

Midterm — March 14, 2007

Write out and sign the honor pledge:

1. (2 pts) Print your name on *each and every* sheet.
2. (8 pts) Write down the equations for the forward and inverse Discrete Fourier Transform. Indicate which is which. Use the “standard” definitions.

3. (2 pts) FPGA technology (component density and speed) has been benefiting from Moore’s law. It is now at a point where (the instructor claims) that it will be a major player in DSP applications. This evidenced by the recent introduction of DSP oriented FPGA devices by Xilinx, Altera, Lattice and others. What do the letters FPGA stand for?

4. (2 pts) Typically a microcomputer or FPGA is be felt to have been designed for use in doing digital signal processing if it possesses a

instruction.

5. (8 pts) A time waveform $x(t)$ is sampled at a rate of f_s for T seconds resulting in a set of N samples.

(a) How are f_s , T , and N related (i.e., equation):

(b) The DFT is taken of the N sample values. What are the frequencies, associated with the following values of k ?

i. $k = 0$ _____ Hz.

ii. $k = 1$ _____ Hz.

iii. $k = -2$ _____ Hz.

6. (4 pts) The filter preceding an A/D converter is termed an anti-_____ filter.

7. (4 pts) The filter following a D/A converter is termed an anti-_____ filter.

8. (2 pts) The TI C5510 divides data memory into pages. The number of 16-bit data words per page is _____ K.

9. (2 pts) The size of the C5510 on-chip memory is _____ Kwords.

10. (2 pts) The C5510 has _____ on-chip timers.

11. (2 pts) The C5510 has _____ McBSP channels.

12. (6 pts) The C5510 supports three address spaces. These are

13. (2 pts) The C5510 has two _____-bit high speed multipliers.

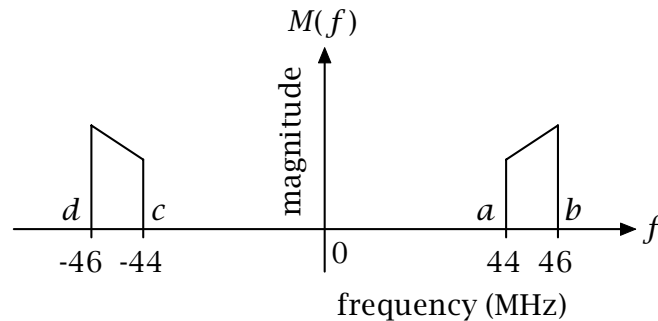
14. (4 pts) The product line of the Xilinx FPGAs used in lab is named _____.

15. (2 pts) The clock rate used with the C5510 DSK is

_____ MHz.

16. (2 pts) The clock rate used on the FPGA boards in the lab is _____ MHz.

17. (10 pts) A useful aspect of sampling is to alias a bandlimited signal to lower frequencies. This is accomplished by using sample rates lower than or equal to Nyquist.



Sketch and label the spectrum after sampling using the following sampling rates:

(a) $f_s = 45$ MHz.

a = _____ MHz.

b = _____ MHz.

c = _____ MHz.

d = _____ MHz.

The Nyquist range is from _____ to _____ MHz.

(b) $f_s = 16$ MHz.

a = _____ MHz.

b = _____ MHz.

c = _____ MHz.

d = _____ MHz.

The Nyquist range is from _____ to _____ MHz.

18. (4 pts) The C5510 has _____ -bit accumulators.

19. (2 pts) The C5510 has _____ status registers.
20. (4 pts) The AIC23 CODEC chip used on the C5510 DSK connects to the C5510 using two McBSP channels, one for setup and one for data transfer.
- (a) Which McBSP channel is used for setup using the SPI protocol? _____
- (b) Which McBSP channel is used for moving sample values between the AIC23 and the C5510? _____
21. True (T) or false (F) (2 pts each):

_____ The AIC23 only supports two sample rates, these are 8 kHz and 48 kHz.

_____ One should operate a DSP processor at as slow a clock rate as possible as determined by the application being implemented.

_____ The TI C compiler generates code for the C5510's floating point unit.

_____ The C5510 has 32 memory mapped registers.

_____ The C5510's PLL is used to convert the 20 MHz USB clock to the CPU's 200 clock.

_____ An advantage of the two's complement number representation is that the same add/sub hardware is used as is with unsigned numbers.

