and is toggled via pin PA5 on the CPU.



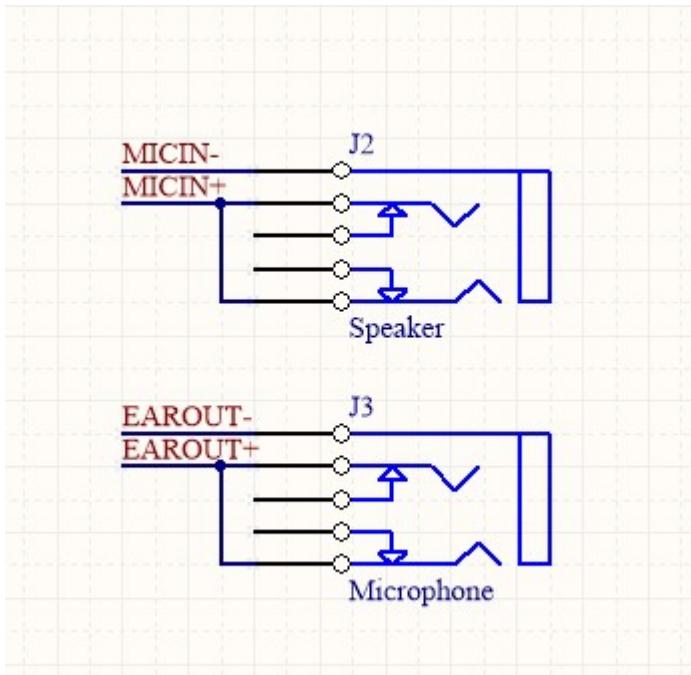
Display and level shifters for display

Audio

The audio circuitry uses the TLV320AIC1106 chip. Depending on whether companding or linear serial stream is desired, R63 or R64 can be stuffed. Currently, the code base only supports linear mode, which corresponds to R64 being stuffed. Data is sent and received from the audio chip via a synchronous serial controller on the ARM chip and a DMA engine on the ARM chip.



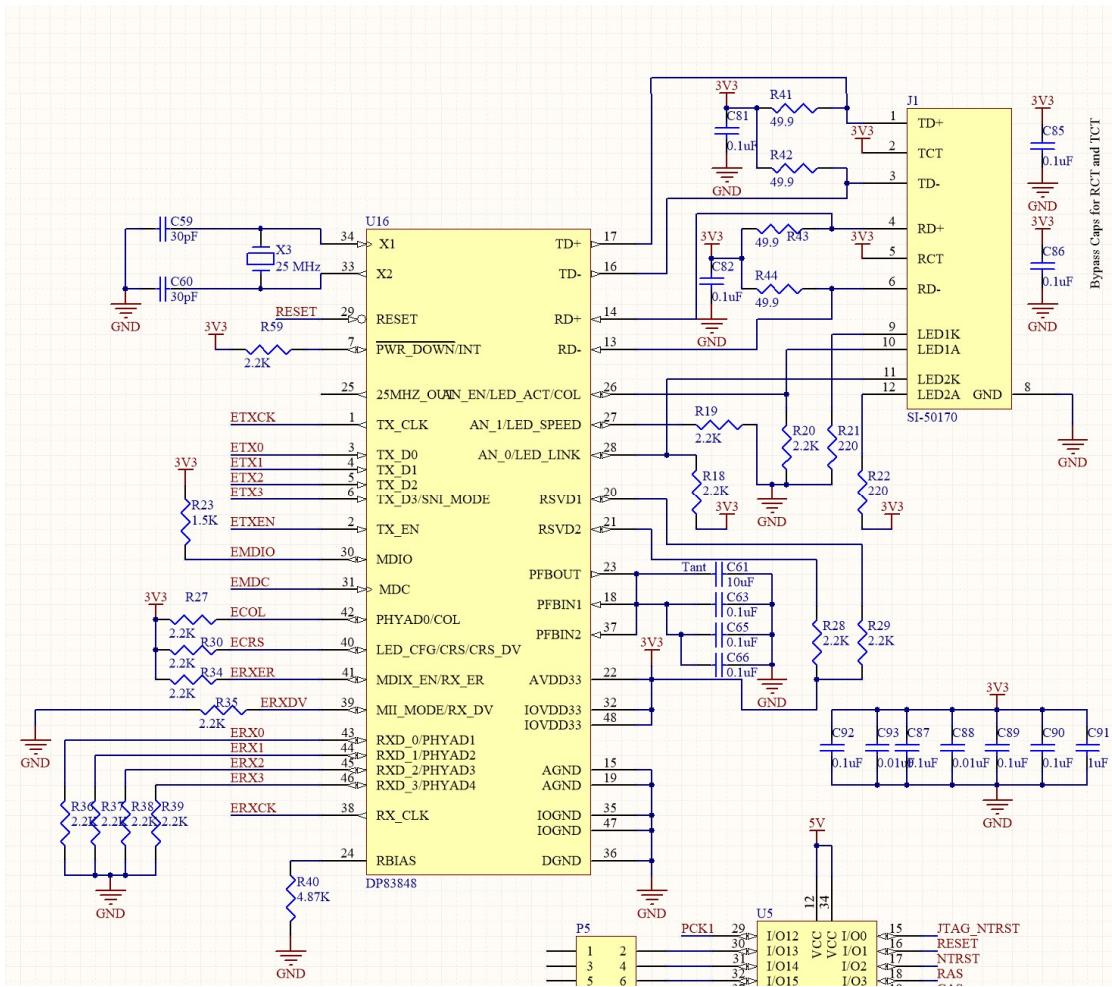
Audio Circuitry



Audio output

Ethernet

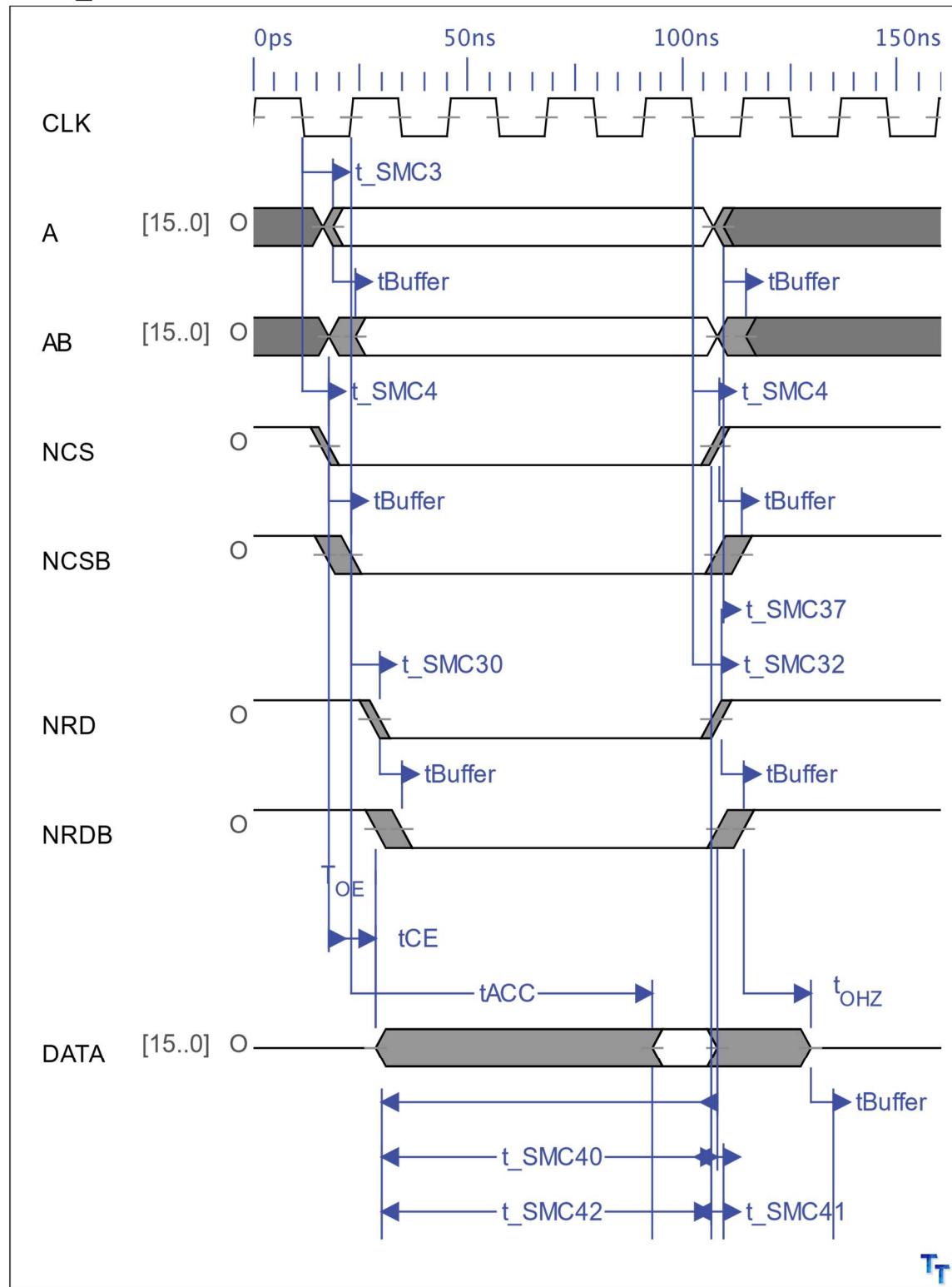
The ethernet circuitry in the schematic is untested, and may not work. It is designed to operate in either 10Base-T or 100Base-T, half or full duplex.

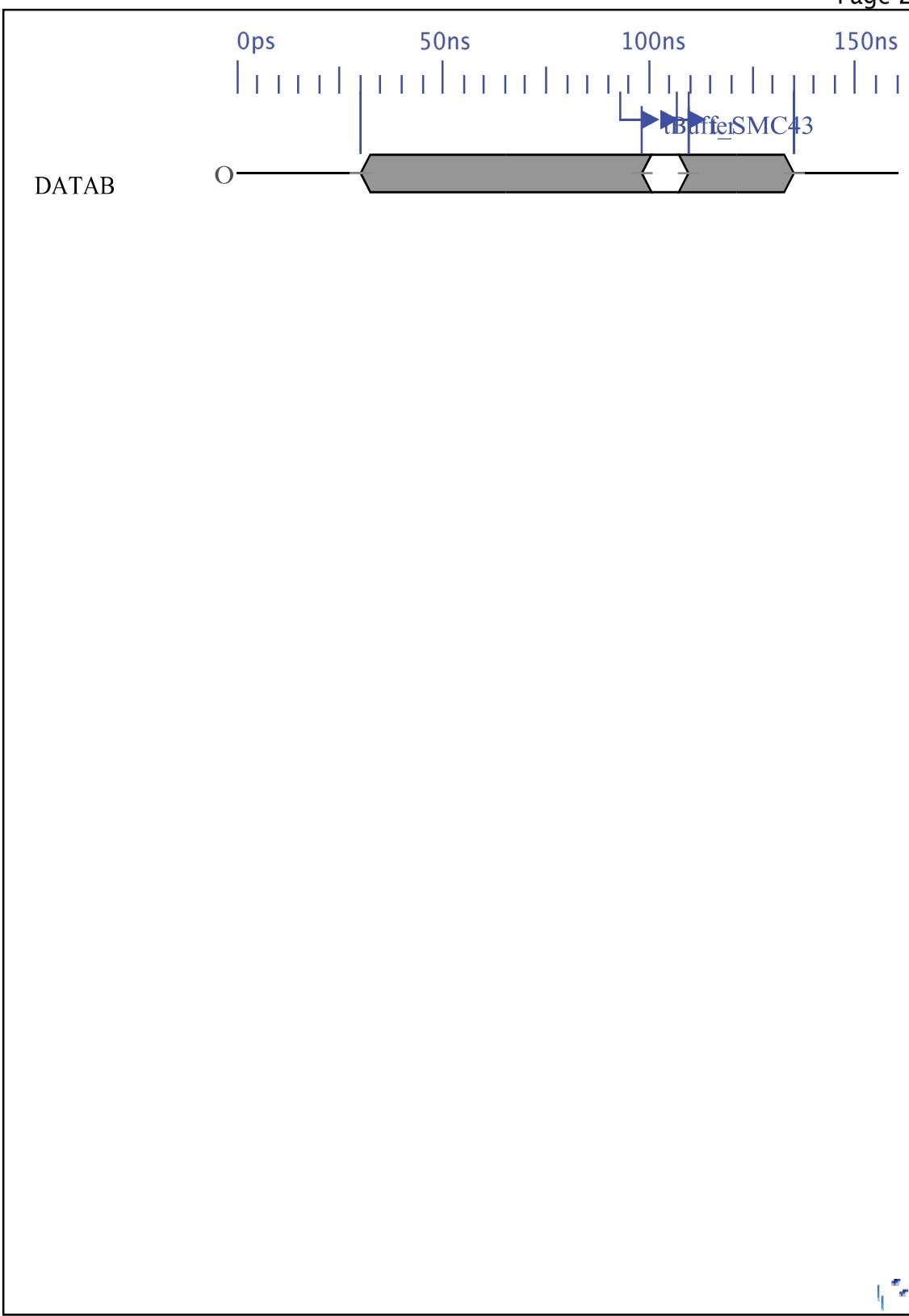


Appendix A (ROM Timing)

ROM_READ

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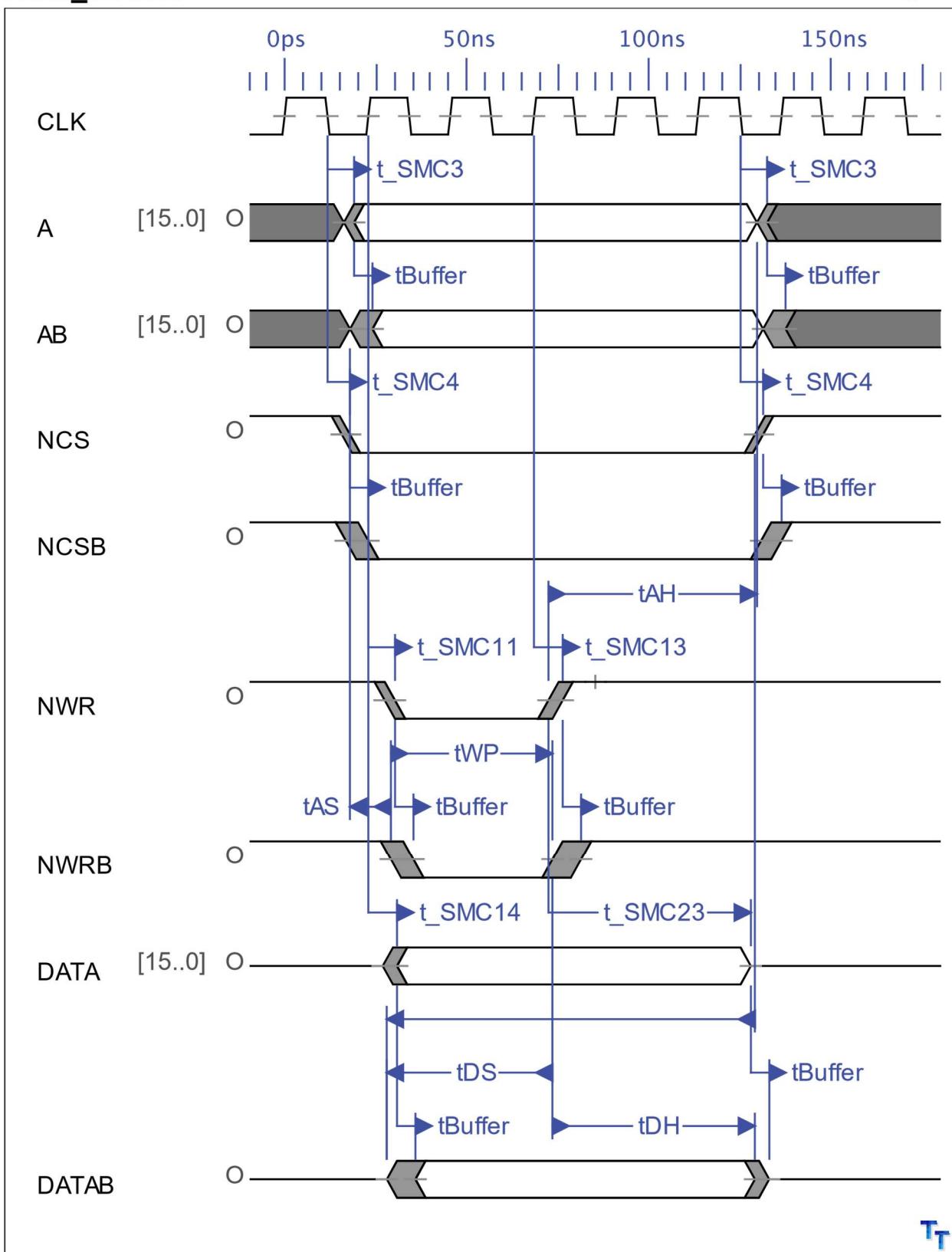
General Data					
SYMBOL	DEFINITION	DESCRIPTION	MIN	MAX	NOTES
t_SMC3	MCK Falling to A1-A25 valid	to be defined	4.9ns	7.5ns	
t_SMC4	MCK Falling to Chip Select	to be defined	4.3ns	6.5ns	
tBuffer		to be defined	1.3ns	5.1ns	
t_SMC1		to be defined			
t_SMC30	MCK Rising to NRD Active	to be defined	4.7ns	7.0ns	
tACC	Address Access time	defined by memory	0ps	70ns	
tCE	Chip Select Access time	defined by memory	0ns	70ns	
T_OE	Output enable access time	defined by memory	0ns	30ns	
t_SMC32		to be defined	4.5ns	6.8ns	
t_SMC40	Data Setup time before NRD	to be defined	7.5ns		
t_SMC4	MCK falling to CHip Select Change	to be defined	4.3ns	6.5ns	
t_SMC41	Data Hold time after NRD rising	to be defined	-3.4ns		
t_SMC37	NRD High to A1-A25 change	to be defined	0.3ns	0.6ns	
t_OHZ	Output Enable High to Output in High-Z	defined by memory	0ns	16ns	
t_SMC42	Data Setup before NCS High	to be defined	7.3ns		
t_SMC43	Data Hold after NCS High	to be defined	-3.2ns		

Notes:

Device: AM29LV040

Results:
1 wait states





General Data					
SYMBOL	DEFINITION	DESCRIPTION	MIN	MAX	NOTES
t_SMC3	MCK Falling to A1-A25 valid	to be defined	4.9ns	7.5ns	
tBuffer		to be defined	1.3ns	5.1ns	
t_SMC14	MCK Rising to D0-D15 Valid	to be defined	4.1ns	7.9ns	
t_SMC4	MCK falling to Chip Select Change	to be defined	4.3ns	6.5ns	
tAS	Address Setup to End of Write	to be defined	0ns		
tDS	Data Setup Time	to be defined	35ns		
tDH	Data Hold Time	to be defined	0ns		
tAH	Address Hold from End of Write	to be defined	45ns		
tWP	Write Pulse	to be defined	35ns		
t_SMC11	MCK Rising to NWR Active (with wait states)	to be defined	4.8ns	7.2ns	
t_SMC13	MCK Rising to NWR Inactive	to be defined	4.1ns	7.9ns	
t_SMC23	MCK Rising to Data Out Invalid (1 hold state)	to be defined	55.7ns		
t_SMC17	NWR High to A1-A25 Change	to be defined	3.3ns		

Notes:

Results:

0 setup

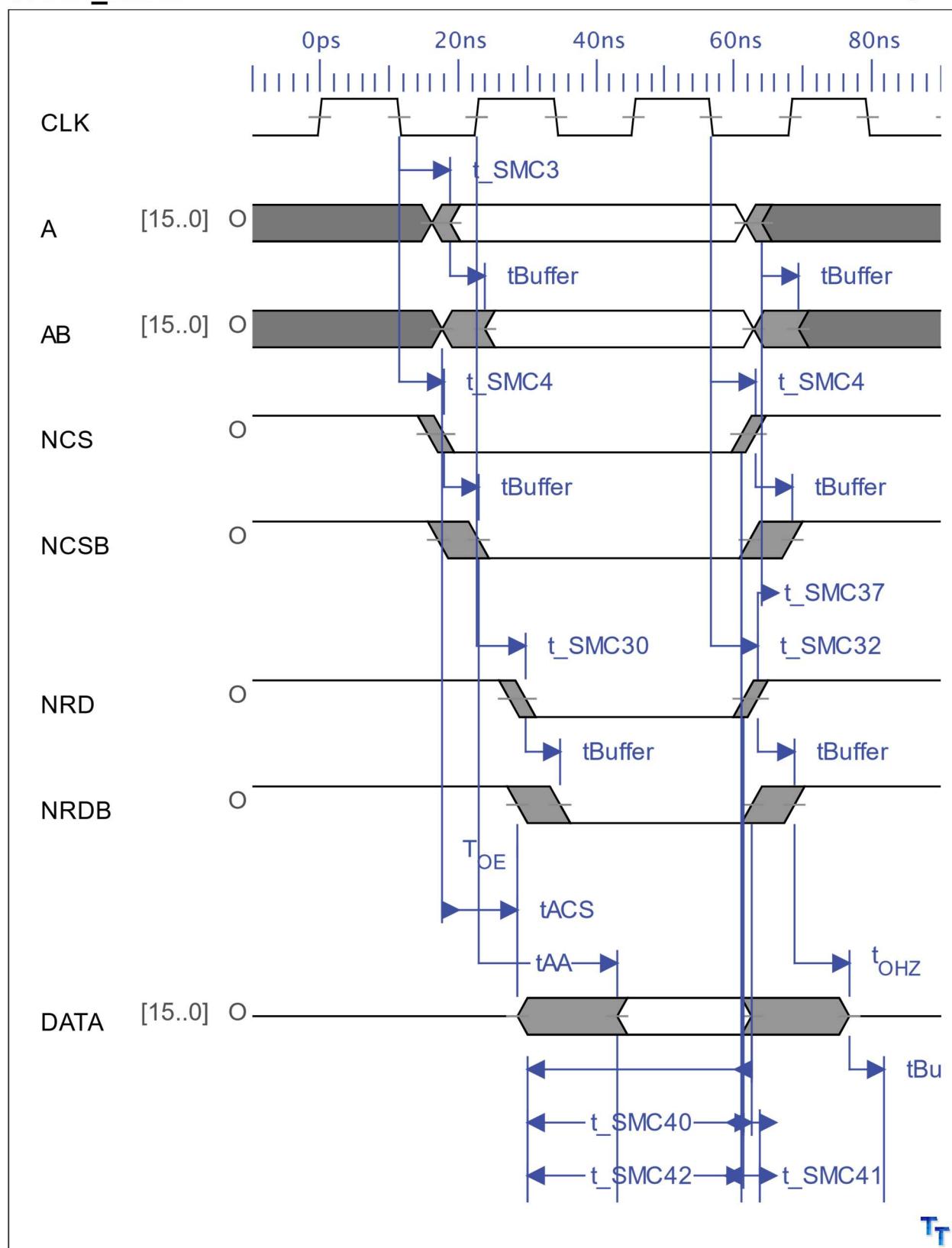
2 wait state (pulse length)

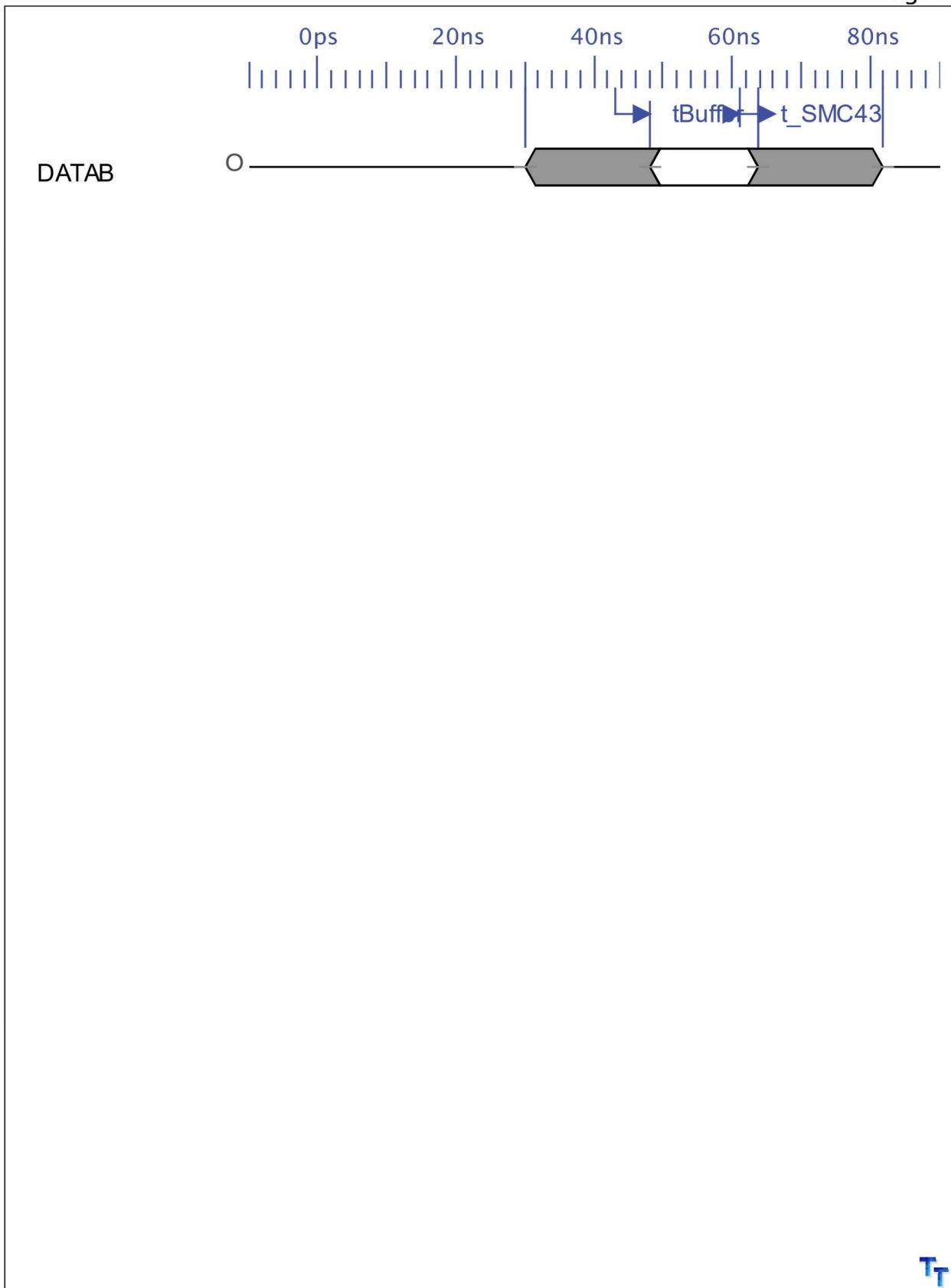
2.5 hold parameter

Appendix B (SRAM Timing)

SRAM_READ

Page 1





General Data					
SYMBOL	DEFINITION	DESCRIPTION	MIN	MAX	NOTES
t_SMC3	MCK Falling to A1-A25 valid	to be defined	4.9ns	7.5ns	
t_SMC4	MCK Falling to Chip Select	to be defined	4.3ns	6.5ns	
tBuffer		to be defined	1.3ns	5.1ns	
t_SMC1		to be defined			
t_SMC30	MCK Rising to NRD Active	to be defined	4.7ns	7.0ns	
tAA	Address Access time	defined by memory	0ps	20ns	
tACS	Chip Select Access time	defined by memory	0ns	20ns	
T_OE	Output enable access time	defined by memory	0ns	8ns	
t_SMC32	MCK falling to NRD inactive	to be defined	4.5ns	6.8ns	
t_SMC40	Data Setup time before NRD	to be defined	7.5ns		
t_SMC4	MCK falling to CHip Select Change	to be defined	4.3ns	6.5ns	
t_SMC41	Data Hold time after NRD rising	to be defined	-3.4ns		
t_SMC37	NRD High to A1-A25 change	to be defined	0.3ns	0.6ns	
t_OHZ	Output Enable High to Output in High-Z	to be defined	0ns	8ns	
t_SMC42	Data Setup before NCS High	to be defined	7.3ns		
t_SMC43	Data Hold after NCS High	to be defined	-3.2ns		

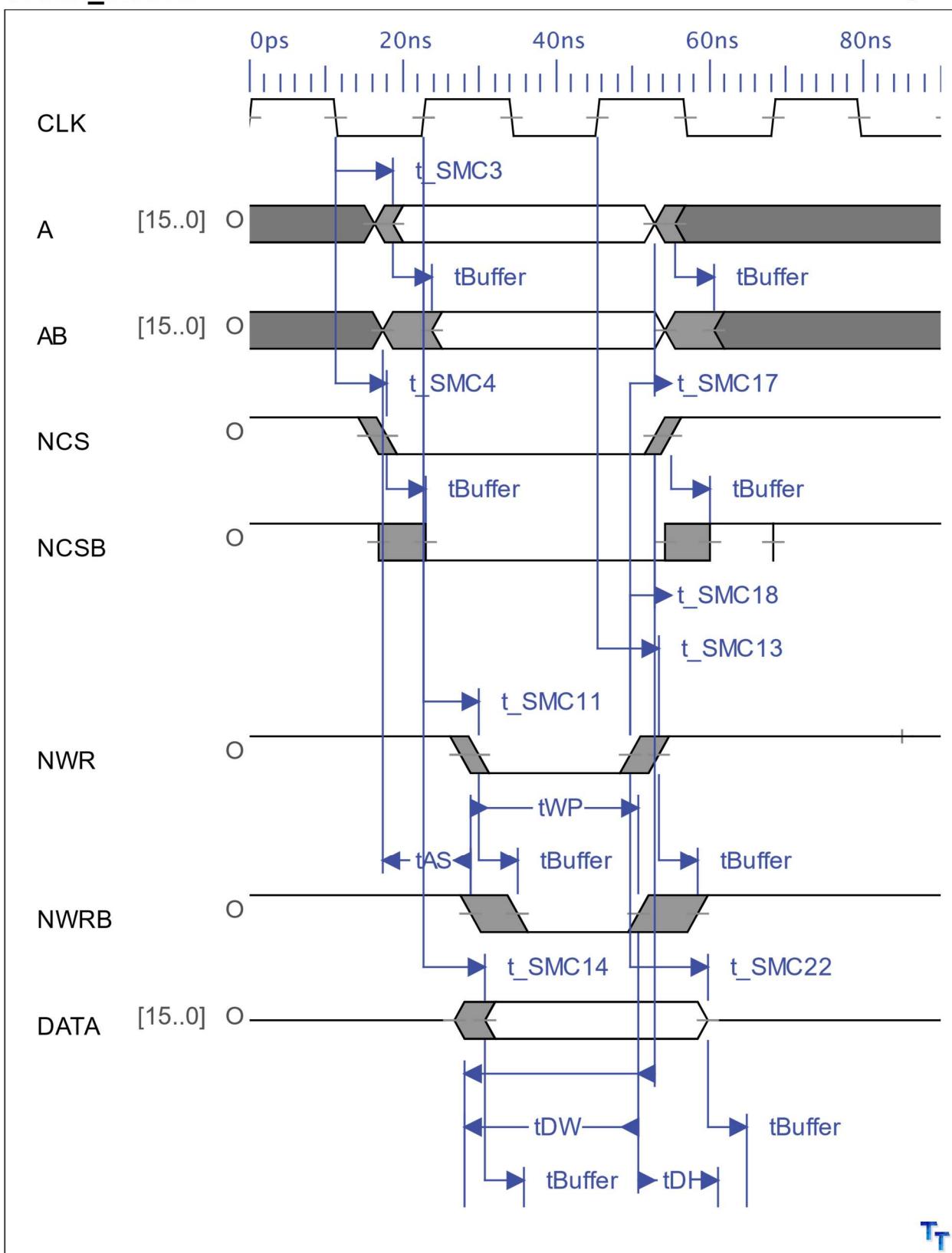
Notes:

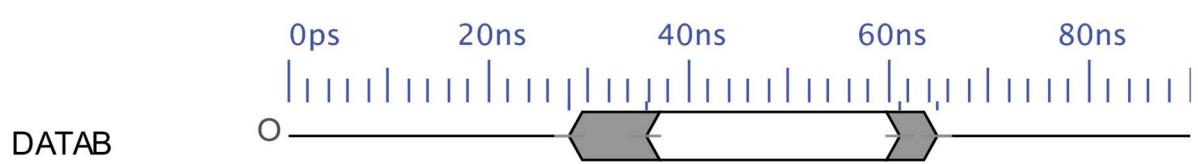
Results:

1 wait states

SRAM_WRITE

Page 1





General Data					
SYMBOL	DEFINITION	DESCRIPTION	MIN	MAX	NOTES
t_SMC3	MCK Falling to A1-A25 valid	to be defined	4.9ns	7.5ns	
tBuffer		to be defined	1.3ns	5.1ns	
t_SMC14	MCK Rising to D0-D15 Valid	to be defined	4.1ns	7.9ns	
t_SMC4	MCK falling to Chip Select Change	to be defined	4.3ns	6.5ns	
tAS	Address Setup to End of Write	to be defined	0ns		
tDW	Data Setup Time	to be defined	9ns		
tDH	Data Hold Time	to be defined	0ns		
tWR	Address Hold from End of Write	to be defined	0ns		
tWP	Write Pulse	to be defined	12ns		
t_SMC11	MCK Rising to NWR Active (with wait states)	to be defined	4.8ns	7.2ns	
t_SMC13	MCK Rising to NWR Inactive	to be defined	4.1ns	7.9ns	
t_SMC22	MCK Rising to Data Out Invalid	to be defined	10.2ns		
t_SMC17	NWR High to A1-A25 Change	to be defined	3.3ns		
t_SMC18	NWR High to Chip Select Inactive	to be defined	3.3ns		

Notes:

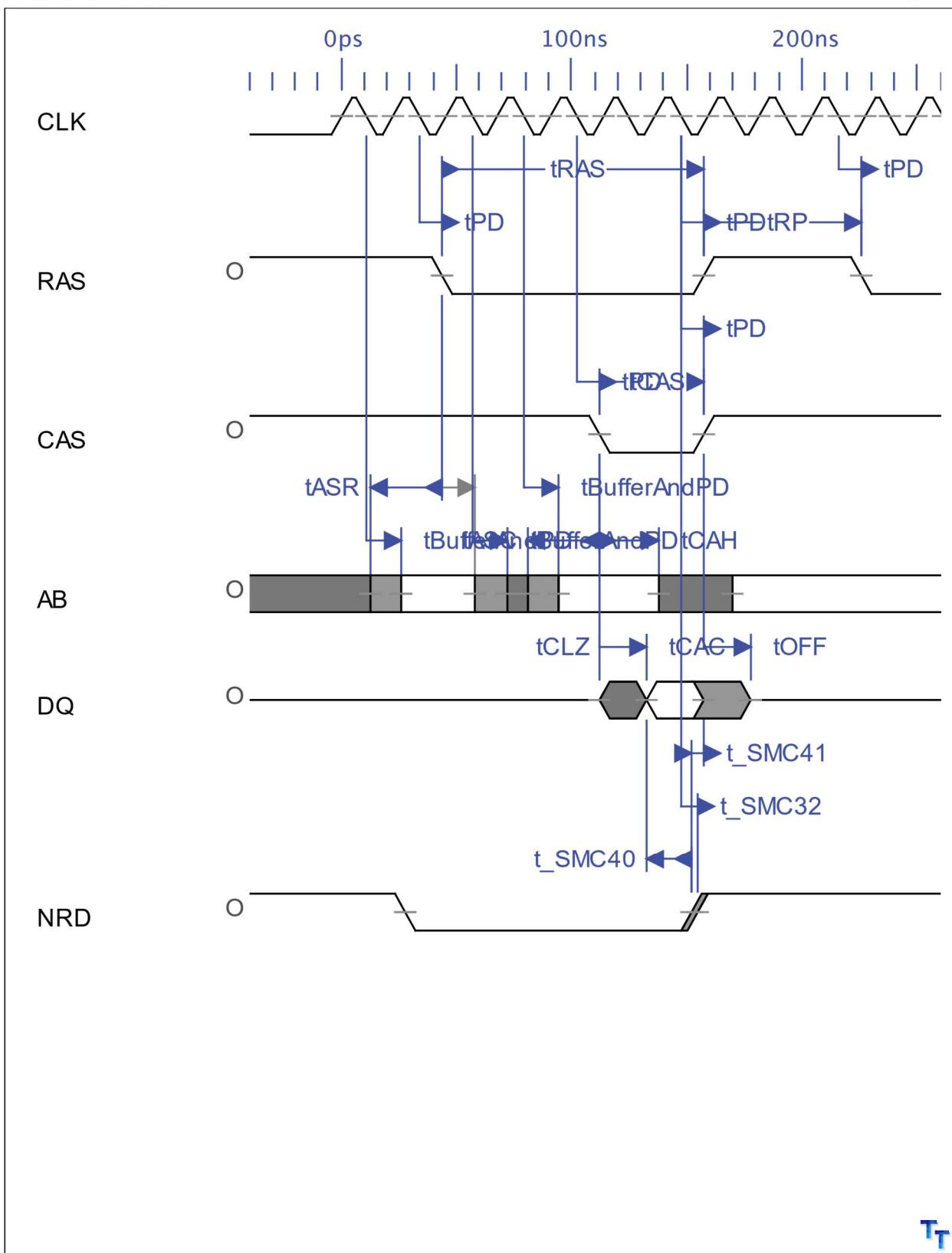
Results:

0 setup

1 wait state (pulse length)

0 hold parameter

Appendix C (DRAM Timing)



General Data					
SYMBOL	DEFINITION	DESCRIPTION	MIN	MAX	NOTES
tASR		to be defined	0ns		
	Row-address setup time before RAS low				
tASC	Column-address setup time before CAS low	to be defined	0ns		
tDS	Data setup time	to be defined	0ns		
tRCS	Read setup time before CAS low	to be defined			
tCWL	W low setup time before CAS	to be defined	20ns		
tRWL	W low setup time before RAS	to be defined			
tWCS	W low setup time before CAS	to be defined	0ns		
tWSR	W high setup time (CAS-before-RAS refresh only)	to be defined	10ns		
tCAH	Column-address hold time after CAS low	to be defined	15ns		
tDHR	Data hold time after RAS low	to be defined	60ns		
tDH	Data hold time	to be defined	15ns		
tAR	Column-address hold time after RAS low	to be defined	60ns		
tRAH	Row-address hold time after RAS low	to be defined	10ns		
tRCH	Read hold time after CAS high	to be defined	0ns		
tRRH	Read hold time after RAS high	to be defined	0ns		
tWCH	Write hold time after CAS low	to be defined	15ns		

tWCR	Write hold time after RAS low	to be defined	60ns
tWHR	W high hold time (CAS-before-RAS refresh only)	to be defined	10ns
tCHR	Delay time, RAS low to CAS high	to be defined	20ns

Page 3

General Data continued...

SYMBOL	DEFINITION	DESCRIPTION	MIN	MAX	NOTES
tCRP	Delay time, CAS high to RAS low	to be defined	0ns		
tCSH	Delay time, RAS low to CAS high	to be defined	80ns		
tCSR	Delay time, CAS low to RAS low	to be defined	10ns		
tRAD	Delay time, RAS low to column-address	to be defined	15ns	40ns	
tRAL	Delay time, column-address to RAS high	to be defined	40ns		
tCAL	Delay time, column-address to CAS high	to be defined	40ns		
tRCD	Delay time, RAS low to CAS low	to be defined	20ns	60ns	
tRPC	Delay time, RAS high to CAS low	to be defined	0ns		
tRSH	Delay time, CAS low to RAS high	to be defined	20ns		
tT	Transition time	to be defined	2ns	50ns	
tRAS	Non-page-mode pulse duration, RAS low	to be defined	80ns	10000ns	
tCAS	Pulse duration, CAS low	to be defined	20ns	10000ns	
tCLZ	CAS to output in low Z	to be defined	0ns		

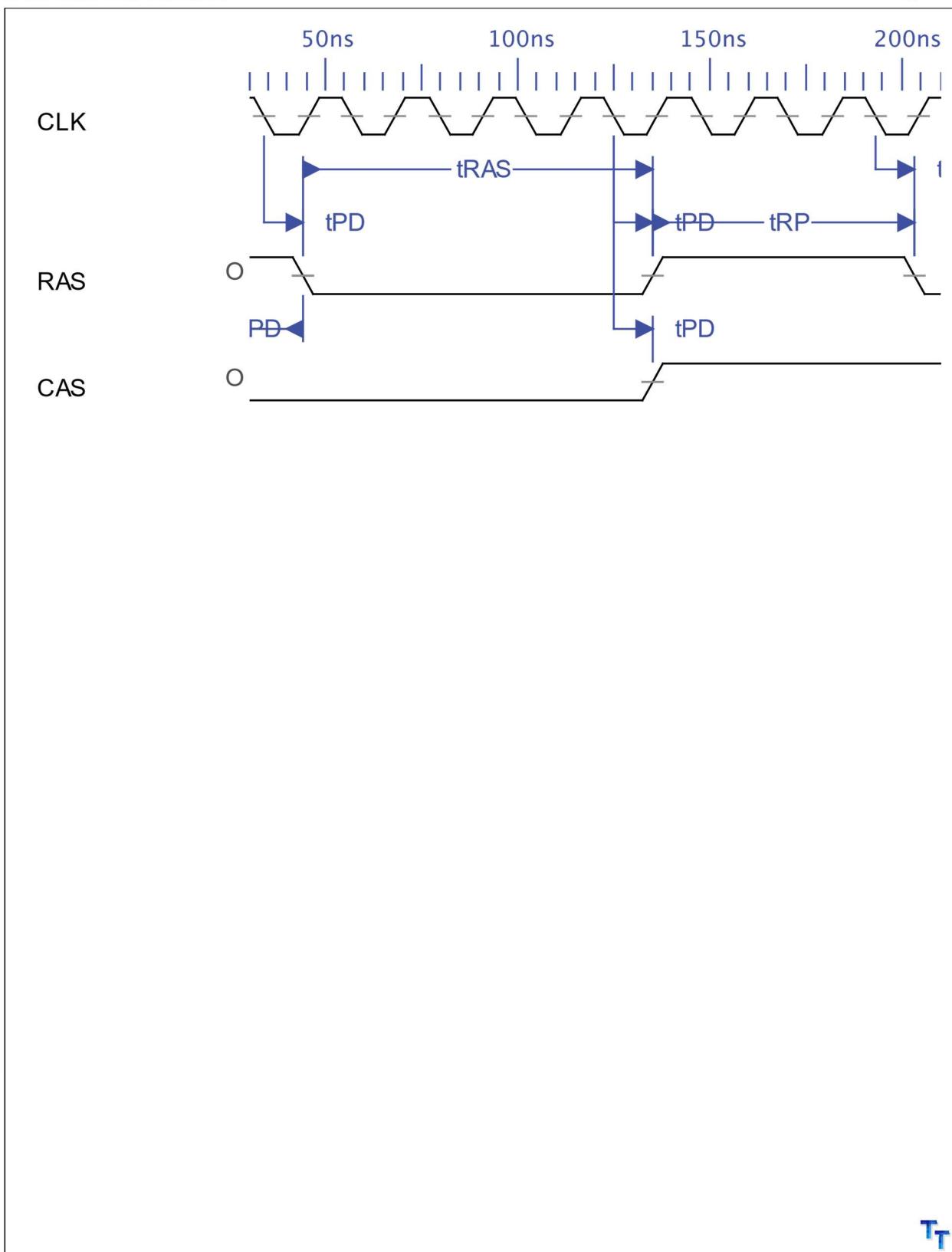
tOFF	output disable time after CAS high	to be defined	0ns	20ns
tBufferAndPD		to be defined	1.3ns	15.1ns
	Buffer propagation delays			
tPD	CPLD worst case path	to be defined		10ns
tCAC	Access time from CAS low	to be defined		20ns
tRAC	Access time from RAS low	to be defined		80ns
tRP	Pulse duration, RAS high	to be defined	60ns	

Page 4

General Data continued...