_____ Two's complement multiplication has the advantage that it can be accomplished using the a multiplier designed to implement unsigned multiplication.

_____ 32-bit fixed point values have the potential to give results more accurate than those obtained using 32-bit floating point.

_____ The C5510 subc instruction can be used to implement unsigned division.

_____ FPGAs allow performance increases over DSP devices because they readily support parallel operation.

_____ It has been stated in the lecture notes that "there must be significant commercial potential" in the class projects.

_____ The class projects need not make any use of digital signal processing.

_____ The MATLAB fftshift function forms the fft and then re-orders the result so that 0 Hz is centered in the output array.

_____ In order to construct a complicated system is is desirable to beak the problem down into smaller manageable pieces. Each subproblem can then be further broken down until the entire system is decomposed into fundamental building blocks.

- _____ All FIR filters have a linear phase response.
- _____ All IIR filters have a linear phase response.
- _____ The FPGA boards used in lab provide off-FPGA memory.
22. (2 pts) When doing signed arithmetic the C5510 needs to _____ the sign bits of a 16-bit value when it is being added into an accumulator.
23. (4 pts) One method of forming the two's complement of a binary number is to _____ and _____.
24. (2 pts) What needs to be placed between the carry in and the carry out of a one-bit adder to make it into a bit-serial adder?
_____.
25. (2 pts) When using a 12-bit A/D converter on a 16-bit processor we would place the sample values in the _____ significant bits of a 16-bit word.
26. (2 pts) The instructor claims that, almost always, if we design a low pass FIR filter having max gain of 1 that the FIR coefficient values will be bounded by _____.
27. (2 pts) The numeric weight associated with the most significant bit of a B-bit straight (unsigned) binary value is _____.
28. (2 pts) The numeric weight associated with the most significant bit of a B-bit two's complement binary value is _____.
29. (2 pts) If we multiply a Q_5 value by a Q_9 value _____ is the Q number of the result.
30. (2 pts) When doing multiplication in the C5510 if we want the result to be automatically left shifted by one afterward we need to set the _____ bit in the status registers.
31. (4 pts) When discarding low bits of a binary bit it is best to round first. The two methods of rounding that we considered are named _____ and _____ rounding.
32. (2 pts) Floating point is not recommended for general use when doing DSP on the C5510 because _____.

33. (6 pts) In VHDL

_____ are the basic logic units.

_____ are the visible connections,

and the _____ defines the internal signals and describes the design.

34. (4 pts) The two basic components of a state machine are

_____ and _____.

35. (2 pts) Xilinx constraint files use file extension _____.

36. (4 pts) The C5510 on-chip ROM contains (how many) _____ 16-bit samples of the _____ function.

37. (2 pts) Many C5510 instructions do not support explicit naming of particular registers. However, because all of the registers are _____ they can be accessed anyway.

38. (8 pts) We have been asked to design a direct digital synthesizer (DDS) using a 32-bit accumulator and an update clock of 48000 Hz.

(a) Frequencies that can be synthesized are multiples of

$$f_{\text{step}} = \underline{\hspace{2cm}} \text{ Hz.}$$

(b) The frequency tuning value (FTV) that will most closely generate a 1000 Hz sinewave is

_____.

39. (2 pts) We say that $h(\)$ is *linear* if

_____.

for all choices of $a, b, x(t)$ and $y(t)$.

40. (2 pts) We say that $h(\)$ is *time-invariant* if for $y(t) = h[x(t)]$ we have

_____.

41. (2 pts) We say that a system is *causal* if

_____.

42. (2 pts) We say a system is *stable* if

_____.

43. (2 pts) Where must a digital filter's transfer function's poles be located in the z -plane if the filter is to be stable?

_____.

44. (2 pts) The moving average filter has z -transform

$$H(z) = 1 + z^{-1} + z^{-2} + z^{-3} + \dots + z^{-(N-1)}.$$

This series can be written in a more compact (closed) form as

_____.

45. (2 pts) The MATLAB program that we use to design filters is named

_____.

46. We are working in C using Q15 values. The following code segment multiplies two Q15 values together to obtain a Q15 result. It does not work correctly. Correct it making minimal change.

```
int x,y,z;
.
.
.
z = (x*y)>>15;
.
.
```

47. (2 pts) The MANT :: NEXP instruction(s) takes a value contained in an accumulator and converts (normalizes) it into Q?? form counting the number shifts required. The value of ?? is _____.