SYMBOL	DEFINITION	DESCRIPTION	MIN	MAX	NOTES
t_SMC40	Data Setup time before NRD	to be defined	7.5ns		
t_SMC41	Data Hold time after NRD rising	to be defined	-3.4ns		

t_SMC32	MCK falling to NRD inactive	to be defined	4.5ns	6.8ns
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General Data					
SYMBOL	DEFINITION	DESCRIPTION	MIN	MAX	NOTES
tASR		to be defined	0ns		
	Row-address setup time before RAS low				
tASC	Column-address setup time before CAS low	to be defined	0ns		
tDS	Data setup time	to be defined	0ns		
tRCS	Read setup time before CAS low	to be defined			
tCWL	W low setup time before CAS	to be defined	20ns		
tRWL	W low setup time before RAS	to be defined			
tWCS	W low setup time before CAS	to be defined	0ns		
tWSR	W high setup time (CAS-before-RAS refresh only)	to be defined	10ns		
tCAH	Column-address hold time after CAS low	to be defined	15ns		
tDHR	Data hold time after RAS low	to be defined	60ns		
tDH	Data hold time	to be defined	15ns		
tAR	Column-address hold time after RAS low	to be defined	60ns		
tRAH	Row-address hold time after RAS low	to be defined	10ns		
tRCH	Read hold time after CAS high	to be defined	0ns		
tRRH	Read hold time after RAS high	to be defined	0ns		
tWCH	Write hold time after CAS low	to be defined	15ns		

tWCR	Write hold time after RAS low	to be defined	60ns
tWHR	W high hold time (CAS-before-RAS refresh only)	to be defined	10ns
tCHR	Delay time, RAS low to CAS high	to be defined	20ns

Page 3

General Data continued...

SYMBOL	DEFINITION	DESCRIPTION	MIN	MAX	NOTES
tCRP	Delay time, CAS high to RAS low	to be defined	0ns		
tCSH	Delay time, RAS low to CAS high	to be defined	80ns		
tCSR	Delay time, CAS low to RAS low	to be defined	10ns		
tRAD	Delay time, RAS low to column-address	to be defined	15ns	40ns	
tRAL	Delay time, column-address to RAS high	to be defined	40ns		
tCAL	Delay time, column-address to CAS high	to be defined	40ns		
tRCD	Delay time, RAS low to CAS low	to be defined	20ns	60ns	
tRPC	Delay time, RAS high to CAS low	to be defined	0ns		
tRSH	Delay time, CAS low to RAS high	to be defined	20ns		
tT	Transition time	to be defined	2ns	50ns	
tRAS	Non-page-mode pulse duration, RAS low	to be defined	80ns	10000ns	
tCAS	Pulse duration, CAS low	to be defined	20ns	10000ns	
tCLZ	CAS to output in low Z	to be defined	0ns		

tOFF	output disable time after CAS high	to be defined	0ns	20ns
tBufferAndPD		to be defined	1.3ns	15.1ns
	Buffer propagation delays			
tPD	CPLD worst case path	to be defined		10ns
tCAC	Access time from CAS low	to be defined		20ns
tRAC	Access time from RAS low	to be defined		80ns
tRP	Pulse duration, RAS high	to be defined	60ns	

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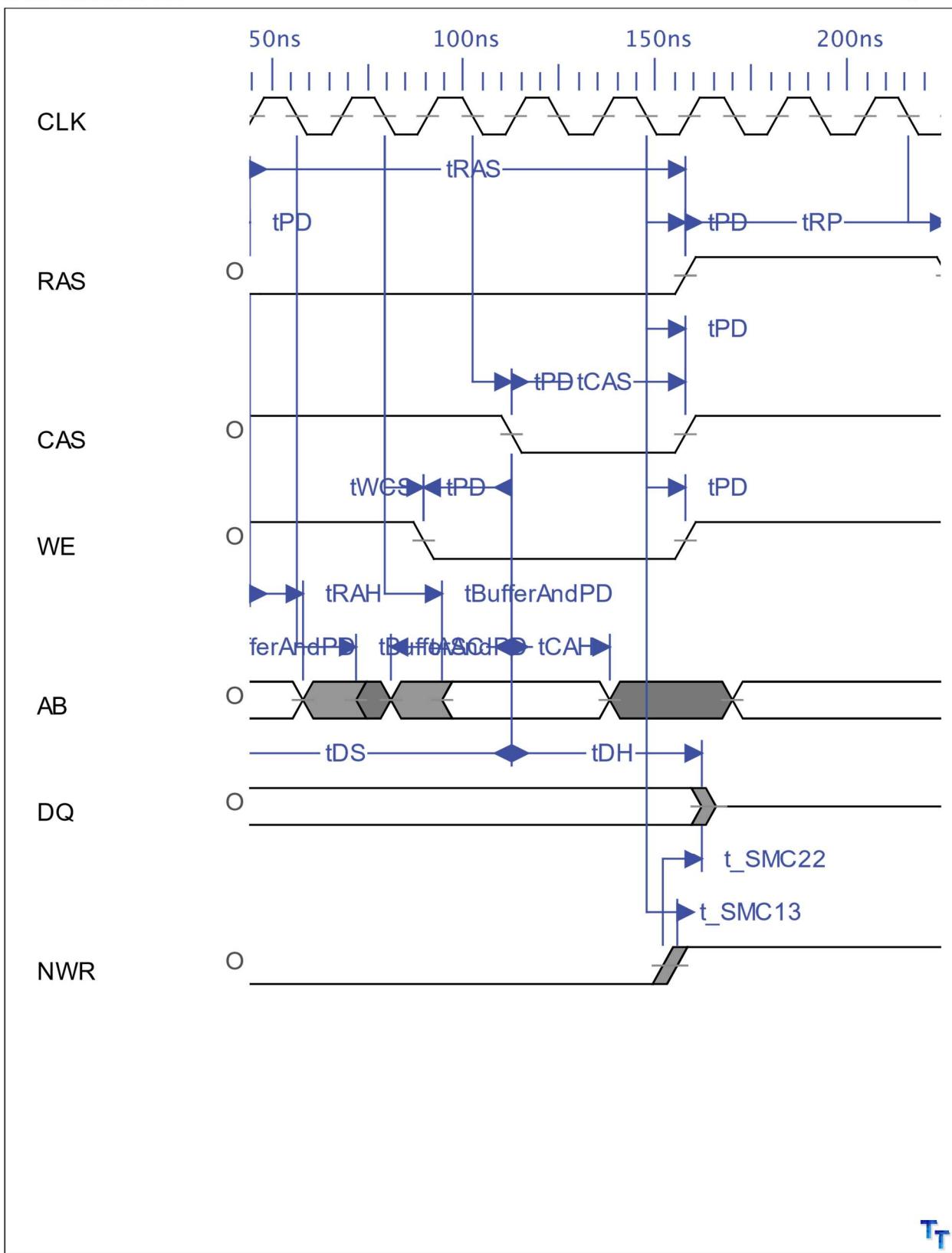
General Data continued...

SYMBOL	DEFINITION	DESCRIPTION	MIN	MAX	NOTES

tCP

Pulse duration,
to be defined
CAS high

10ns



General Data					
SYMBOL	DEFINITION	DESCRIPTION	MIN	MAX	NOTES
tASR		to be defined	0ns		
	Row-address setup time before RAS low				
tASC	Column-address setup time before CAS low	to be defined	0ns		
tDS	Data setup time	to be defined	0ns		
tRCS	Read setup time before CAS low	to be defined			
tCWL	W low setup time before CAS	to be defined	20ns		
tRWL	W low setup time before RAS	to be defined			
tWCS	W low setup time before CAS	to be defined	0ns		
tWSR	W high setup time (CAS-before-RAS refresh only)	to be defined	10ns		
tCAH	Column-address hold time after CAS low	to be defined	15ns		
tDHR	Data hold time after RAS low	to be defined	60ns		
tDH	Data hold time	to be defined	15ns		
tAR	Column-address hold time after RAS low	to be defined	60ns		
tRAH	Row-address hold time after RAS low	to be defined	10ns		
tRCH	Read hold time after CAS high	to be defined	0ns		
tRRH	Read hold time after RAS high	to be defined	0ns		
tWCH	Write hold time after CAS low	to be defined	15ns		

tWCR	Write hold time after RAS low	to be defined	60ns
tWHR	W high hold time (CAS-before-RAS refresh only)	to be defined	10ns
tCHR	Delay time, RAS low to CAS high	to be defined	20ns

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General Data continued...

SYMBOL	DEFINITION	DESCRIPTION	MIN	MAX	NOTES
tCRP	Delay time, CAS high to RAS low	to be defined	0ns		
tCSH	Delay time, RAS low to CAS high	to be defined	80ns		
tCSR	Delay time, CAS low to RAS low	to be defined	10ns		
tRAD	Delay time, RAS low to column-address	to be defined	15ns	40ns	
tRAL	Delay time, column-address to RAS high	to be defined	40ns		
tCAL	Delay time, column-address to CAS high	to be defined	40ns		
tRCD	Delay time, RAS low to CAS low	to be defined	20ns	60ns	
tRPC	Delay time, RAS high to CAS low	to be defined	0ns		
tRSH	Delay time, CAS low to RAS high	to be defined	20ns		
tT	Transition time	to be defined	2ns	50ns	
tRAS	Non-page-mode pulse duration, RAS low	to be defined	80ns	10000ns	
tCAS	Pulse duration, CAS low	to be defined	20ns	10000ns	
tCLZ	CAS to output in low Z	to be defined	0ns		

tOFF	output disable time after CAS high	to be defined	0ns	20ns
tBufferAndPD		to be defined	1.3ns	15.1ns
	Buffer propagation delays			
tPD	CPLD worst case path	to be defined		10ns
tCAC	Access time from CAS low	to be defined		20ns
tRAC	Access time from RAS low	to be defined		80ns
tRP	Pulse duration, RAS high	to be defined	60ns	

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General Data continued...

SYMBOL	DEFINITION	DESCRIPTION	MIN	MAX	NOTES
tBuffer		to be defined	1.3ns	5.1ns	
t_SMC13	MCK Falling to NWR inactive	to be defined	4.1ns	7.9ns	

t_SMC22

MCK Rising to
Data out invalid

to be defined

10.2ns

Appendix D (DRAM Abel Code)

MODULE DRAM

TITLE 'DRAM Interface - State Machine Version'

" DRAM Interface EE52 Project

" Description: Controls DRAM access

" Revision History:

" Will Werst 3/12/2017 Wrote code

" Pins

```

"      pin  1           input  unused
"      pin  2           input  unused
"      pin  3           input  unused
"      pin  4           input  unused
"      pin  5           input  unused
"      pin  6           input  unused
"      pin  7           input  unused
"      pin  8           input  unused
"      pin  9           input  unused
"      pin 10          input  unused
"      pin 11          input  unused
"      pin 12          input  unused
"      pin 13          input  unused
"      pin 14          input  unused
!JTAG_NTRST pin  15;        "JTAG NTRST input
!NReset pin  16;          "Reset input
!NTRST pin  17 ISTYPE 'com'; "TRST output
RAS    pin  18 ISTYPE 'com'; "RAS line
CAS    pin  19 ISTYPE 'com'; "CAS line
!DRAM_WE pin  20 ISTYPE 'com'; "Write Enable Line to DRAM
!R_A_EN pin  21 ISTYPE 'com'; "Buffer row address enable
!C_A_EN pin  22 ISTYPE 'com'; "Buffer column address enable line
"      pin  23          input  unused
"      pin  24          input  unused
!NCS   pin  25;          "input chip select
!NWE   pin  26;          "input for whether write access
!NWAIT pin  27 ISTYPE 'reg'; "output for making cpu wait for refresh finish
!MCLK  pin  28;          "main clock input
!RCLK  pin  29;          "refresh clock input
"      pin  13          output unused
"      pin  14          output unused
"      pin  15          output unused
"      pin  16          output unused
St0   pin 37    ISTYPE 'reg'; "output state bit 0
St1   pin 38    ISTYPE 'reg'; "output state bit 1
St2   pin 39    ISTYPE 'reg'; "output state bit 2
St3   pin 40    ISTYPE 'reg'; "output state bit 3
St4   pin 41    ISTYPE 'reg'; "output state bit 4
RefRqst pin    ISTYPE 'reg'; "refresh request bit
RefInProgress pin ISTYPE 'reg_SR'; "bit indicating refresh just finished, used to
implement logic for holding nwait one more cycle
RefInProgressDelay pin ISTYPE 'reg_D';
"      pin  17          output unused
"      pin  18          output unused

```

"the states

```

StateBits = [ St4, St3, St2, St1, St0 ];      " state bits
                                                " state assignments
Idle     = [ 0, 0, 0, 0, 0 ];      " idle state (waiting for a cycle to start)
Access0  = [ 0, 0, 0, 0, 1 ];      " enable row address for Access
Access1  = [ 0, 0, 0, 1, 0 ];      " RAS line low
Access2  = [ 0, 0, 0, 1, 1 ];      " disable row address for Access
Access3  = [ 0, 0, 1, 0, 0 ];      " enable column address for Access
Access4  = [ 0, 0, 1, 0, 1 ];      " CAS line low
Access5  = [ 0, 0, 1, 1, 0 ];      " Wait for data access
Access6  = [ 0, 0, 1, 1, 1 ];      " Wait for data access
Access7  = [ 0, 1, 0, 0, 0 ];      " Wait for data access
Access8  = [ 0, 1, 0, 0, 1 ];      " RAS, CAS line high
Access9  = [ 0, 1, 0, 1, 0 ];      " Pre-charge
Access10 = [ 0, 1, 0, 1, 1 ];      " Pre-charge
Ref0     = [ 0, 1, 1, 0, 0 ];      " CAS low
Ref1     = [ 0, 1, 1, 0, 1 ];      " RAS low
Ref2     = [ 0, 1, 1, 1, 0 ];      " Wait
Ref3     = [ 0, 1, 1, 1, 1 ];      " Wait
Ref4     = [ 1, 0, 0, 0, 0 ];      " Wait
Ref5     = [ 1, 0, 0, 0, 1 ];      " RAS, CAS high
Ref6     = [ 1, 0, 0, 1, 0 ];      " Pre-charge
Ref7     = [ 1, 0, 0, 1, 1 ];      " Pre-charge
Inval0   = [ 1, 0, 1, 0, 0 ];
Inval1   = [ 1, 0, 1, 0, 1 ];
Inval2   = [ 1, 0, 1, 1, 0 ];
Inval3   = [ 1, 0, 1, 1, 1 ];
Inval4   = [ 1, 1, 0, 0, 0 ];
Inval5   = [ 1, 1, 0, 0, 1 ];
Inval6   = [ 1, 1, 0, 1, 0 ];
Inval7   = [ 1, 1, 0, 1, 1 ];      " Invalid state
Inval8   = [ 1, 1, 1, 0, 0 ];      " Invalid state
Inval9   = [ 1, 1, 1, 0, 1 ];      " Invalid state
Inval10  = [ 1, 1, 1, 1, 0 ];      " Invalid state
Inval11  = [ 1, 1, 1, 1, 1 ];      " Invalid state

```

EQUATIONS

```

" NWAIT equation
NWAIT := (NCS & (RefInProgress));

NTRST = NReset & JTAG_NTRST;
DRAM_WE = NWE & NCS;

" clocks for the registered outputs (state bits)
StateBits.CLK = MCLK;           " use the global clock pin
NWAIT.CLK = !MCLK;

RefInProgress.S = (StateBits == Ref0);
RefInProgress.R = (StateBits == Idle);
RefInProgress.CLK = MCLK;
RefInProgressDelay.D = RefInProgress;
RefInProgressDelay.CLK = MCLK;
RefRqst.CLK = RCLK;
RefRqst.AR = (StateBits == Ref7);
RefRqst := 1;

STATE_DIAGRAM StateBits      " a Mealy state machine

STATE Idle:                  " in the idle state waiting for an access

```

```

RAS = 1;
CAS = 1;
"DRAM_WE = 1;
R_A_EN = 0;
C_A_EN = 0;

IF (NReset) THEN Idle;
ELSE IF (RefRqst) THEN Ref0;
"ELSE IF (NCS & NWE) THEN Write0;
ELSE IF (NCS) THEN Access0;
ELSE Idle;           " otherwise just stay here

```

STATE Access0:

```

RAS = 1;
CAS = 1;
"DRAM_WE = 1;
R_A_EN = 1;
C_A_EN = 0;

IF (NReset) THEN      Idle;
ELSE                 Access1;

```

STATE Access1:

```

RAS = 0;
CAS = 1;
"DRAM_WE = 1;
R_A_EN = 1;
C_A_EN = 0;

IF (NReset) THEN      Idle;
ELSE                 Access2;

```

STATE Access2:

```

RAS = 0;
CAS = 1;
"DRAM_WE = 1;
R_A_EN = 0;
C_A_EN = 0;

IF (NReset) THEN      Idle;
ELSE                 Access3;

```

STATE Access3:

```

RAS = 0;
CAS = 1;
"DRAM_WE = 1;
R_A_EN = 0;
C_A_EN = 1;

IF (NReset) THEN      Idle;
ELSE                 Access4;

```

STATE Access4:

```

RAS = 0;
CAS = 0;
"DRAM_WE = 1;
R_A_EN = 0;
C_A_EN = 1;

IF (NReset) THEN      Idle;
ELSE                 Access5;

```

STATE Access5:

```
RAS = 0;
CAS = 0;
"DRAM_WE = 1;
R_A_EN = 0;
C_A_EN = 1;

IF (NReset) THEN           Idle;
ELSE                      Access6;
```

STATE Access6:

```
RAS = 0;
CAS = 0;
"DRAM_WE = 1;
R_A_EN = 0;
C_A_EN = 1;

IF (NReset) THEN           Idle;
ELSE                      Access7;
```

STATE Access7:

```
RAS = 0;
CAS = 0;
"DRAM_WE = 1;
R_A_EN = 0;
C_A_EN = 1;

IF (NReset) THEN           Idle;
ELSE                      Access8;
```

STATE Access8:

```
RAS = 1;
CAS = 1;
"DRAM_WE = 1;
R_A_EN = 0;
C_A_EN = 0;

IF (NReset) THEN           Idle;
ELSE                      Access9;
```

STATE Access9:

```
RAS = 1;
CAS = 1;
"DRAM_WE = 1;
R_A_EN = 0;
C_A_EN = 0;

IF (NReset) THEN           Idle;
ELSE                      Access10;
```

STATE Access10:

```
RAS = 1;
CAS = 1;
"DRAM_WE = 1;
R_A_EN = 0;
C_A_EN = 0;
```

```
GOTO Idle;
```

```
STATE Ref0:
```

```
RAS = 1;  
CAS = 0;  
"DRAM_WE = 1;  
R_A_EN = 0;  
C_A_EN = 0;
```

```
IF (NReset) THEN      Idle;  
ELSE                  Ref1;
```

```
STATE Ref1:
```

```
RAS = 0;  
CAS = 0;  
"DRAM_WE = 1;  
R_A_EN = 0;  
C_A_EN = 0;
```

```
IF (NReset) THEN      Idle;  
ELSE                  Ref2;
```

```
STATE Ref2:
```

```
RAS = 0;  
CAS = 0;  
"DRAM_WE = 1;  
R_A_EN = 0;  
C_A_EN = 0;
```

```
IF (NReset) THEN      Idle;  
ELSE                  Ref3;
```

```
STATE Ref3:
```

```
RAS = 0;  
CAS = 0;  
"DRAM_WE = 1;  
R_A_EN = 0;  
C_A_EN = 0;
```

```
IF (NReset) THEN      Idle;  
ELSE                  Ref4;
```

```
STATE Ref4:
```

```
RAS = 0;  
CAS = 0;  
"DRAM_WE = 1;  
R_A_EN = 0;  
C_A_EN = 0;
```

```
IF (NReset) THEN      Idle;  
ELSE                  Ref5;
```

```
STATE Ref5:
```

```
RAS = 1;
```

```
CAS = 1;
"DRAM_WE = 1;
R_A_EN = 0;
C_A_EN = 0;

IF (NReset) THEN      Idle;
ELSE                  Ref6;
```

STATE Ref6:

```
RAS = 1;
CAS = 1;
"DRAM_WE = 1;
R_A_EN = 0;
C_A_EN = 0;

IF (NReset) THEN      Idle;
ELSE                  Ref7;
```

STATE Ref7:

```
RAS = 1;
CAS = 1;
"DRAM_WE = 1;
R_A_EN = 0;
C_A_EN = 0;

GOTO      Idle;
```

STATE Inval0:

```
RAS = 1;
CAS = 1;
"DRAM_WE = 1;
R_A_EN = 0;
C_A_EN = 0;

GOTO      Idle;
```

STATE Inval1:

```
RAS = 1;
CAS = 1;
"DRAM_WE = 1;
R_A_EN = 0;
C_A_EN = 0;

GOTO      Idle;
```

STATE Inval2:

```
RAS = 1;
CAS = 1;
"DRAM_WE = 1;
R_A_EN = 0;
C_A_EN = 0;

GOTO      Idle;
```

STATE Inval3:

```
RAS = 1;
CAS = 1;
"DRAM_WE = 1;
R_A_EN = 0;
C_A_EN = 0;

GOTO      Idle;
```

```
STATE Inval4:  
    RAS = 1;  
    CAS = 1;  
    "DRAM_WE = 1;  
    R_A_EN = 0;  
    C_A_EN = 0;  
  
    GOTO          Idle;  
  
STATE Inval5:  
    RAS = 1;  
    CAS = 1;  
    "DRAM_WE = 1;  
    R_A_EN = 0;  
    C_A_EN = 0;  
  
    GOTO          Idle;  
  
STATE Inval6:  
    RAS = 1;  
    CAS = 1;  
    "DRAM_WE = 1;  
    R_A_EN = 0;  
    C_A_EN = 0;  
  
    GOTO          Idle;  
  
STATE Inval7:  
    RAS = 1;  
    CAS = 1;  
    "DRAM_WE = 1;  
    R_A_EN = 0;  
    C_A_EN = 0;  
  
    GOTO          Idle;  
  
STATE Inval8:  
    RAS = 1;  
    CAS = 1;  
    "DRAM_WE = 1;  
    R_A_EN = 0;  
    C_A_EN = 0;  
  
    GOTO          Idle;  
  
STATE Inval9:  
    RAS = 1;  
    CAS = 1;  
    "DRAM_WE = 1;  
    R_A_EN = 0;  
    C_A_EN = 0;  
  
    GOTO          Idle;  
  
STATE Inval10:  
    RAS = 1;  
    CAS = 1;  
    "DRAM_WE = 1;  
    R_A_EN = 0;  
    C_A_EN = 0;  
  
    GOTO          Idle;  
  
STATE Inval11:  
    RAS = 1;
```

```

CAS = 1;
"DRAM_WE = 1;
R_A_EN = 0;
C_A_EN = 0;

GOTO Idle;

TEST_VECTORS

( [ MCLK, RCLK, NReset, NCS, NWE ] -> [ RAS, CAS, DRAM_WE, R_A_EN, C_A_EN, NWAIT,
RefRqst, St0, St1, St2, St3, St4 ] )

[ 0, 0, 0, 0, 0 ] -> [ .X., .X., .X., .X., .X. ];

" reset the system
[ .C., 0, 1, 1, 1 ] -> [ 1, 1, 1, 0, 0, 0,
.X., .X., .X., .X., .X. ];
[ .C., 0, 1, 1, 1 ] -> [ 1, 1, 1, 0, 0, 0,
.X., .X., .X., .X., .X. ];
[ .C., 0, 1, 1, 1 ] -> [ 1, 1, 1, 0, 0, 0,
.X., .X., .X., .X., .X. ];

" Single Access
[ .C., 0, 0, 1, 0 ] -> [ 1, 1, 1, 1, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Access0
[ .C., 0, 0, 1, 0 ] -> [ 0, 1, 1, 1, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Access1
[ .C., 0, 0, 1, 0 ] -> [ 0, 1, 1, 0, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Access2
[ .C., 0, 0, 1, 0 ] -> [ 0, 1, 1, 0, 0, 1,
0, .X., .X., .X., .X., .X. ]; "Access3
[ .C., 0, 0, 1, 0 ] -> [ 0, 0, 1, 0, 1, 0,
0, .X., .X., .X., .X., .X. ]; "Access4
[ .C., 0, 0, 1, 0 ] -> [ 0, 0, 1, 0, 1, 0,
0, .X., .X., .X., .X., .X. ]; "Access5
[ .C., 0, 0, 1, 0 ] -> [ 1, 1, 1, 0, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Access6
[ .C., 0, 0, 0, 0 ] -> [ 1, 1, 1, 0, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Pre-charge
[ .C., 0, 0, 0, 0 ] -> [ 1, 1, 1, 0, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Pre-charge
[ .C., 0, 0, 0, 0 ] -> [ 1, 1, 1, 0, 0, 0,
0, 0, 0, 0, 0 ]; "Idle

" Single write
[ .C., 0, 0, 1, 1 ] -> [ 1, 1, 1, 1, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Write0
[ .C., 0, 0, 1, 1 ] -> [ 0, 1, 1, 1, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Write1
[ .C., 0, 0, 1, 1 ] -> [ 0, 1, 1, 0, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Write2
[ .C., 0, 0, 1, 1 ] -> [ 0, 1, 1, 0, 0, 1,
0, .X., .X., .X., .X., .X. ]; "Write3
[ .C., 0, 0, 1, 1 ] -> [ 0, 0, 1, 0, 0, 1,
0, .X., .X., .X., .X., .X. ]; "Write4
[ .C., 0, 0, 1, 1 ] -> [ 0, 0, 1, 0, 0, 1,
0, .X., .X., .X., .X., .X. ]; "Write5
[ .C., 0, 0, 1, 1 ] -> [ 1, 1, 1, 0, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Write6
[ .C., 0, 0, 0, 0 ] -> [ 1, 1, 1, 0, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Pre-charge

```

```

[ .C., 0, 0, 0, 0 ] -> [ 1, 1, 1, 0, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Pre-charge
[ .C., 0, 0, 0, 0 ] -> [ 1, 1, 1, 0, 0, 0,
0, 0, 0, 0, 0 ]; "Idle

" Consecutive Accesses
[ .C., 0, 0, 1, 0 ] -> [ 1, 1, 1, 1, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Access0
[ .C., 0, 0, 1, 0 ] -> [ 0, 1, 1, 1, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Access1
[ .C., 0, 0, 1, 0 ] -> [ 0, 1, 1, 0, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Access2
[ .C., 0, 0, 1, 0 ] -> [ 0, 1, 1, 0, 0, 1,
0, .X., .X., .X., .X., .X. ]; "Access3
[ .C., 0, 0, 1, 0 ] -> [ 0, 0, 1, 0, 1, 0,
0, .X., .X., .X., .X., .X. ]; "Access4
[ .C., 0, 0, 1, 0 ] -> [ 0, 0, 1, 0, 1, 0,
0, .X., .X., .X., .X., .X. ]; "Access5
[ .C., 0, 0, 1, 0 ] -> [ 1, 1, 1, 0, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Access6
[ .C., 0, 0, 0, 0 ] -> [ 1, 1, 1, 0, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Pre-charge
[ .C., 0, 0, 0, 0 ] -> [ 1, 1, 1, 0, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Pre-charge
[ .C., 0, 0, 0, 0 ] -> [ 1, 1, 1, 0, 0, 0,
0, 0, 0, 0, 0 ]; "Idle
[ .C., 0, 0, 1, 0 ] -> [ 1, 1, 1, 1, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Access0
[ .C., 0, 0, 1, 0 ] -> [ 0, 1, 1, 1, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Access1
[ .C., 0, 0, 1, 0 ] -> [ 0, 1, 1, 0, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Access2
[ .C., 0, 0, 1, 0 ] -> [ 0, 1, 1, 0, 0, 1,
0, .X., .X., .X., .X., .X. ]; "Access3
[ .C., 0, 0, 1, 0 ] -> [ 0, 0, 1, 0, 1, 0,
0, .X., .X., .X., .X., .X. ]; "Access4
[ .C., 0, 0, 1, 0 ] -> [ 0, 0, 1, 0, 1, 0,
0, .X., .X., .X., .X., .X. ]; "Access5
[ .C., 0, 0, 1, 0 ] -> [ 1, 1, 1, 0, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Access6
[ .C., 0, 0, 0, 0 ] -> [ 1, 1, 1, 0, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Pre-charge
[ .C., 0, 0, 0, 0 ] -> [ 1, 1, 1, 0, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Pre-charge
[ .C., 0, 0, 0, 0 ] -> [ 1, 1, 1, 0, 0, 0,
0, 0, 0, 0, 0 ]; "Idle

" Refresh
[ 0, .C., 0, 0, 0 ] -> [ .X., .X., .X., .X., .X.,
1, .X., .X., .X., .X., .X. ]; "Trigger the refresh request
[ .C., 0, 0, 0, 0 ] -> [ 1, 0, 1, 0, 0, 0,
1, .X., .X., .X., .X., .X. ]; "Ref0
[ .C., 0, 0, 0, 0 ] -> [ 0, 0, 1, 0, 0, 0,
1, .X., .X., .X., .X., .X. ]; "Ref1
[ .C., 0, 0, 0, 0 ] -> [ 0, 0, 1, 0, 0, 0,
1, .X., .X., .X., .X., .X. ]; "Ref2
[ .C., 0, 0, 0, 0 ] -> [ 0, 0, 1, 0, 0, 0,
1, .X., .X., .X., .X., .X. ]; "Ref3
[ .C., 0, 0, 0, 0 ] -> [ 0, 0, 1, 0, 0, 0,
1, .X., .X., .X., .X., .X. ]; "Ref4
[ .C., 0, 0, 0, 0 ] -> [ 1, 1, 1, 0, 0, 0,
1, .X., .X., .X., .X., .X. ]; "Ref5
[ .C., 0, 0, 0, 0 ] -> [ 1, 1, 1, 0, 0, 0,
1, .X., .X., .X., .X., .X. ]; "Ref6
[ .C., 0, 0, 0, 0 ] -> [ 1, 1, 1, 0, 0, 0,
0, .X., .X., .X., .X., .X. ]; "Ref7

```

```
[ .C., 0, 0, 0, 0 ] -> [ 1, 1, 1, 0, 0,
```

```
END DRAM
```

Appendix E (Software)

```
@Done
@oooooooooooooooooooooooooooooooooooooooooooooooooooo
@                                     Boot.inc
@                                     Contains definitions used by boot.s
@                                     Revision History:
@ Name          Comment           Date
@ Will Werst   Initial version  Some lonely night around 6/10/17
@ Will Werst   Comment          October 2017
```

@@@@ SMC Definitions

```
@ SRAM
@ RWHOLD, RWSETUP    0x00----- 1/2 cycle setup and hold
@ ACSS              0x--00---- Standard chip select waveform
@                   0x----30-- connected to 16-bit device
@ 1 Wait state     0x-----81 Enable 1 wait state
.equ SMC_CSR1_VAL, 0x00003081

@ DRAM
@ RWHOLD, RWSETUP    0x30----- 3 RWHOLD
@ ACSS              0x--00---- Standard chip select waveform
@ 8 bit             0x----43-- Connected to 8-bit device with 3 clock cycles data float
@ 7 Wait state     0x-----87 Enable 7 wait state
.equ SMC_CSR2_VAL, 0x30004387

@ ROM
@ RWHOLD, RWSETUP    0x00----- 1/2 cycle setup and hold
@ ACSS              0x--00---- Standard chip select waveform
@                   0x----40-- Connected to 8-bit device
@ 3 Wait state     0x-----83 Enable 3 wait state
.equ SMC_CSR7_VAL, 0x00004083
```

@@@@ PMC Definitions

```
.equ PMC_PLLAR_VAL, 0x20153F05 @ MULA = 21 + 1, DIVA = 5, PLLACOUNT =63, OUTA = 00
.equ PMC_MCKR_VAL, 0x00000006 @0x0000000E for dram
.equ PMC_PCK0_VAL, 0x00000006
.equ PMC_PCER_VAL, 0x00000001C @Enable PIOA, PIOC
.equ PMC_PCK1_VAL, 0x00000019 @MCK source, Pre-scale by 64

.equ PMC_MCKR_MDIV, 0 @Run cpu 1+1 times faster than MCK
```

@@@@ PIOA Definitions

```
.equ PIOA_BSR_VAL, 0x01000000
.equ PIOA_OER_VAL, 0x01000000
.equ PIOA_PDR_VAL, 0x01000000
```

@@@@ PIOC Definitions

```
.equ PIOC_ASR_VAL, 0x08000000
.equ PIOC_OER_VAL, 0x08000000
.equ PIOC_PDR_VAL, 0x08000000
```

- Clock
- ROM and SRAM chips selects

@ It then copies the main program from the ROM to the SRAM and jumps to the beginning of code in the SRAM.

@ Revision History:

2010/02/02	Joseph Schmitz	Modified code from Arthur Chang to make it available to the students.
2011/01/27	Joseph Schmitz	Split from crt0.s to boot.s
2011/01/31	Joseph Schmitz	Updated exception vectors to include special word value at ARM vector 6. (see 13.3.2)
2011/02/06	Joseph Schmitz	Added documentation on exception vectors.
2017/05/21	William Werst	Modified to work for this project

```
.include "at91rm9200.inc"  
.include "system.inc"  
.include "macro.inc"  
.include "boot.inc"
```

.text
.arm

Exception	Description
Reset	Occurs when the processor reset pin is asserted. This exception is only expected to occur for signalling power-up, or for resetting as if the processor has just powered up. A soft reset can be done by branching to the reset vector (0x0000).
Undefined Instruction	Occurs if neither the processor, or any attached coprocessor, recognizes the currently executing instruction. Software Interrupt (SWI) This is a user-defined synchronous interrupt instruction. It allows a program running in User mode, for example, to request privileged operations that run in Supervisor mode, such as an RTOS function.
Software Interrupt	Occurs when the processor generates a software interrupt.
Prefetch Abort	Occurs when the processor attempts to execute an instruction that has prefetched from an illegal

address.

⑥ Data Abort Occurs when a data transfer instruction attempts to load or store data at an illegal address.

⑥ Vector 6 Used to specify the number of bytes to download from and external boot memory into internal SRAM on reset.

⑥ IRQ Occurs when the processor external interrupt request pin is asserted (LOW) and the I bit in the CPSR is clear.

⑥ FIQ Occurs when the processor external fast interrupt request pin is asserted (LOW) and the F bit in the CPSR is clear.

⑥ The format is as follows:

⑥ reset: Reset vector
⑥ undef: Undefine instruction
⑥ swi: Software interrupt
⑥ abort: Prefect abort
⑥ data: Data abort
⑥ btldr: Defines how much data to download from the boot memory
⑥ irq: Normal interrupt (low priority). Actual ISR address loaded from AI
⑥ fiq: Fast interrupt (high priority)

IRQTable:
.org 0x0

```
reset:
    B    _start
undef:
    B    undef
swi:
    B    swi
prefetch:
    B    prefetch
data:
    B    data
btldr:
    .word 0x00000008
irq:
    LDR PC, [PC, #-0xF20]
fiq:
    B    fiq
```

```
@@@ Startup Code (system reset restarts here) @@@@@@@@@@@@.org 0x20
```

```
.global _start
```

@ In this file you must do the following (at least for now):

- Switch to the master clock

- Wait for it to stabilize. The datasheet tells you how long this will take. You will need to force your CPU to do no external memory operations during this time. There is an easy way to do this, but think about it and only ask me if you still can't come up with anything


```

mSET_HREG SMC_CSR1, SMC_CSR1_VAL

@Setup DRAM
mSET_HREG SMC_CSR2, SMC_CSR2_VAL

@Setup ROM
mSET_HREG SMC_CSR7, SMC_CSR7_VAL

@@@ Verify DRAM and SRAM are functioning
@@Check SRAM valid

@Test SRAM
LDR r0, =SRAM_START
LDR r1, =SRAM_SIZE
BL mem_test
CMP r0, #TRUE
BNE memtestfail

@Test DRAM
LDR r0, =DRAM_START
LDR r1, =DRAM_SIZE
BL mem_test
CMP r0, #TRUE
BNE memtestfail

@@@ Copy Code from External ROM -> External SRAM @@@@@@@@
LDR r0, =SRAM_SIZE - 4
LDR r1, =ROM_START
LDR r2, =SRAM_START
CopyROMToSRAM:
LDR r3, [r1, r0]
STR r3, [r2, r0]
SUBS r0, #4
BHS CopyROMToSRAM

@Check that code loaded into SRAM matches code in ROM
LDR r0, =SRAM_SIZE - 4
LDR r1, =ROM_START
LDR r2, =SRAM_START
CheckCopyToSRAM:
LDR r3, [r1, r0]
LDR r4, [r2, r0]
CMP r3, r4
BNE LoadToSRAMFailed
SUBS r0, #4
BHS CheckCopyToSRAM
@@@ Branch to the Main Body of Code Now Located in the External SRAM @@@@@

@Uncomment this to branch to the copied code
BL SRAM_START

@if don't want to branch to low_level_init, fall through to BootEndLoop
BootEndLoop:
B BootEndLoop

memtestfail:
B memtestfail

LoadToSRAMFailed:
B LoadToSRAMFailed

.end

```

```
@Done
@ crt0.s
@ Initialization file for EE52 ARM VoIP phone project. It sets up the IRQ
@ vector table, initializes the stacks for both the IRQ and System modes,
@ sets up the Master Clock, all of the chip selects for external memories,
@ and will eventually call all of the initialization functions for each
@ hardware block. Finally it invokes the main user interface code.
@ Revision History:
@ 2008/02/02 Joseph Schmitz Modified code from Arthur Chang to make it
@ available to the students.
@ 2011/01/27 Joseph Schmitz Split into crt0.s and boot.s.
@ 2011/01/31 Joseph Schmitz Removed unused comments.
@ 2012/01/24 Glen George Updated comments, modified included files,
@ and cleaned up the code a little.
@ 2012/01/29 Glen George Added comments explaining initialization.
```

```
.include "at91rm9200.inc"  
.include "system.inc"  
.include "macro.inc"  
.include "interfac.inc"
```

.text
.arm

@ In this file you must do at least the following:

- As you write other functions/code for the various hardware blocks, you will call the initialization functions for them from here as well.

@ low level init

④ Description: Initializes the ARM processor modes, calls the initialization functions for the different parts of the code, and then calls the main loop.

Operational Description: Initializes arm processor modes, then goes through and calls a sequence of initialization functions for various files. Finally, the main loop is called (or for the audio demo, audio_demo is called)

@ Arguments: None

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④

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```

@ Algorithms: None
@ Data Structures: None
@ Limitations: None
@ Registers Changed (besides ARM convention r0-r3): None
@ Known Bugs: None
@ Special notes: None
@ Revision History:
@ Name           Comment           Date
@ Will Werst    Initial version  Some lonely night around 6/10/17

```

```
.global low_level_init
```

```
low_level_init:
```

```

@Uncomment instruction below to prevent ROM code from executing after
@bootloader runs. This effectively creates a dummy ROM code that does nothing.
@B low_level_init

```

```
@ Stack and IRQ Initialization
```

```
LDR      r0, =TOP_STACK          @load address for top of the stack
```

```

@ put the CPU in interrupt mode and set the stack pointer for this mode
MSR      cpsr_c, #ARM_MODE_IRQ | I_BIT | F_BIT
MOV      sp, r0

```

```

@ adjust the starting stack address for the interrupt stack just setup
SUB      r0, r0, #IRQ_STACK_SIZE

```

```

@ put the CPU in supervisor mode and set the stack pointer for this mode
MSR      cpsr_c, #ARM_MODE_SVC | I_BIT | F_BIT
MOV      sp, r0

```

```

@ adjust the starting stack address for the supervisor mode stack just setup
SUB      r0, r0, #SVC_STACK_SIZE

```

```

@ finally, put the CPU in user mode and set the stack pointer for this mode
MSR      cpsr_c, #ARM_MODE_USR | F_BIT
MOV      sp, r0

```

```
00000000000000000000000000000000
```

```
@ user initialization goes here @
00000000000000000000000000000000
```

```

BL init_system          @ Initialize the system
BL keypad_init          @ Initialize the keypad
BL audio_init           @ Initialize the audio
BL display_init          @ Initialize the display

```

```
loop:
```

```

@BL      audioDemo        @ Uncomment this line to run the audioDemo
BL      main               @ run the main function (no arguments)

```

```

B      low_level_init      @ if main returns (shouldn't)
                           @ reinitialize everything and start
                           @ over

```

```
.end
```

Done
Audio.inc
Contains definitions used by audio.s

@ Description: Defines register values used by the audio system.

@ Revision History:

@ Name	Comment	Date
@ Will Werst	Initial version	Some lonely night around 6/10/17
@ Will Werst	Comment	October 2017

```

@ 0000 0000 0000 0000 ---- ---- ---- ---- Reserved
@ ----- ----- 1---- ---- ---- ---- Software reset
@ ----- ----- -000 00-- ---- ---- Reserved
@ ----- ----- ----- 01 ---- ---- Enable transmit
@ ----- ----- ----- 0000 00-- ----- 01 Reserved
@ ----- ----- ----- ----- --01 Enable receive

.equ    SSC0_CR_VAL, 0x00008101

.equ    SSC0_CMR_VAL, 0x0000000B
@ 0111 1111 ----- ----- ----- ----- @CLK = 48 MHz / (2*(10+1) = 2 MHz
@ ----- 0000 0000 ----- ----- ----- Period: 2*(127+1) = 256 bits
@ ----- ----- 0000 ----- ----- ----- STTDLY: No delay
@ ----- ----- ----- 0001 ----- ----- Reserved
@ ----- ----- ----- 00----- START: Transmit Start
@ ----- ----- ----- 00----- Reserved
@ ----- ----- ----- --0----- CKI: Rising edge
@ ----- ----- ----- ---0 00-- CKO: No clock output
@ ----- ----- ----- ----- --01 CKS: TK Clock signal
@ ----- ----- ----- ----- ----- Reserved

@ 0111 1111 0000 0001 0000 0001 0000 0001 @Period 256 bits, 0 start delay, start on
.equ    SSC0_RCMR_VAL, 0x7F000101           transmit, Clock on falling edge, TK Clock signal is clock
transmit, Clock on falling edge, TK Clock signal is clock

```

```
0000 000- ----- ----- ----- ----- ----- ----- Reserved
@-----0----- ----- ----- ----- ----- ----- FSEDGE: Positive Edge
@-----0----- ----- ----- ----- ----- ----- Reserved
@-----000----- ----- ----- ----- ----- ----- FSOS: None
@-----0000----- ----- ----- ----- ----- ----- FSLEN: 0
@-----0000----- ----- ----- ----- ----- ----- Reserved
@-----0000----- ----- ----- ----- ----- ----- DATNB: 0+1
@-----1--- ----- ----- ----- ----- ----- MSBF: Most significant Bit first
@-----0----- ----- ----- ----- ----- ----- Reserved
@-----0----- ----- ----- ----- ----- ----- LOOP: False
@-----0 1111----- ----- ----- ----- ----- ----- DATLEN: 16 bits per bit stream
@ 0000 0000 0010 0000 0000 0000 1000 1111
.equ    SSC0_RFMR_VAL, 0x0020008F
clock, 16 DATNB
@Positive edge frame sync, positive pulse 1
```

0111 1111 ---- ---- ---- ----	Period: $2*(127+1) = 256$ bits
---- ---- 0000 0000 ---- ----	STTDLY: No delay
---- ---- ---- 0000 ---- ----	Reserved
---- ---- ---- 0011 ---- ----	START: High TF Signal
---- ---- ---- 00 ---- ----	Reserved
---- ---- ---- --1---- ----	CKI: Rising edge
---- ---- ---- ---0 01--	CKO: Continuous Transmit Clock
---- ---- ---- ---- --00	CKS: Divided clock
---- ---- ---- ---- ---- ----	Reserved

```
@ 0111 1111 0000 0000 0011 0020 0100  
.equ    SSC0_TCMR_VAL, 0x7F000324  
  
@ 0000 000- ----- ----- ----- -----  
@ -----0 ----- ----- ----- -----  
@ ----- 1--- ----- ----- ----- -----  
signal  
@ ----- -010 ----- ----- ----- -----  
@ ----- ----- 0000 ----- ----- -----  
@ ----- ----- ----- 0000 ----- -----  
@ ----- ----- ----- ----- 0000 -----  
@ ----- ----- ----- ----- 1--- -----  
@ ----- ----- ----- ----- -0-- -----  
@ ----- ----- ----- ----- --0- -----  
@ ----- ----- ----- ----- ---0 1111  
@ 0000 0000 1010 0000 0000 0000 0000 1111  
.equ    SSC0_TFMR_VAL, 0x0020008F
```

Reserved
FSEDGE: Positive Edge
FSDEN: Shift during transmit frame sync

FSOS: Positive pulse
FSLEN: 0
Reserved
DATNB: 0+1
MSBF: Most significant Bit first
Reserved
DATDEF: 0 is default bit
DATLEN: 16 bits per bit stream

@Define system volume

```
@done
@
@oooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooo
@
@
@ Audio.s
@
@ Description: Contains code for controlling the audio component of
@ the EE52 VoIP Project
@
@ Table of Contents:
@   - audio_init: Call to initialize this code file before
@                 calling anything else
@   - call_start: Call to initiate a call
@   - call_halt: Call to halt a call that has been started with call_start
@   - update_rx: Handler used to update the receive buffer
@   - update_tx: Handler used to update the transmit buffer
@   - setVolume: Call to set the volume
@   - audioDemo: A test function used to demo the audio code on its own,
@                 by looping the audio input back to the audio output.
```

@ Revision History:

@ Name Comment Date
@ Will Werst Initial version Some lonely night around 6/10/17
@ Will Werst Comment October 2017

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```
.include "at91rm9200.inc"  
.include "system.inc"  
.include "interfac.inc"  
.include "audio.inc"  
.include "macro.inc"
```

.text
.arm

Arguments: None

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© Shared variables: None

@ Global Variables: None

@ Inputs: SSC0 (audio se

Outputs: SSCO (audio serial communication) - initialize

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© Data structures: None

```

@ Limitations: None
@ Registers Changed (besides ARM convention r0-r3): None
@ Known Bugs: None
@ Special notes: None
@ Revision History:
@ Name           Comment          Date
@ Will Werst    Initial version  Some lonely night around 6/10/17

.global audio_init
audio_init:
    mSTARTFNC
    mSET_HREG  PMC_PCER,      (1 << 14)      @Enable the peripheral clock
    mSET_HREG  SSC0_CR,       SSC0_CR_VAL     @Setup the serial controller
    mSET_HREG  SSC0_CMRR,     SSC0_CMRR_VAL   @Setup the serial clock rate
    mSET_HREG  SSC0_RCMR,     SSC0_RCMR_VAL   @Setup receive clock mode
    mSET_HREG  SSC0_RFMR,     SSC0_RFMR_VAL   @Setup receive frame mode
    mSET_HREG  SSC0_TCMR,     SSC0_TCMR_VAL   @Setup transmit clock mode
    mSET_HREG  SSC0_TFMR,     SSC0_TFMR_VAL   @Setup transmit frame mode
    mSET_HREG  PIOB_ASRL,    0xF             @Setup serial output pins
    mSET_HREG  PIOB_PDRL,    0xF             @Setup serial output pins
    mSET_HREG  PIOB_OERL,    0xF             @Setup serial output pin
    mSET_HREG  SSC0_CR,       0x00000101    @Enable serial
    mSET_HREG  SSC0_PTCL,    0x00000101    @Enable DMA
    mRETURNFNC

@ call_start
@ Description: Initializes a call with the initial receive buffer pointer (r0)
@ Operational Description: Passes the initial buffer pointer (r0) to the
@                           function that handles adding new buffers
@                           to the system.
@ Arguments: r0 - pointer to first buffer in DRAM
@ Return values: None
@ Local variables: None
@ Shared variables: None
@ Global Variables: None
@ Inputs: None
@ Outputs: None
@ Error Handling: None
@ Algorithms: None
@ Data Structures: None
@ Limitations: None
@ Registers Changed (besides ARM convention r0-r3): None
@ Known Bugs: update_rx should be called, not update_tx. This ends up being
@              fine for long term operation because only the first buffer
@              played is affected, which is why it worked in the demo.

```

@ Special notes: None

@ Revision History:

Name	Comment	Date
Will Werst	Initial version	Some lonely night around 6/10/17

.global call_start

```
call_start:
    mSTARTFNC                      @Call start function macro
    BL update_tx
    mRETURNFNC                      @Call return from function macro
```

@ call_halt

@ Description: Halts the current call regardless of the state of buffers.
@ If the call is already halted, this has no effect.

@ Operational Description: The counter registers for the DMA engine are cleared. This will stop any memory accesses from occurring through the DMA and into the buffers.

@ Arguments: None

@ Return values: None

@ Local variables: None

@ Shared variables: None

@ Global Variables: None

@ Inputs: None

@ Outputs: SSC0 - the counter registers for DMA are cleared

@ Error Handling: None

@ Algorithms: None

@ Data Structures: None

@ Limitations: None

@ Registers Changed (besides ARM convention r0-r3): None

@ Known Bugs: None

@ Special notes: None

@ Revision History:

Name	Comment	Date
Will Werst	Initial version	Some lonely night around 6/10/17

.global call_halt

```
call_halt:
    mSTARTFNC                      @Call start function macro
    @Clear the counters in all DMA registers for audio
    mSET_HREG    SSC0_RNCR, 0        @Clear the counter register for the
                                    @next DMA buffer receive
    mSET_HREG    SSC0_RCR, 0        @Clear the counter register for the
                                    @buffer currently being received
    mSET_HREG    SSC0_TNCR, 0        @Clear the counter register for the
                                    @next DMA buffer transmit
```

```

mSET_HREG    SSC0_TCR, 0          @Clear the counter register for the
                                  @buffer currently being transmitted
mRETURNFNC

@ update_rx
@
@ Description: Takes a pointer, and either uses it and returns true, or
@               discards it and returns false.
@
@ Operational Description: The next counter register is pulled from
@                           the DMA engine and compared to 0, to see
@                           if the next register in DMA is empty. If
@                           it is, the new register is added to the
@                           DMA engine, and true is returned. Else,
@                           false is returned.
@
@ Arguments: r0 - pointer to new record buffer
@
@ Return values: bool - true if passed buffer is used, else false.
@
@ Local variables:
@
@ Shared variables:
@
@ Global Variables:
@
@ Inputs: SSC0 - sets up DMA receive
@
@ Outputs: None
@
@ Error Handling: None
@
@ Algorithms: None
@
@ Data Structures: None
@
@ Limitations: None
@
@ Registers Changed (besides ARM convention r0-r3): None
@
@ Known Bugs: None
@
@ Special notes: None
@
@ Revision History:
@ Name           Comment           Date
@ Will Werst     Initial version  Some lonely night around 6/10/17

.global update_rx
update_rx:
    mSTARTFNC          @Call start function macro
    mLOADTOREG r1, SSC0_RNCR   @Load the length of the next receive
                                @buffer currently queued up
    CMP    r1, #0           @Check if next receive buffer is empty
    LDRNE  r1, =FALSE        @If memory is not empty
                            @Post-demo comment: I'm pretty sure this
                            @should have been r0, not sure why this
                            @worked
    BNE    endUpdate_RX    @return false since new buffer not needed
    @BEQ    rx_empty        @Call return function macro
rx_empty:
    mSTOREFROMREG r0, r1, SSC0_RNPR  @Store r0 (next pointer) into next
                                    @pointer register
    mSET_HREG    SSC0_RNCR, (AUDIO_BUflen / 2) - 1 @Store buffer length in half-words
    LDR    r0, =TRUE          @Return success

```

```
endUpdate_RX:
    mRETURNFNC
```

```
@ update_tx
@
@ Description: Takes a transmit buffer pointer, and either uses it and returns
@               true, or discards it and returns false.
@
@ Operational Description: The next counter register is pulled from
@                           the DMA engine and compared to 0, to see
@                           if the next register in DMA is empty. If
@                           it is, the new register is added to the
@                           DMA engine, and true is returned. Else,
@                           false is returned.
@
@ Arguments: r0 - pointer to new transmit buffer
@
@ Return values: bool - true if passed buffer is used, else false.
@
@ Local variables: None
@
@ Shared variables: None
@
@ Global Variables: None
@
@ Inputs: None
@
@ Outputs: SSC0 - sets up DMA transmit
@
@ Error Handling: None
@
@ Algorithms: None
@
@ Data Structures: None
@
@ Limitations: None
@
@ Registers Changed (besides ARM convention r0-r3): None
@
@ Known Bugs: None
@
@ Special notes: None
@
@ Revision History:
@ Name           Comment          Date
@ Will Werst     Initial version Some lonely night around 6/10/17
```

```
.global update_tx
update_tx:
    mSTARTFNC
    mLOADTOREG r1, SSC0_TNCR
    CMP r1, #0
    LDRNE r1, =FALSE
                                @Check if next transmit buffer is empty
                                @If memory is not empty
                                @Post-demo comment: I'm pretty sure this
                                @should have been r0, not sure why this
                                @worked
    BNE endUpdate_TX
    @BEQ tx_empty
tx_empty:
    PUSH {r0-r3}
    LDR r1, =(AUDIO_BUFLEN - 2)
    LDR r2, =AUDIO_VOLUME
    BL setVolume
    POP {r0-r3}
    mSTOREFROMREG r0, r1, SSC0_TNPR
                                @Store registers to free up for temp
                                @Load buffer length
                                @Load the volume setpoint
                                @Set volume
                                @Restore register
                                @Save next transmit register
```

```
mSET_HREG    SSC0_TNCR,   (AUDIO_BUflen / 2) - 1 @Save length of next transmit
                                         @Register in half-words
    LDR      r0,      =TRUE                  @Return true
endUpdate_TX:
    mRETURNFNC
```

@ setVolume

@

@ Description: Goes through the transmit buffer and sets the volume bits

@

@ Operational Description: The transmit buffer is looped over in reverse, and
each byte is OR-masked with the volume, and saved back
in-place in the buffer.

@

@

@ Arguments: r0 - pointer to transmit buffer to set volume for

r1 - length of transmit buffer in bytes

r2 - volume, encoded as the bits to preserve in each byte

@ Return values: None

@

@ Local variables: None

@

@ Shared variables: None

@

@ Global Variables: None

@

@ Inputs: None

@

@ Outputs: None

@

@ Error Handling: None

@

@ Algorithms: None

@

@ Data Structures: None

@

@ Limitations: None

@

@ Registers Changed (besides ARM convention r0-r3): None

@

@ Known Bugs: None

@

@ Special notes: None

@

@ Revision History:

Name	Comment	Date
------	---------	------

Will Werst	Initial version	Some lonely night around 6/10/17
------------	-----------------	----------------------------------

setVolume:

mSTARTFNC

updateValue:

LDRH r3, [r0,r1]	@Get byte of audio
ORR r3, r3, r2	@Set the high bits for volume control
STRH r3, [r0,r1]	@Store byte of audio
SUB r1, #2	@Decrement to next byte
CMP r1, #0	@Check if at last byte
BGE updateValue	@If not, continue
mRETURNFNC	@Return

@ audioDemo

@

@ Description: Audio is looped back from the microphone to the speaker
continuously

@

@ Operational Description: Five buffers are looped through, starting with receive as buffer 1 and transmit as buffer 3. The loop is unrolled, and the loop has no exit condition.

@ Arguments: None

@ Return values: None (never returns)

@ Local variables: Buf[1..5] - buffers for storing audio data

@ Shared variables: None

@ Global Variables: None

@ Inputs: None

@ Outputs: None

@ Error Handling: None

@ Algorithms: None

@ Data Structures: Circular buffer

@ Limitations: Loop is unrolled, and the buffers are defined separately rather than as an array. Changing buffer count is not trivial.

@ Registers Changed (besides ARM convention r0-r3): None

@ Known Bugs: None

@ Special notes: None

@ Revision History:

Name	Comment	Date
Will Werst	Initial version	Some lonely night around 6/10/17

```
.global audioDemo
audioDemo:
    mSTARTFNC
loopAudioDemo:
    Bufl_rx:
        LDR      r0, =Buf1
        BL       update_rx
        CMP      r0, #TRUE
        BNE     Bufl_rx

        LDR      r0, =Buf3
        BL       update_tx

Buf2_rx:
    LDR      r0, =Buf2
    BL       update_rx
    CMP      r0, #TRUE
    BNE     Buf2_rx

    LDR      r0, =Buf4
    BL       update_tx

Buf3_rx:
    LDR      r0, =Buf3
    BL       update_rx
    CMP      r0, #TRUE
    BNE     Buf3_rx
```

```
LDR      r0, =Buf5
BL      update_tx

Buf4_rx:
LDR      r0, =Buf4
BL      update_rx
CMP r0, #TRUE
BNE Buf4_rx

LDR      r0, =Buf1
BL      update_tx

Buf5_rx:
LDR      r0, =Buf5
BL      update_rx
CMP r0, #TRUE
BNE Buf5_rx

LDR      r0, =Buf2
BL      update_tx

B      loopAudioDemo
mRETURNFNC

.data

.balign 4
Buf1:      @Audio buffer 1
    .skip 256
Buf2:      @Audio buffer 2
    .skip 256
Buf3:      @Audio buffer 3
    .skip 256
Buf4:      @Audio buffer 4
    .skip 256
Buf5:      @Audio buffer 5
    .skip 256

.end
```

```

@ Description: Defines register values used by the NHDC12832 Display driver code
@ Revision History:
@ Name           Comment           Date
@ Will Werst    Initial version  Some lonely night around 6/10/17
@ Will Werst    Comment          October 2017

@Pin definitions
.equ   DISP_MOSI,   1           @MOSI pin is A1
.equ   DISP_SPCK,   2           @Clock pin is A2
.equ   DISP_CS,     3           @Chip Select pin is A3
.equ   DISP_A0,     4           @Mode select pin is A4
.equ   DISP_BCKLIGHT, 5        @Backlight pin is A5
.equ   DISP_RST,    6           @Reset pins is A6

@SPI Status register bit definitions
.equ   SPI_SR_TXBUFE, 0x80

@SPI Handler definitions
.equ   COM_QUEUE_LENGTH, 16

@Register definitions

@ 0000 0000 0000 0000 0000 0000 ---- ---- Reserved
@ ----- ----- ----- ----- 1--- ----- SWRST
@ ----- ----- ----- ----- -000 00--
@ ----- ----- ----- ----- --10 Disable
@ 0000 0000 0000 0000 0000 0000 1000 0010
.equ   SPI_CR_RESET, 0x00000082

@ 0000 0000 0000 0000 0000 0000 ---- ---- Reserved
@ ----- ----- ----- ----- 0--- ----- SWRST
@ ----- ----- ----- ----- -000 00--
@ ----- ----- ----- ----- --01 Enable
@ 0000 0000 0000 0000 0000 0000 0000 0001
.equ   SPI_CR_EN, 0x00000001

@ 0000 0000 0000 0000 0000 0000 ---- ---- Reserved
@ ----- ----- ----- ----- 0--- ----- SWRST
@ ----- ----- ----- ----- -000 00--
@ ----- ----- ----- ----- --10 Disable
@ 0000 0000 0000 0000 0000 0000 0000 0010
.equ   SPI_CR_DIS, 0x00000002

@ 0000 0000 ----- ----- ----- DLYBCS: 0
@ ----- 0000 ----- ----- Reserved
@ ----- 1110 ----- ----- PCS: NPCS0 is where display is
@ ----- 0000 0000 ----- Reserved
@ ----- 0--- ----- 0--- Local Loopback: Disabled
@ ----- -00- ----- Reserved
@ ----- -1--- Mode fault detection: Disabled
@ ----- 1--- DIV32: SPI clocks at MCK/32
@ ----- -0-- PCSDEC: Chip selects directly connected
@ ----- -0- PS: Fixed Peripheral select
@ ----- -1 MSTR: SPI is in Master mode

```

```

@ 0000 0000 0000 1110 0000 0000 0001 1001
.equ SPI_MR_VAL, 0x0000E0019

@ 0000 0000 ---- ---- ---- ---- DLYBCT: 0
@ ---- ---- 0000 0000 ---- ---- DLYBS: 0
@ ---- ---- ---- 0000 0100 ---- SCBR: SPCK Baudrate = MCK/ (2*4) = 5.5 MHz. Device
max is 20 MHz
@ ----- 0000 ---- BITS: 8 bits
@ ----- 00-- Reserved
@ ----- --0- NCPHA: 1
@ ----- ---1 CPOL: 1
@ 0000 0000 0000 0000 1111 0100 0000 0001
.equ SPI_CSR0_VAL, 0x000000401

@ 0000 0000 0000 0000 0000 0000 ---- Reserved
@ ----- 1000 0000 Only enable ENDTX
@ 0000 0000 0000 0000 0000 0010 0000
.equ SPI_IER_VAL, 0x000000080

@ 0000 0000 0000 0000 0000 00-- Reserved
@ ----- --01 ----- Enable Transmit
@ ----- 0000 00-- Reserved
@ ----- --10 ----- Disable Receive (no receiving for display)
@ 0000 0000 0000 0000 0001 0000 0010

.equ SPI_DMA_ENABLE, 0x00000101

@ 0000 0000 0000 0000 0000 00-- Reserved
@ ----- --10 ----- Disable Transmit
@ ----- 0000 00-- Reserved
@ ----- --10 ----- Disable Receive
@ 0000 0000 0000 0000 0001 0000 0010

.equ SPI_DMA_DISABLE, 0x00000202

@ 0000 0000 0000 0000 0000 0--- Reserved
@ ----- -11- SCRTYPE: Positive edge
@ ----- --0 0--- Reserved
@ ----- -010 Priority: 2
@ 0000 0000 0000 0000 0000 0110 0010
.equ AIC_SMR13_VAL, 0x00000062

@ -----

```

@State definitions for the display redrawing

```

.equ STATE_COMMANDS, 0
.equ STATE_DATA, 1

```

@NHD-C12832 Definitions

```

.equ NUM_PAGES, 4
.equ NUM_COLS, 128
.equ NHD_ON, 0xAF      @Enable display command
.equ NHD_OFF, 0xAE     @Disable display command
.equ NHD_RMW, 0xE0      @Read-modify-write command
.equ NHD_RESET, 0xE2    @Reset command
.equ NHD_PAGE_PREF, 0xB0 @Prefix for page address set command
.equ NHD_COLU_PREF, 0x10 @Prefix for upper column address set command
.equ NHD_COLL_PREF, 0x00 @Prefix for lower column address set command

```

@ASCII Definitions

```
.equ    ASCII_DOT,      0x2E      @ '.' character
.equ    ASCII_NULL,     0x00      @ ASCII null termination

@Miscellaneous definitions
.equ    NUM_OCTETS_IP,  4
```

```
@Done
@Display.s

@ Description: Contains code for controlling the display component of
@ the EE52 VoIP Project
@ Table of Contents:
- display_init: Call to initialize the shared variables and peripherals
    for interfacing with the C12832 Display
- display_memory_addr: Displays the passed memory address on display
- display_IP: Displays the passed IP address on display
- display_status: Displays the passed status on display
- redraw: Redraws the display buffer
- queueDisplayCommand: Queues a command to send to the display
- setBacklight: Sets the backlight on or off
- displayHandler: Handles setting up display DMA stream and also
    sending commands to display
```

@ Revision History:

Name	Comment	Date
Will Werst	Initial version	Some lonely night around 6/10/17
Will Werst	Comment	October 2017

```
.include "macro.inc"
.include "display.inc"
.include "pio.inc"
.include "at91rm9200.inc"
.include "system.inc"
.include "interfac.inc"
```

```
.arm
.text
```

```
@ display_init
@ Description: Initializes the display
@ Operational Description: The PIO pins are initialized,
    and then a series of commands
    are queued up to initialize the
    display. Then, the display handler
    is installed and kickstarted by starting
    the display output DMA engine.
```

@ Arguments: None

@ Return values: None

@ Local variables: None

@ Shared variables: None

@ Global Variables: None

@ Inputs: None

@ Outputs: None

@ Error Handling: None

@ Algorithms: None

```

@ Data Structures: None
@ Limitations: None
@ Registers Changed (besides ARM convention r0-r3): None
@ Known Bugs: None
@ Special notes: None
@ Revision History:
@ Name           Comment           Date
@ Will Werst    Initial version  Some lonely night around 6/10/17

.global display_init
display_init:
    mSTARTFNC

    @First, initialize the PIO pins
    mSET_HREG    PMC_PCER,      (1 << 13)
    LDR         r0,  =0xE          @MOSI, SPCK, NPCS0
    LDR         r1,  =PIO_A
    LDR         r2,  =(PIO_PERA | PIO_OUTPUT)
    BL          configPIOPin

    LDR         r0,  =(1 << DISP_A0) | (1 << DISP_BCLIGHT) | (1 << DISP_RST)
    LDR         r1,  =PIO_A
    LDR         r2,  =(PIO_NORM | PIO_OUTPUT)
    BL          configPIOPin

    mSET_HREG PIOA_CODR,      (1 << DISP_RST) @Reset display

    @Need to wait for the display to reset, this loop
    @introduces a delay to allow the display to reset
    LDR r0, =0xFFFF
count:
    SUB r0, #1
    CMP r0, #0
    BNE count
    @Done with delay

    mSET_HREG PIOA_SODR,      (1 << DISP_RST) @Stop reset signal to display

    @Set backlight on
    LDR         r0, =TRUE
    BL          setBacklight

    @Enqueue all of the commands for initializing display now
    LDR         r0, =NHD_RESET
    BL          queueDisplayCommand
    @LDR        r0, =NHD_ON
    @BL         queueDisplayCommand
    @LDR        r0, =0x2F
    @BL         queueDisplayCommand
    @LDR        r0, =0x26
    @BL         queueDisplayCommand
    @LDR        r0, =NHD_RMW
    @BL         queueDisplayCommand
    @LDR        r0, =0xA4
    @BL         queueDisplayCommand
    @LDR        r0, =0x81
    @BL         queueDisplayCommand
    @LDR        r0, =0x2F
    @BL         queueDisplayCommand

```

```

LDR    r0, =0xAE
BL     queueDisplayCommand
LDR    r0, =0xA2
BL     queueDisplayCommand

LDR    r0, =0xA0
BL     queueDisplayCommand
LDR    r0, =0xC8
BL     queueDisplayCommand

LDR    r0, =0x22
BL     queueDisplayCommand
LDR    r0, =0x2F
BL     queueDisplayCommand

LDR    r0, =0x40
BL     queueDisplayCommand
LDR    r0, =0xAF
BL     queueDisplayCommand

LDR    r0, =0x81
BL     queueDisplayCommand
LDR    r0, =0x17
BL     queueDisplayCommand

LDR    r0, =0xA6
BL     queueDisplayCommand

@Setup SPI
mSET_HREG  SPI_CR, SPI_CR_RESET
mSET_HREG  SPI_MR, SPI_MR_VAL
mSET_HREG  SPI_CSR0, SPI_CSR0_VAL

@Install interrupt for when DMA finished to display
mSET_HREG  AIC_SVR13, displayHandler
mSET_HREG  AIC_SMR13, AIC_SMR13_VAL
mSET_HREG  AIC_IECR, (1 << 13)

@Finish setting up SPI and enable DMA interrupt
mSET_HREG  SPI_CR, SPI_CR_EN
mSET_HREG  SPI_PTCR, SPI_DMA_ENABLE @Enable the DMA controller
mSET_HREG  SPI_IER, SPI_IER_VAL
mRETURNFNC

@ display_memory_addr
@
@ Description: Displays the passed memory address on the display.
@
@ Operational Description: registers 4-7 are pushed to stack so they
can be used. The string is composed by looking
up each character in a hexToAscii table.
After the string is finished being written,
the buffers are redrawn using the redraw
function, and then the method returns.
The display is redrawn the next time the DMA
engine writes the buffer to the display
@

@ Arguments: r0 - unsigned int of address to display
@
@ Return values: None
@
@ Local variables: None
@
@ Shared variables: TextMessageR2[W] - The message displayed on 2nd line
is replaced with the memory address

```

```

@                                         string representation generated
@                                         by this function.

@ Global Variables: None
@ Inputs: None
@ Outputs: None
@ Error Handling: None
@ Algorithms: None
@ Data Structures: None
@ Limitations: None
@ Registers Changed (besides ARM convention r0-r3): None
@ Known Bugs: None
@ Special notes: None
@ Revision History:
@ Name           Comment          Date
@ Will Werst    Initial version  Some lonely night around 6/10/17

```

```

.global display_memory_addr
display_memory_addr:
    mSTARTFNC

    PUSH    {r4-r7}
    LDR r5, =TextMessageR2          @String to write to
    LDR r6, =0                      @ASCII string position

    MOV r7, r0                      @Store memory address to use later
    @Get tens digit
    LDR r1, =10
    MOV r0, r7
    BL divide
    LDR r1, =hexToASCII
    LDRB r0, [r1, r0]
    STRB r0, [r5, r6]
    ADD r6, #1

    @Remove tens digit value from memory address
    LDR r1, =10
    MOV r0, r7
    BL mod
    MOV r7, r0                      @r7 now contains original address with tens digit 0

    @Get ones digit
    LDR r1, =hexToASCII
    LDRB r0, [r1, r0]
    STRB r0, [r5, r6]
    ADD r6, #1

    @Add null termination to string
    LDRB r0, =ASCII_NULL
    STRB r0, [r5, r6]

    BL redraw                       @Redraw the buffer

    POP {r4-r7}

```

mRETURNFNC

```
@ display_IP
@
@ Description:
@
@ Operational Description: registers 4-7 are pushed to stack so they
@ can be used. The octets are then extracted from
@ the input IP address to be displayed, and each
@ octet is pushed to the stack. Then, each octet
@ is popped off the stack in a loop and added to
@ the 2nd row on display string.
@ Finally, the redraw method is used to update
@ the display buffers.
@

@ Arguments: None
@
@ Return values: None
@
@ Local variables: None
@
@ Shared variables: TextMessageR2[W] - The message displayed on 2nd line
@ is replaced with the IP address
@ string representation generated
@ by this function.
@

@ Global Variables: None
@
@ Inputs: None
@
@ Outputs: None
@
@ Error Handling: None
@
@ Algorithms: None
@
@ Data Structures: None
@
@ Limitations: None
@
@ Registers Changed (besides ARM convention r0-r3): None
@
@ Known Bugs: None
@
@ Special notes: None
@
@ Revision History:
@ Name Comment Date
@ Will Werst Initial version Some lonely night around 6/10/17
```

```
.global display_IP
display_IP:
    mSTARTFNC

    PUSH {r4-r7}
    @Get 4th octet
    AND r1, r0, #0xFF
    LSR r0, #8
    PUSH {r1}

    @Get 3rd octet
    AND r1, r0, #0xFF
    LSR r0, #8
    PUSH {r1}

    @Get 2nd octet
```

```

AND r1, r0, #0xFF
LSR r0, #8
PUSH {r1}

@Get 1st octet
AND r1, r0, #0xFF
LSR r0, #8
PUSH {r1}

LDR r4, =NUM_OCTETS_IP
LDR r5, =TextMessageR2          @String to write to
LDR r6, =0                      @ASCII string position
OctetToASCII:
POP {r0}                         @Get next octet
MOV r7, r0                        @Store octet so can operate on it and recover later

@Get hundreds digit
LDR r1, =100
MOV r0, r7
BL divide
LDR r1, =hexToASCII
LDRB r0, [r1, r0]
STRB r0, [r5, r6]
ADD r6, #1

@Remove hundreds digit value from octet
LDR r1, =100
MOV r0, r7
BL mod
MOV r7, r0                        @r7 now contains original octet with hundreds digit 0

@Get tens digit
LDR r1, =10
MOV r0, r7
BL divide
LDR r1, =hexToASCII
LDRB r0, [r1, r0]
STRB r0, [r5, r6]
ADD r6, #1

@Remove tens digit value from octet
LDR r1, =10
MOV r0, r7
BL mod
MOV r7, r0                        @r7 now contains original octet with hundreds and tens digit 0

@Get ones digit
LDR r1, =hexToASCII
LDRB r0, [r1, r0]
STRB r0, [r5, r6]
ADD r6, #1

@Add '.' character to terminate string
LDRB r0, =ASCII_DOT
STRB r0, [r5, r6]
ADD r6, #1

SUB r4, #1
CMP r4, #0
BHI OctetToASCII

@Add null termination to string
LDRB r0, =ASCII_NULL
SUB r6, #1                          @Left a '.' character at end, will overwrite with null.

```

```

STRB    r0, [r5, r6]

BL redraw

POP {r4-r7}
mRETURNFNC

@ display_status
@
@ Description: Displays the passed display status
@
@ Operational Description: The string corresponding to the passed display status
@ is looked up and rendered to the display buffer. If
@ the status is STATUS_IDLE, the rest of the display
@ is cleared.
@
@ Arguments: r0 - status to display
@
@ Return values: None
@
@ Local variables: None
@
@ Shared variables: TextMessageR1[W] - The message displayed on 1nd line
@ is replaced with the status
@ string representation generated
@ by this function.
@
@ Global Variables: None
@
@ Inputs: None
@
@ Outputs: None
@
@ Error Handling: None
@
@ Algorithms: None
@
@ Data Structures: None
@
@ Limitations: None
@
@ Registers Changed (besides ARM convention r0-r3): None
@
@ Known Bugs: None
@
@ Special notes: None
@
@ Revision History:
@ Name           Comment          Date
@ Will Werst     Initial version  Some lonely night around 6/10/17

```

```

.global display_status
display_status:
    mSTARTFNC
    CMP    r0, #STATUS_IDLE      @Check if status is idle
    LDREQ   r1, =TextMessageR2  @And if so, clear the display
    LDREQ   r2, =ASCII_NULL
    @Clear the 2nd row of display
    STREQB r2, [r1]

    @Load the status message to TextMessageR1
    LDR    r1, =StatusMessages
    LDR    r1, [r1, r0, LSL #2]
    mSTOREFROMREG r1, r0, TextMessageR1

```

```

@Redraw the display
BL  redraw
mRETURNFNC

@ redraw
@

@ Description: The display buffer is redrawn. Call
@               after changing TextMessageR1 or TextMessageR2.
@

@ Operational Description: The display is cleared using the clear_displaybuffer
@ C method in displayrenderer.c. Then, the 1st and 2nd
@ row are rendered using the render_displaybuffer
@ C method in displayrenderer.c
@

@ Arguments: None
@

@ Return values: None
@

@ Local variables: None
@

@ Shared variables: None
@

@ Global Variables: None
@

@ Inputs: None
@

@ Outputs: None
@

@ Error Handling: None
@

@ Algorithms: None
@

@ Data Structures: None
@

@ Limitations: None
@

@ Registers Changed (besides ARM convention r0-r3): None
@

@ Known Bugs: None
@

@ Special notes: None
@

@ Revision History:
@ Name           Comment          Date
@ Will Werst    Initial version  Some lonely night around 6/10/17

.global redraw
redraw:
    mSTARTFNC
    LDR r0, =DispBuffer
    LDR r1, =(NUM_COLS*NUM_PAGES)
    BL  clear_displaybuffer

    LDR r0, =TextMessageR1
    LDR r0, [r0]
    LDR r1, =DispBuffer
    LDR r2, =NUM_COLS
    BL  render_displaybuffer

    LDR r0, =TextMessageR2
    LDR r1, =(DispBuffer+NUM_COLS)
    LDR r2, =NUM_COLS
    BL  render_displaybuffer

```

mRETURNFNC

```

@ queueDisplayCommand
@
@ Description: queues the command passed in r0 to be sent to the display.
@
@ Operational Description: Interrupts are disabled since this accesses
@                           the command queue which is also accessed in
@                           the displayHandler. The command is enqueued if
@                           there is space. If the command was enqueued
@                           successfully, the method exits with TRUE, else FALSE.
@
@

@ Arguments: r0 - command to send over SPI
@
@ Return values: r0 - TRUE if added successfully, FALSE if not added.
@
@ Local variables: None
@
@ Shared variables: CommandQueueSize[RW] - read to check queue size,
@                   and incremented after adding queue element.
@                   ActiveCommandQueue[W] - command is enqueued.
@
@ Global Variables: None
@
@ Inputs: None
@
@ Outputs: None
@
@ Error Handling: If queue is full, the method exits with FALSE
@
@ Algorithms: None
@
@ Data Structures: Queue
@
@ Limitations: None known
@
@ Registers Changed (other than r0-r3): None
@
@ Known Bugs: None known
@
@ Special notes: None
@
@ Revision History:
@ Name           Comment          Date
@ Will Werst    Initial version  6/22/2017

```

queueDisplayCommand:

```

    mSTARTFNC
    mSTARTCRITCODE
    mLOADTOREG r1, CommandQueueSize
    CMP r1, #COM_QUEUE_LENGTH
    BLO addCommandToQ
    @B CommandQFull

```

CommandQFull:

```

    LDR r0, =FALSE
    B sDCEndCritCode

```

addCommandToQ:

```

    LDR r2, =ActiveCommandQueue
    LDR r2, [r2]
    STRB r0, [r2,r1]
    ADD r1, #1
    mSTOREFROMREG r1, r0, CommandQueueSize
    LDR r0, =TRUE

```

sDCEndCritCode:

```
mENDCRITCODE                                @Exit critical code, r7 used by this macro

mRETURNFNC

@ setBacklight
@
@ Description: Enables or disables the backlight.
@
@ Operational Description: The backlight is set on or off.
@
@ Arguments: r0 - TRUE if backlight should be enabled, otherwise backlight disabled.
@
@ Return values: None
@
@ Local variables: None
@
@ Shared variables: None
@
@ Global Variables: None
@
@ Inputs: None
@
@ Outputs: Backlight of display
@
@ Error Handling: None
@
@ Algorithms: None
@
@ Data Structures: None
@
@ Limitations: None known
@
@ Registers Changed (besides r0-r3): None
@
@ Known Bugs: None known
@
@ Special notes: None
@
@ Revision History:
@ Name           Comment          Date
@ Will Werst    Initial version  6/22/2017
```

```
setBacklight:
  mSTARTFNC
    CMP      r0, #TRUE          @Check which action to take
    BEQ      backlightOn        @if true, enable backlight
    BNE      backlightOff       @else, disable backlight
backlightOn:
  mSET_HREG  PIOA_SODR, (1 << DISP_BCKLIGHT)
  B        endSetBacklight
backlightOff:
  mSET_HREG  PIOA_CODR, (1 << DISP_BCKLIGHT)
  B        endSetBacklight
endSetBacklight:
  mRETURNFNC
```

```
@ displayHandler
@
@ Description: Handles sending commands to the display
@
@ Operational Description: This interrupt routine handles a state machine that
@                         updates the display. This state machine has two
@                         states: Commands, and Data. The different states
@                         are handled as follows:
@                         Commands: The ActiveCommandQueue is switched to the other queue.
```

The command to

@ switch to the next page of data is enqueued if possible.
 @ If there is space for this command, then the state
 transitions
 @ to Data next, and the current page is updated to the
 next page, else the state stays at Commands.
 @ The display is transitioned to command mode (DISP_A0
 pin is set to 0 in PIO). Then, the DMA controller
 @ is set to transmit all commands in the now-inactive
 command queue.
 @ Data: The DMA controller is setup to transmit the next page of data
 from DispBuffer.

@

@

@

@ Arguments: None

@

@ Return values: None

@

@ Local variables: None

@

@ Shared variables: ActiveCommandQueue[RW] - Read from to send commands, and toggled back and forth between

queue 1 and queue 2.

@

@

@ displayHandlerState[RW] - Checked to determine whether sending data or

commands.

@ displayCurPage[RW] - Checked to determine which page in display buffer to

send next.

@ displayBuffer[R] - Data is read from here to send to display

@

@ Global Variables: None

@

@ Inputs: None

@

@ Outputs: SPI to display

@

@ Error Handling: None

@

@ Algorithms: None

@

@ Data Structures: Queues

@

@ Limitations: None

@

@ Registers Changed: None

@

@ Known Bugs: None known

@

@ Special notes: None

@

@ Revision History:

Name	Comment	Date
Will Werst	Initial version	6/22/2017

Name	Comment	Date
Will Werst	Initial version	6/22/2017

Name	Comment	Date
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Will Werst	Initial version	6/22/2017

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```

    CMP r0, #STATE_DATA
    BEQ stateData
    B endDisplayHandler
stateCommand:
    LDR r0, =(NHD_COLL_PREF | 0x0)
    BL queueDisplayCommand
    LDR r0, =(NHD_COLU_PREF | 0x0)
    BL queueDisplayCommand
    mLOADTOREG r0, displayCurPage
    ORR r0, r0, #NHD_PAGE_PREF
    BL queueDisplayCommand
    CMP r0, #TRUE
    LDREQ r0, =STATE_DATA
    LDREQ r1, =displayHandlerState
    STREQ r0, [r1]
    LDR r0, =ActiveCommandQueue
    LDR r1, [r0]

    PUSH {r1}
    LDR r2, =CommandQueue1

    CMP r1, r2
    LDREQ r2, =CommandQueue2

    STR r2, [r0]

    @Setup DMA for sending commands
    mSET_HREG PIOA_CODR, (1 << DISP_A0)
    POP {r1}
    mSTOREFROMREG r1, r0, SPI_TPR
    mLOADTOREG r1, CommandQueueSize
    mSTOREFROMREG r1, r0, SPI_TCR

    LDR r1, =CommandQueueSize
    queue
    LDR r0, =0
    STR r0, [r1]
    B endDisplayHandler
stateData:
    @Setup DMA for sending data
    mSET_HREG PIOA_SODR, (1 << DISP_A0)
    mLOADTOREG r0, displayCurPage

    LDR r1, =NUM_COLS
    MUL r0, r0, r1
    LDR r1, =DispBuffer
    ADD r0, r0, r1
    mSTOREFROMREG r0, r2, SPI_TPR
    LDR r1, =NUM_COLS
    mSTOREFROMREG r1, r2, SPI_TCR

    LDR r0, =STATE_COMMANDS
    LDR r1, =displayHandlerState
    STR r0, [r1]
    mLOADTOREG r0, displayCurPage

    ADD r0, #1
    CMP r0, #NUM_PAGES
    LDREQ r0, =0
    mSTOREFROMREG r0, r1, displayCurPage
    @B endDisplayHandler
endDisplayHandler:
    mSET_HREG SPI_CR, SPI_CR_EN

```

@Should never hit this state

@Add the page address set command

@Check if command added
@If it was, transition states
@Else, the state is left as STATE_COMMANDS

@Load the address of activeCommandQueue pointer
@Dereference activeCommandQueue to get
@pointer to active queue's start.
@Save pointer to current active queue for later.
@Load pointer to CommandQueue1 to
@compare to active command queue
@Compare the queues
@If active queue is 1, switch to queue 2.
@Else, queue 2 is active and want to switch to
queue 1
@switch to the new queue

@Clear A0 (sending commands)
@Get the queue of commands to send
@Set pointer to now inactive command queue
@Set count of bytes to send to command queue size

@clear command queue size since now using different

@Set A0 (sending data)
@Calculate the pointer to the current
@buffer page

@Set pointer to display buffer

@Set length of DMA

@Transition states

@Calculate the pointer to the current
@buffer page

```

mSET_HREG    SPI_PTCR,      SPI_DMA_ENABLE  @Enable the DMA controller
mRETURNINT

.data
.balign 4

@Pointer to null-terminated ASCII string
displayHandlerState:
    .word STATE_COMMANDS
displayUpdated:
    .word TRUE
displayCurPage:
    .word 0

hexToASCII:          @Table to map hex bytes to ASCII characters
    .byte 0x30
    .byte 0x31
    .byte 0x32
    .byte 0x33
    .byte 0x34
    .byte 0x35
    .byte 0x36
    .byte 0x37
    .byte 0x38
    .byte 0x39
    .byte 0x41
    .byte 0x42
    .byte 0x43
    .byte 0x44
    .byte 0x45
    .byte 0x46

.balign 4
TextMessageR1:
    .word St_IDLE_MES
TextMessageR2:
    .skip 22           @Max 21 characters on display plus null termination
.balign 4
StatusMessages:
    .word St_IDLE_MES
    .word St_OFFHOOK_MES
    .word St_RINGING_MES
    .word St_CONNECTING_MES
    .word St_CONNECTED_MES
    .word St_SET_IP_MES
    .word St_SET_SUBNET_MES
    .word St_SET_GATEWAY_MES
    .word St_MEM_SAVE_MES
    .word St_MEM_RECALL_MES
    .word St_RECALLED_MES
    .word St_ILLEGAL_MES

St_IDLE_MES:
    .asciz "Idle"
St_OFFHOOK_MES:
    .asciz "Off Hook"
St_RINGING_MES:
    .asciz "Ringing"
St_CONNECTING_MES:
    .asciz "Connecting"
St_CONNECTED_MES:
    .asciz "Connected"
St_SET_IP_MES:
    .asciz "Set IP"
St_SET_SUBNET_MES:

```

```
.asciz "Set Subnet"
St_SET_GATEWAY_MES:
    .asciz "Set Gateway"
St_MEM_SAVE_MES:
    .asciz "Memory Save"
St_MEM_RECALL_MES:
    .asciz "Memory Recall"
St_RECALLED_MES:
    .asciz "Recalled Message"
St_ILLEGAL_MES:
    .asciz "Illegal Message"
```

```
CommandQueueSize:
    .word 0x00000000
ActiveCommandQueue:
    .word CommandQueue1
```

```
CommandQueue1:
    .skip (COM_QUEUE_LENGTH)
CommandQueue2:
    .skip (COM_QUEUE_LENGTH)
DispBuffer:
    .skip (NUM_COLS*NUM_PAGES)
.balign 4
.end
```

```

//Done
/*********************************************************************
/*
     Display Renderer
     5x7 Dot Matrix Codes
     taken from Digital Oscilloscope Project
     EE/CS 52
*/
*****
```

/*
This file contains the render_displaybuffer function. It takes as input a pointer to the start of the display buffer to write to, and an ASCII string to render there

Revision History

5/27/08	Glen George	Initial revision of ascii_patterns (from 3/10/95 version of char57.asm).
6/10/17	Will Werst	Initial code

*/

```

const unsigned char ascii_char_patterns[] = {

    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* UNUSED (0x00) */ 
    0x04, 0x0E, 0x15, 0x04, 0x04, 0x04, 0x04, /* up arrow (0x01) */ 
    0x04, 0x04, 0x04, 0x04, 0x15, 0x0E, 0x04, /* down arrow (0x02) */ 
    0x00, 0x04, 0x08, 0x1F, 0x08, 0x04, 0x00, /* left arrow (0x03) */ 
    0x00, 0x11, 0x11, 0x11, 0x1B, 0x14, 0x10, /* greek u (mu) (0x04) */ 
    0x00, 0x04, 0x02, 0x1F, 0x02, 0x04, 0x00, /* right arrow (0x05) */ 
    0x00, 0x11, 0x0A, 0x04, 0x0A, 0x11, 0x00, /* multiply symbol (0x06) */ 
    0x00, 0x04, 0x00, 0x1F, 0x00, 0x04, 0x00, /* divide symbol (0x07) */ 
    0x04, 0x04, 0x1F, 0x04, 0x04, 0x00, 0x1F, /* plus/minus symbol (0x08) */ 
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* UNUSED (0x09) */ 
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* UNUSED (0x0A) */ 
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* UNUSED (0x0B) */ 
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* UNUSED (0x0C) */ 
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* UNUSED (0x0D) */ 
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* UNUSED (0x0E) */ 
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* UNUSED (0x0F) */ 
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* UNUSED (0x10) */ 
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* UNUSED (0x11) */ 
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* UNUSED (0x12) */ 
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* UNUSED (0x13) */ 
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* UNUSED (0x14) */ 
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* UNUSED (0x15) */ 
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* UNUSED (0x16) */ 
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* UNUSED (0x17) */ 
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* UNUSED (0x18) */ 
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* UNUSED (0x19) */ 
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* UNUSED (0x1A) */ 
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* UNUSED (0x1B) */ 
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* UNUSED (0x1C) */ 
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* UNUSED (0x1D) */ 
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* UNUSED (0x1E) */ 
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* UNUSED (0x1F) */ 
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, /* space (0x20) */ 
    0x04, 0x04, 0x04, 0x04, 0x04, 0x04, 0x04, /* ! */ 
    0x0A, 0x0A, 0x0A, 0x00, 0x00, 0x00, 0x00, /* " */ 
    0x0A, 0x0A, 0x1F, 0x0A, 0x1F, 0x0A, 0x0A, /* # */ 
    0x04, 0x0F, 0x14, 0x0E, 0x05, 0x1E, 0x04, /* $ */ 
    0x18, 0x19, 0x02, 0x04, 0x08, 0x13, 0x03, /* % */ 
    0x08, 0x14, 0x14, 0x08, 0x15, 0x12, 0x0D, /* & */ 
    0x0C, 0x0C, 0x08, 0x10, 0x00, 0x00, 0x00, /* ' */ 
    0x02, 0x04, 0x08, 0x08, 0x04, 0x02, 0x02, /* ( */ 
    0x08, 0x04, 0x02, 0x02, 0x02, 0x04, 0x08, /* ) */ 
    0x04, 0x15, 0x0E, 0x1F, 0x0E, 0x15, 0x04, /* * */ 
    0x00, 0x04, 0x04, 0x1F, 0x04, 0x04, 0x00, /* + */
```

0x00, 0x00, 0x00, 0x0C, 0x0C, 0x08, 0x10,	/* ,	*/
0x00, 0x00, 0x00, 0x1F, 0x00, 0x00, 0x00,	/* -	*/
0x00, 0x00, 0x00, 0x00, 0x00, 0x0C, 0x0C,	/* .	*/
0x00, 0x01, 0x02, 0x04, 0x08, 0x10, 0x00,	/* /	*/
0x0E, 0x11, 0x13, 0x15, 0x19, 0x11, 0x0E,	/* 0	*/
0x04, 0x0C, 0x04, 0x04, 0x04, 0x04, 0x0E,	/* 1	*/
0x0E, 0x11, 0x01, 0x0E, 0x10, 0x10, 0x1F,	/* 2	*/
0x0E, 0x11, 0x01, 0x06, 0x01, 0x11, 0x0E,	/* 3	*/
0x02, 0x06, 0x0A, 0x12, 0x1F, 0x02, 0x02,	/* 4	*/
0x1F, 0x10, 0x1E, 0x01, 0x01, 0x11, 0x0E,	/* 5	*/
0x06, 0x08, 0x10, 0x1E, 0x11, 0x11, 0x0E,	/* 6	*/
0x1F, 0x01, 0x02, 0x04, 0x08, 0x10, 0x10,	/* 7	*/
0x0E, 0x11, 0x11, 0x0E, 0x11, 0x11, 0x0E,	/* 8	*/
0x0E, 0x11, 0x11, 0x0F, 0x01, 0x02, 0x0C,	/* 9	*/
0x00, 0x0C, 0x0C, 0x00, 0x0C, 0x0C, 0x00,	/* :	*/
0x0C, 0x0C, 0x00, 0x0C, 0x08, 0x10,	/* ;	*/
0x02, 0x04, 0x08, 0x10, 0x08, 0x04, 0x02,	/* <	*/
0x00, 0x00, 0x1F, 0x00, 0x1F, 0x00, 0x00,	/* =	*/
0x08, 0x04, 0x02, 0x01, 0x02, 0x04, 0x08,	/* >	*/
0x0E, 0x11, 0x01, 0x02, 0x04, 0x00, 0x04,	/* ?	*/
0x0E, 0x11, 0x01, 0x0D, 0x15, 0x15, 0x0E,	/* @	*/
0x04, 0xA, 0x11, 0x11, 0x1F, 0x11, 0x11,	/* A	*/
0x1E, 0x09, 0x09, 0x0E, 0x09, 0x09, 0x1E,	/* B	*/
0x0E, 0x11, 0x10, 0x10, 0x10, 0x11, 0x0E,	/* C	*/
0x1E, 0x09, 0x09, 0x09, 0x09, 0x09, 0x1E,	/* D	*/
0x1F, 0x10, 0x10, 0x1C, 0x10, 0x10, 0x1F,	/* E	*/
0x1F, 0x10, 0x10, 0x1C, 0x10, 0x10, 0x10,	/* F	*/
0x0F, 0x10, 0x10, 0x13, 0x11, 0x11, 0x0F,	/* G	*/
0x11, 0x11, 0x11, 0x1F, 0x11, 0x11, 0x11,	/* H	*/
0x0E, 0x04, 0x04, 0x04, 0x04, 0x0E,	/* I	*/
0x01, 0x01, 0x01, 0x01, 0x11, 0x0E,	/* J	*/
0x11, 0x12, 0x14, 0x18, 0x14, 0x12, 0x11,	/* K	*/
0x10, 0x10, 0x10, 0x10, 0x10, 0x1F,	/* L	*/
0x11, 0x1B, 0x15, 0x15, 0x11, 0x11, 0x11,	/* M	*/
0x11, 0x19, 0x15, 0x13, 0x11, 0x11, 0x11,	/* N	*/
0x0E, 0x11, 0x11, 0x11, 0x11, 0x11, 0x0E,	/* O	*/
0x1E, 0x11, 0x11, 0x1E, 0x10, 0x10, 0x10,	/* P	*/
0x0E, 0x11, 0x11, 0x11, 0x15, 0x12, 0x0D,	/* Q	*/
0x1E, 0x11, 0x11, 0x1E, 0x14, 0x12, 0x11,	/* R	*/
0x0E, 0x11, 0x10, 0x0E, 0x01, 0x11, 0x0E,	/* S	*/
0x1F, 0x04, 0x04, 0x04, 0x04, 0x04,	/* T	*/
0x11, 0x11, 0x11, 0x11, 0x11, 0x0E,	/* U	*/
0x11, 0x11, 0x11, 0xA, 0x0A, 0x04, 0x04,	/* V	*/
0x11, 0x11, 0x11, 0x11, 0x15, 0x1B, 0x11,	/* W	*/
0x11, 0x11, 0xA, 0x04, 0x0A, 0x11, 0x11,	/* X	*/
0x11, 0x11, 0xA, 0x04, 0x04, 0x04, 0x04,	/* Y	*/
0x1F, 0x01, 0x02, 0x04, 0x08, 0x10, 0x1F,	/* Z	*/
0x0E, 0x08, 0x08, 0x08, 0x08, 0x0E,	/* [*/
0x00, 0x10, 0x08, 0x04, 0x02, 0x01, 0x00,	/* \	*/
0x0E, 0x02, 0x02, 0x02, 0x02, 0x0E,	/*]	*/
0x04, 0xA, 0x11, 0x00, 0x00, 0x00, 0x00,	/* ^	*/
0x00, 0x00, 0x00, 0x00, 0x00, 0x1F,	/* _	*/
0x06, 0x06, 0x04, 0x02, 0x00, 0x00, 0x00,	/* =	*/
0x00, 0x00, 0x0E, 0x01, 0x0F, 0x11, 0x0F,	/* a	*/
0x10, 0x10, 0x16, 0x19, 0x11, 0x19, 0x16,	/* b	*/
0x00, 0x00, 0x0E, 0x11, 0x10, 0x11, 0x0E,	/* c	*/
0x01, 0x01, 0x0D, 0x13, 0x11, 0x13, 0x0D,	/* d	*/
0x00, 0x00, 0x0E, 0x11, 0x1F, 0x10, 0x0E,	/* e	*/
0x02, 0x05, 0x04, 0x0E, 0x04, 0x04, 0x04,	/* f	*/
0x0D, 0x13, 0x13, 0x0D, 0x01, 0x11, 0x0E,	/* g	*/
0x10, 0x10, 0x16, 0x19, 0x11, 0x11, 0x11,	/* h	*/
0x04, 0x00, 0x0C, 0x04, 0x04, 0x04, 0x0E,	/* i	*/
0x01, 0x00, 0x01, 0x01, 0x01, 0x11, 0x0E,	/* j	*/
0x10, 0x10, 0x12, 0x14, 0x18, 0x14, 0x12,	/* k	*/
0x0C, 0x04, 0x04, 0x04, 0x04, 0x04, 0x0E,	/* l	*/
0x00, 0x00, 0x1A, 0x15, 0x15, 0x15, 0x15,	/* m	*/

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0x00, 0x00, 0x16, 0x19, 0x11, 0x11, 0x11, /* n */ */
0x00, 0x00, 0x0E, 0x11, 0x11, 0x0E, 0x0E, /* o */ */
0x16, 0x19, 0x11, 0x19, 0x16, 0x10, 0x10, /* p */ */
0x0D, 0x13, 0x11, 0x13, 0x0D, 0x01, 0x01, /* q */ */
0x00, 0x00, 0x16, 0x19, 0x10, 0x10, 0x10, /* r */ */
0x00, 0x00, 0x0F, 0x10, 0x0E, 0x01, 0x1E, /* s */ */
0x04, 0x04, 0x1F, 0x04, 0x04, 0x05, 0x02, /* t */ */
0x00, 0x00, 0x11, 0x11, 0x13, 0x0D, 0x0D, /* u */ */
0x00, 0x00, 0x11, 0x11, 0x11, 0x0A, 0x04, /* v */ */
0x00, 0x00, 0x11, 0x15, 0x15, 0x0A, 0x0A, /* w */ */
0x00, 0x00, 0x11, 0x0A, 0x04, 0x0A, 0x11, /* x */ */
0x11, 0x11, 0x11, 0x0F, 0x01, 0x11, 0x0E, /* y */ */
0x00, 0x00, 0x1F, 0x02, 0x04, 0x08, 0x1F, /* z */ */
0x02, 0x04, 0x04, 0x08, 0x04, 0x04, 0x02, /* { */ */
0x04, 0x04, 0x04, 0x00, 0x04, 0x04, 0x04, /* | */ */
0x08, 0x04, 0x04, 0x02, 0x04, 0x04, 0x08, /* } */ */
0x08, 0x15, 0x02, 0x00, 0x00, 0x00, 0x00, /* ~ */ */
0x0A, 0x15, 0x0A, 0x15, 0x0A, 0x15, 0x0A, /* DEL (0x7F) */ */

```

{;

/* library include files */

/* local include files */
/* none */

/*
render_displaybuffer

Description: Renders the passed string to the passed buffer.

Operation: The buffer is a sequence of bytes that specify how each column of pixels should be set, with each bit in a byte setting one pixel in a column. The code goes through all the columns, and picks out the appropriate bits from the ascii_char_patterns.

Arguments: *string - pointer to start of null-terminated string
*buffer - pointer to start of display buffer
length - length of string

Return Value: None

Input: None.
Output: None.

Error Handling: None.

Algorithms: None.
Data Structures: None.

Shared Variables:

Author: Will Werst
Last Modified: June 23, 2017

*/

```

void render_displaybuffer(char *string, char *buffer, int length){
    int col;
    for (col = 0; col < length; col++){
        /*if (col % 6 == 0){
            buffer[col] = 0x00;
            continue;
        }
        for (int i = 0; i < 6; i++){
            buffer[col + i] = patterns[*(string + col / 6)][i];
        }
    }
}

```

```
 */  
int cur_str_pos = (col / 6);  
char cur_char = string[cur_str_pos];  
if (cur_char == 0x00){  
    break;  
}  
int row;  
for (row = 0; row < 7; row++){  
    if ((ascii_char_patterns[cur_char*7 + row] & (0x10 >> (col % 6))) != 0) { //  
        If the current value is blank  
        buffer[col] = buffer[col] ^ (0x1 << row);  
    }  
}  
}  
  
// Clears the passed buffer  
void clear_displaybuffer(char *buffer, int length){  
    int col;  
    for (col = 0; col < 512; col++){  
        buffer[col] = 0x00;  
    }  
}  
  
// Does what it says it does  
int divide(int num, int den){  
    return num / den;  
}  
  
// Does what it says it does  
int mod(int num, int den){  
    return num % den;  
}
```

```
@Done
@***** /*****
@/* */                                */
@/*          INTERFAC.H                  */
@/*          Interface Definitions      */
@/*          Include File               */
@/*          VoIP Telephone Project    */
@/*          EE/CS 52                   */
@/* */                                */
@***** /*****
```

@ This file contains the constants for interfacing between the C code and
@ the assembly code/hardware.

@ Revision History:

@	Name	Comment	Date
@	Glen George	Initial revision.	6/3/06
@	Glen George	Added ETHER_INTF definition.	6/7/06
@	Glen George	Added MAC_ADDR_H and MAC_ADDR_L definitions.	3/8/11
@	Will Werst	Changed values to match my specification	Some lonely night around 6/10/17

```

MEMORY_SIZE,           32
SAMPLE_RATE,          8000

MAC_ADDR_H,           0xEA09
MAC_ADDR_L,          0x87654321

ETHER_INTF,          "et0"

KEY_0,                0
KEY_1,                1
KEY_2,                2
KEY_3,                3
KEY_4,                4
KEY_5,                5
KEY_6,                6
KEY_7,                7
KEY_8,                8
KEY_9,                9
KEY_ESC,              10
KEY_BACKSPACE,        11
KEY_SEND,              12
KEY_OFFHOOK,           13
KEY_ONHOOK,            14
KEY_SET_IP,             15
KEY_SET_SUBNET,         16
KEY_SET_GATEWAY,        17
KEY_MEM_SAVE,           18
KEY_MEM_RECALL,          19
KEY_ILLEGAL,            20

STATUS_IDLE,            0
STATUS_OFFHOOK,          1
STATUS_RINGING,           2
STATUS_CONNECTING,         3
STATUS_CONNECTED,          4
STATUS_SET_IP,             5
STATUS_SET_SUBNET,          6
STATUS_SET_GATEWAY,         7
STATUS_MEM_SAVE,            8
STATUS_MEM_RECALL,          9
STATUS_RECALLED,            10

```

```
.equ STATUS_ILLEGAL,      11
.equ AUDIO_BUflen,        256
```

```
@Done
@             keypad.inc
@             Contains definitions used by keypad.s
@             Description: Defines register values used by the keypad
@             Revision History:
@             Name          Comment           Date
@             Will Werst   Initial version   Some lonely night around 6/10/17
@             Will Werst   Comment         October 2017
```

```
.equ RDY_PIN,      26          @Ready pin location for interrupts  
.equ MAXDEBCOUNT,   10000  
.equ KEY_HANGUPBTN, 21  
.equ KEY_SHIFT,     22
```

@ Shared variables: LastKeypress - initialized to KEY_ILLEGAL

```

@Done
@macro.inc
Defines various macros used throughout the code base

@ Description: Defines register values used by the audio system.

@ Revision History:
@ Name           Comment           Date
@ Will Werst    Initial version  Some lonely night around 6/10/17
@ Will Werst    Comment          October 2017

@Macro for setting Hardware register at destination with value val
@Registers modified: r0, r1
.macro mSET_HREG dest, value

LDR r0, =\dest
LDR r1, =\value
STR r1, [r0]

.endm

.macro mLOADTOREG reg, mem_loc

    LDR \reg, =\mem_loc
    LDR \reg, [\reg]

.endm

.macro mSTOREFROMREG reg, temp_reg, mem_loc

    LDR \temp_reg, =\mem_loc
    STR \reg, [\temp_reg]

.endm

.macro mSTARTFNC
    PUSH {lr}
.endm

.macro mRETURNFNC
    POP {pc}
.endm

.macro mSTARTINT
    PUSH {r0-r3, lr}
.endm

.macro mRETURNINT
    mSET_HREG AIC_EOICR, 1
    POP {r0-r3, lr}
    SUBS pc, lr, #WORD_SIZE
.endm

@ Macros to handle critical code. Note that r7 is used, the value is restored
@ after critical code section, but since the stack is used to store value
@ in critical code start, its value cannot be preserved during the critical
@ code section.

```

```
.macro mSTARTCRITCODE
    PUSH {r7}
    MRS r7, cpsr
    PUSH {r7}
    ORR r7, r7, #(I_BIT | F_BIT)
    MSR cpsr_c, r7
.endm

.macro mENDCRITCODE
    POP {r7}
    MSR cpsr, r7
    POP {r7}
.endm
```

```
@Done
@ Memtest.s
@ 
@ 
@ 
@ Description: Contains code for testing the SRAM and DRAM
@           This code is normally ran before copying the system from ROM to SRAM or DRAM
@ 
@ Table of Contents:
@   - mem_test: Tests the memory address range that is passed.
@           The test erases anything stored here before.
@ 
@ 
@ 
@ 
@ 
@ Revision History:
@ Name          Comment          Date
@ Will Werst    Initial version Some lonely night around 6/10/17
@ Will Werst    Comment        October 2017

.include "at91rm9200.inc"
.include "system.inc"

.text
.arm

@ mem_test
@ 
@ Description: Tests memory of passed memory section.
@           In the process of testing memory, this function destroys all data
@           that was in the memory already.
@ 
@ Operational Description: The code works by writing a sequence of numbers
@           to successive bytes in the memory that are fairly
@           random and do not repeat on any  $2^n$  periodicity, and
@           hence should expose any address line connectivity issues.
@           A sequence is written to memory, and then read back
@           and checked against the expected sequence. Then,
@           another sequence is written to memory, and this is continued
@           until r3, the incrementer value, overflows. If
@           the memory does not show any errors, it is assumed
@           to be good. While this is not an exhaustive memory
@           test, it is a simple test that can be used to verify
@           basic memory functionality.
@ 
@ Arguments: r0 - starting address to test memory integrity
@           r1 - length of data to test memory integrity of
@ 
@ Return values: r0 - TRUE if success, FALSE if failure
@           r1 - value read from memory
@           r2 - value expected in memory
@           r3 - relative address where error occurred
@ 
@ Local variables: r0 - base address - unchanged
@           r1 - length of memory - unchanged
@           r2 - relative location into memory
@           r3 - incrementer value used to generate sequences of data to load into memory
@           r4 - value to load into memory
```

```

@ Shared variables: None
@
@ Global Variables: None
@
@ Inputs: None
@
@ Outputs: None
@
@ Error Handling: None
@
@ Algorithms: None
@
@ Data Structures: None
@
@ Limitations: Does not verify that DRAM refresh is working correctly.
@
@ Registers Changed (besides ARM convention r0-r3): None
@
@ Known Bugs: None
@
@ Special notes: None
@
@ Revision History:
@ Name           Comment          Date
@ Will Werst    Initial version  6/22/2017

```

```

.global mem_test
mem_test:
    PUSH {r4, r5, lr}
    LDR r3, =0
    LDR r4, =0
mem_test_loop:
    LDR r5, =0x3F35D4B3
    ADDS r3, r5
    BCS success
    LDR r2, =0
    PUSH {r4}
writedata:
    STR r4, [r0, r2]
    ADDS r4, r3
    SBC r4, r4, #1
    ADD r2, #4
    CMP r2, r1
    BLT writedata
    LDR r2, =0
    POP {r4}
checkdata:
    LDR r5, [r0, r2]
    CMP r5, r4
    BNE failure
    ADDS r4, r3
    SBC r4, r4, #1
    ADD r2, #4
    CMP r2, r1
    BLT checkdata
    B mem_test_loop
failure:
    LDR r0, =FALSE
    MOV r1, r5
    MOV r3, r2
    MOV r2, r4
    B mem_test_end
success:
    LDR r0, =TRUE
    B mem_test_end

```

```
mem_test_end:  
    POP {r4, r5, pc}
```

```
.end
```

```

@Done
@          pio.inc
@          Contains definitions used by pio.s

@ Description: Defines register values used by the pio controller
@                 for this project
@ Revision History:
@ Name           Comment           Date
@ Will Werst    Initial version  Some lonely night around 6/10/17
@ Will Werst    Comment         October 2017

@PIO Bank definitions
.equ   PIO_A,      0           @Constant for specifying PIOA in config fun
.equ   PIO_B,      1           @Constant for specifying PIOB in config fun
.equ   PIO_C,      2           @Constant for specifying PIOA in config fun

@PIO pin configuration definitions
@ Bit use for defining configurations:
@ Bit [1:0] - PIO type (PIO_NORM, PIO_PerA, PIO_PerB)
@ Bit [2]   - PIO input or output (PIO_OUTPUT)
@ Bit [3]   - PIO interrupt enable (PIO_INT_EN)

@ Bit [1:0]
.equ   PIO_TYPE_MASK, 0x3     @Used to mask out PIO type config bits
.equ   PIO_NORM,      0x0
.equ   PIO_PERA,      0x1
.equ   PIO_PERB,      0x2

@ Bit [2]
.equ   PIO_OUTPUT_MASK, 0x4   @Used to mask out PIO output config bits
.equ   PIO_OUTPUT,    0x4

@ Bit [3]
.equ   PIO_INT_MASK,   0x8   @Used to mask out PIO interrupt config bits
.equ   PIO_INT_EN,    0x8

```

@ Name	Comment	Date
@ Will Werst	Initial version	6/22/2017

@ Description: Defines system-level constants, like TRUE or FALSE, and
@ also defines constants used by system.s

@ Revision History:

@ Name	Comment	Date
@ Will Werst	Initial version	Some lonely night around 6/10/17
@ Will Werst	Comment	October 2017

Memory definitions

```
    .equ      SRAM_START,      0x20000000
    .equ      SRAM_SIZE,       0x20000
    .equ      DRAM_START,      0x30000000
    .equ      DRAM_SIZE,       0x100000
    .equ      DRAM_NUM_ROWS,   1024
    .equ      DRAM_MILLIS_PER_REF, 256
    .equ      ROM_START,       0x80000000
    .equ      ROM_SIZE,        0x80000
```

@ Stack definitions

```
@ top of the stack, usually the end of the external SRAM  
.equ      TOP_STACK, 0x2001FFFF0
```

```
@ interrupt stack size (see chapter 13 of the manual)
      .equ    IRQ_STACK_SIZE, 128
```

```
@ supervisor mode stack size (see chapter 13 of the manual)
    .equ      SVC_STACK_SIZE, 128
```

6 General Definitions

.equ TRUE, 1
.equ FALSE, 0

~~④ System function definitions~~

```
@ timer definitions
.equ    SLCK_CNT_SEC,    32768
.equ    PIT_INTERVAL,    33          @SLCK ticks per PIT interrupt
.equ    MILLIS_IN_SEC,   1000
```

```
@Done
@ System.s
@ Contains code for system-level functions, like timers
@ 
@ 
@ Description: Currently only contains code for initializing the system
@                 clock.
@ 
@ 
@ Table of Contents:
@   - init_system: Call to initialize the timers in the system.
@   - elapsed_time: Returns the number of milliseconds since the last
@                   elapsed_time call.
@   - timerHandler: Handles the timer callbacks, and calling the oneMillisElapsed
@                   function when appropriate
@   - oneMillisElapsed: Called every time 1 ms elapses. This handles
@                     incrementing the millis shared variable, and
@                     anything else that the system needs, like
@                     DRAM refresh.
```

© Revision History:
© Name Comment Date
© Will Werst Initial version Some lonely night around 6/10/17
© Will Werst Comment October 2017

```
.include "at91rm9200.inc"
.include "macro.inc"
.include "system.inc"

.text
.arm

@ init_system
@
@ Description: Initializes the code in this file. Call before
@               using anything in this file.
@
@ Operational Description: A timer interrupt is setup, and then
@                           some status registers are read to clear them.
@
@ Arguments: None
@
@ Return values: None
@
@ Local variables: None
@
@ Shared variables: None
@
@ Global Variables: None
@
@ Inputs: None
@
@ Outputs: None
@
@ Error Handling: None
@
```

@ Algorithms: None
 @ Data Structures: None
 @ Limitations: None
 @ Registers Changed (besides ARM convention r0-r3): None
 @ Known Bugs: None
 @ Special notes: None

@ Revision History:

@ Name	Comment	Date
@ Will Werst	Initial version	Some lonely night around 6/10/17

```
.global init_system
init_system:
    mSTARTFNC
    mSET_HREG    AIC_SMR1,    0x00000021      @Initialize the system timer interrupt
    mSET_HREG    AIC_SVR1,    timerHandler      @Set callback
    mSET_HREG    ST_PIMR,     PIT_INTERVAL      @Set timer period
    mSET_HREG    ST_IER,      0x00000001      @Enable interrupt
    mSET_HREG    AIC_IECR,    0x00000002      @Enable interrupt
    LDR        r0,         =ST_SR            @Read status registers to clear them
    LDR        r0,         [r0]              @Read status registers to clear them
    LDR        r0,         =RTC_SR            @Read status registers to clear them
    LDR        r0,         [r0]              @Read status registers to clear them
    LDR        r0,         =PMC_SR            @Read status registers to clear them
    LDR        r0,         [r0]
    mRETURNFNC
```

@ elapsed_time

@ Description: Returns the number of milliseconds which have elapsed since the last time this function was called.

@ Operational Description: The current millis count is loaded, and the last millis count is loaded as well. The result is generated by subtracting last_millis from millis, and then last_millis is set to the current value of millis.

@ Arguments: None

@ Return values: r0 - number of milliseconds since the last time the function was called.

@ Local variables: None

@ Shared variables: millis[R] - the current millis count is read
 last_millis[RW] - the previous millis count is read and updated

@ Global Variables: None

@ Inputs: None

@ Outputs: None

@ Error Handling: None

@ Algorithms: None

@ Data Structures: None

```

@ Limitations: None
@
@ Registers Changed (besides ARM convention r0-r3): None
@
@ Known Bugs: None known
@
@ Special notes: None
@
@ Revision History:
@ Name           Comment           Date
@ Will Werst    Initial version  Some lonely night around 6/10/17

@ returns: number of milliseconds since last function call
.global elapsed_time
elapsed_time:
    mSTARTFNC
    mLoadToReg r0, millis          @load current milliseconds
    mLoadToReg r1, last_millis     @load last milliseconds
    mStoreFromReg r0, r2, last_millis @store current milliseconds into last milliseconds
    SUB      r0, r0, r1            @get difference

    mRETURNFNC

@ timerHandler
@
@ Description: Handles incrementing the timer_counter.
@             This function is called from an interrupt.
@
@ Operational Description: The timer_counter variable is
@             incremented by the number of milli-ticks of slow clock
@             per interrupt, and then any full milliseconds are
@             removed from timer_counter and the oneMillisElapsed
@             function is called for each one of these full
@             milliseconds.
@
@ Arguments: None
@
@ Return values: None
@
@ Local variables: None
@
@ Shared variables: timer_counter[RW] - This counter
@                     contains the number of milli-ticks
@                     of the slow clock. It is updated by method.
@
@ Global Variables: None
@
@ Inputs: None
@
@ Outputs: None
@
@ Error Handling: None
@
@ Algorithms: None
@
@ Data Structures: None
@
@ Limitations: None
@
@ Registers Changed (besides ARM convention r0-r3): None
@
@ Known Bugs: None
@
@ Special notes: None
@

```

```

@ Revision History:
@ Name           Comment          Date
@ Will Werst    Initial version  Some lonely night around 6/10/17

@ variables:
@   r1 - timer_counter

timerHandler:
    mSTARTINT
    LDR    r0,      =ST_SR           @Read status register to clear it
    LDR    r0,      [r0]             @
    LDR    r0,      =RTC_SR         @Read RTC register to clear it
    LDR    r0,      [r0]             @
    LDR    r0,      =PMC_SR         @Read power management controller
    LDR    r0,      [r0]             @status register to clear it
    LDR    r0,      =(PIT_INTERVAL*MILLIS_IN_SEC) @Load number of milli-ticks
                                         @of slow clock between interrupts.
    mLoadToReg r1, timer_counter   @And add the number of milli-ticks
    ADD    r1, r1, r0              @to the current count of milli-ticks

transferFullMillisCounts:
    CMP    r1, #SLCK_CNT_SEC     @Check to see if a millisecond has elapsed
    BLO    endTimerHandler       @No full milliseconds to transfer
    PUSH   {r1}
    BL     oneMillisElapsed     @Call the function to increment millis
                                @and also take any action that should
                                @be done when a millisecond has elapsed
    POP    {r1}
    SUB    r1, #SLCK_CNT_SEC     @Take off the number of counts in timer_counter
                                @associated with one millisecond elapsing
    B     transferFullMillisCounts @Go back and check if more milliseconds to transfer

endTimerHandler:
    mStoreFromReg r1, r0, timer_counter @Save the remainder milli-ticks
    mRETURNINT

```

@ oneMillisElapsed

@

@ Description: This function should be called by the timerHandler
@ every time one millisecond elapses.

@

@ Operational Description: The millis variable is incremented, and then
@ any other actions that should be taken every
@ millisecond are done. Currently this is only
@ a DRAM refresh.

@

@ Arguments: None

@

@ Return values: None

@

@ Local variables: None

@

@ Shared variables: None

@

@ Global Variables: None

@

@ Inputs: None

@

@ Outputs: None

@

@ Error Handling: None

@

@ Algorithms: None

@

@ Data Structures: None

@

@ Limitations: None

@

```

@ Registers Changed (besides ARM convention r0-r3): None
@
@ Known Bugs: None
@
@ Special notes: None
@
@ Revision History:
@ Name           Comment          Date
@ Will Werst    Initial version  Some lonely night around 6/10/17

@ oneMillisElapsed
@ Description: Function used to increment millisecond, and also do any other
@               actions such as refresh DRAM
@

oneMillisElapsed:
    mSTARTFNC
    mLoadToReg r0, millis          @Load millis
    ADD      r0, #1                @Increment millis
    mStoreFromReg r0, r2, millis   @save millis

    @Refresh DRAM, need to refresh 1024 rows every 16 ms
    LDR      r0,      =((DRAM_NUM_ROWS / DRAM_MILLIS_PER_REF)) @Figure out how many rows to refresh
    LDR      r1,      =DRAM_START    @Load start address of DRAM
    mLoadToReg r2,      dramRefreshRow @Load the row that was refreshed last

dramRefresh:
    LDRB    r3, [r1, r2]          @Refresh row
    ADD     r2, #1                @Go to next row
    CMP     r2, #DRAM_NUM_ROWS   @Check if gone through all rows
    LDRHS   r2, =0                @If so, go back to row 0
    SUBS   r0, #1                @Decrement row counter
    BHI    dramRefresh          @If still rows to refresh, continue refreshing
    @B    endDRAMRefresh        @Done refreshing

endDRAMRefresh:
    mStoreFromReg r2, r0, dramRefreshRow @Save row that was worked on
    @B  endOneMillisElapsed

endOneMillisElapsed:
    mRETURNFNC                  @Done, return

.

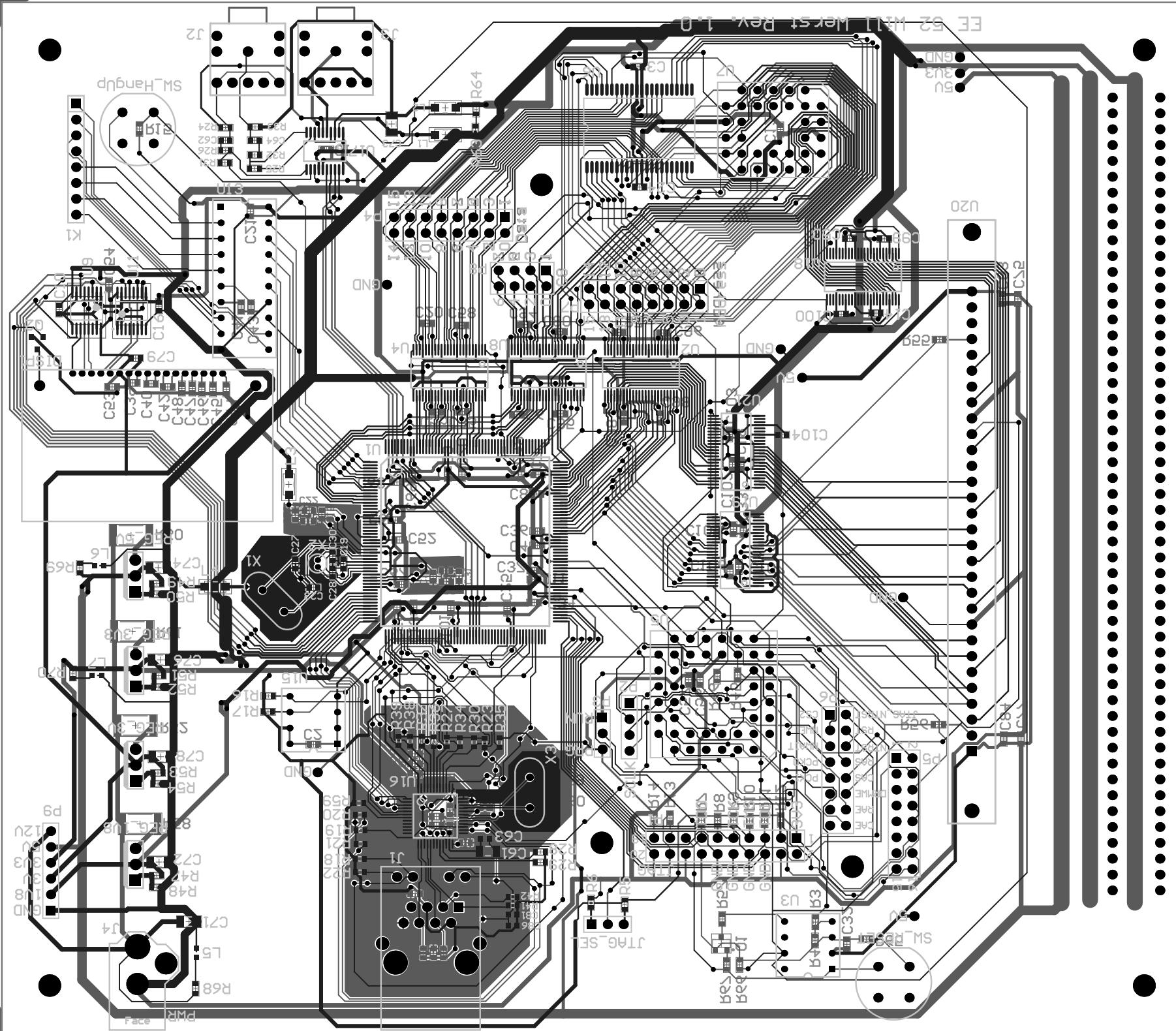
.data

millis:             @Stores milliseconds elapsed since start
    .word 0x00000000
last_millis:        @Stores milliseconds since last elapsed_time call
    .word 0x00000000
timer_counter:      @Counter for converting slow clock ticks to milliseconds
    .word 0x00000000
dramRefreshRow:     @Counter for which row to refresh next
    .word 0x00000000

.end

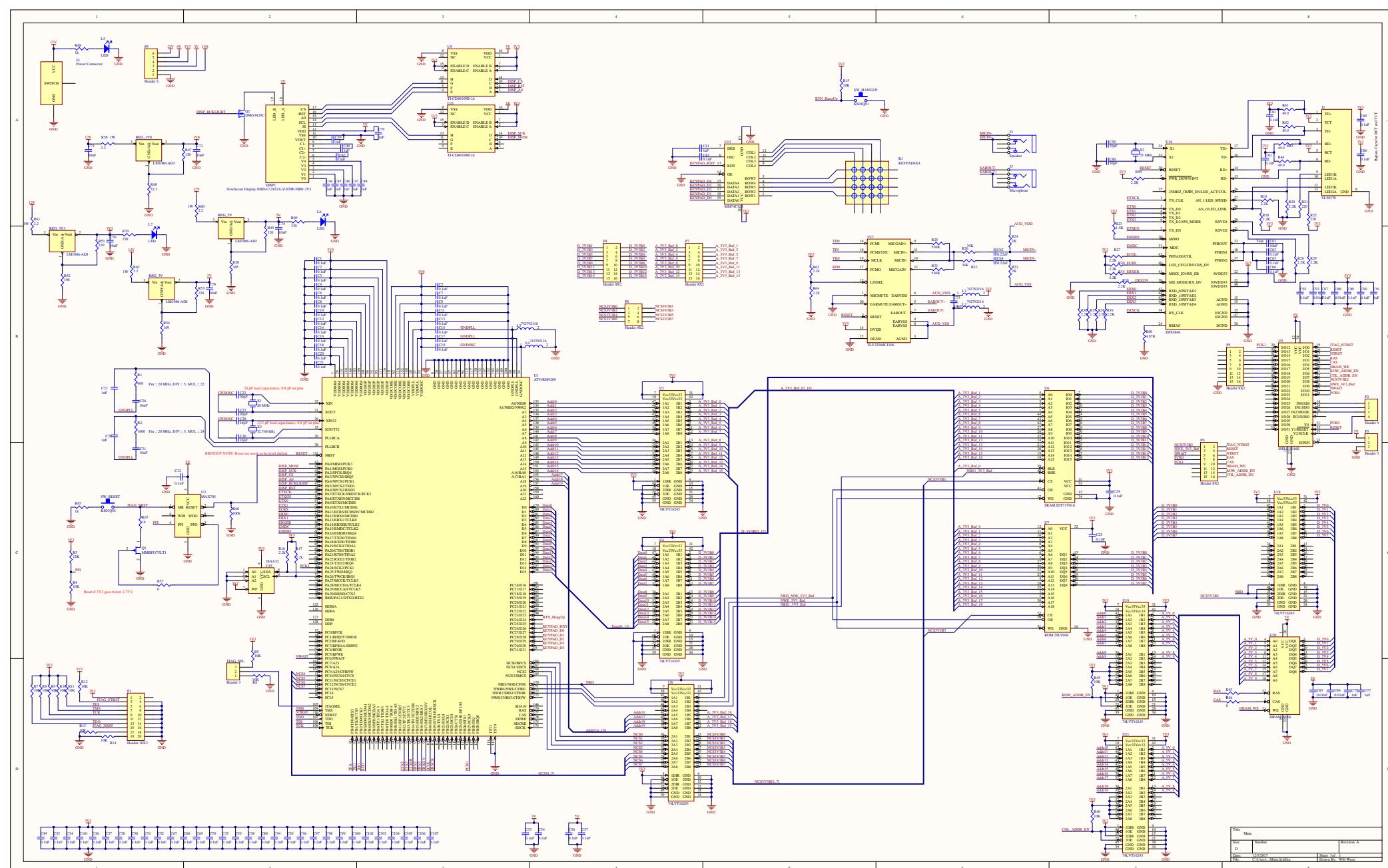
```

Appendix F (Printed Circuit Board)



Boards

Appendix G (Schematics)



Boards