48. (4 pts) When we characterize a filter the two most commonly quantities associated with it's transfer function that are used are

_____ and _____.

49. (4 pts) Given a set of N values $x[0], x[1], \dots, x[N - 1]$ we form the DFT to obtain a set of N values $X[0], X[1], \dots, X[N - 1]$. We next form the DFT of the complex conjugates of these values to obtain a set of values $y[0], y[1], \dots, y[N - 1]$.

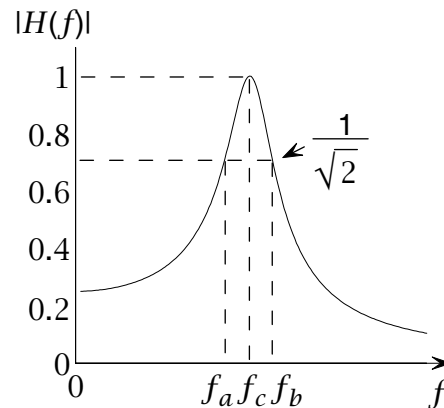
How are the $x[]$ and $y[]$ values related?

50. (6 pts) From lecture we have the transfer function of a pole pair that is near the unit circle as shown. What is the:

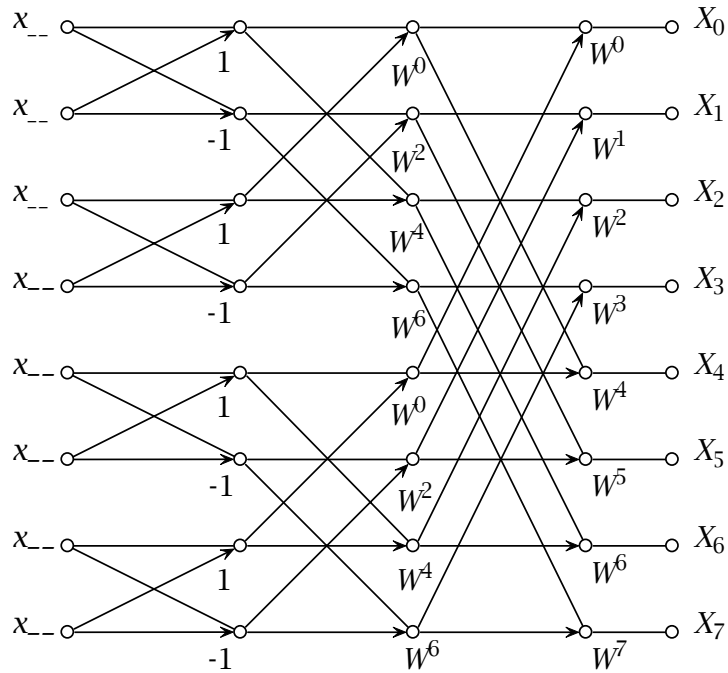
center frequency $f_c =$ _____ ,

bandwidth $BW =$ _____ ,

quality factor $Q =$ _____ .



51. (4 pts) For the following decimation-in-time FFT data flow diagram what are the required index values on the input x values?



52. (4 pts) Write the equation describing the Fourier Transform Frequency Shifting Theorem.

-
53. (4 pts) What does the following instruction do?

```
add *ar0-<<#16,ac0
```

54. (4 pts) What does the following instruction do?

```
rnd(hi(saturate(ac0))),*ar1+
```

55. (8 pts) What do the following symbols denote when programming using the TI mnemonic assembler?

\$ _____
* _____
@ _____

56. (6 pts) A waveform is sampled using rate 8000 samples per second.

The alias frequency is _____ Hz.

Two seconds of waveform samples are DFT'd. The frequency step between DFT values is _____ Hz.

If the waveform had been sampled at 16000 Hz and the DFT of two seconds of sampled had been formed, the frequency step between DFT values would have been _____ Hz.

57. (8 pts) Using the C5510 C/C++ system, variables declared as

char use _____ bits.

int use _____ bits.

long use _____ bits.

double use _____ bits.

58. (8 pts) The C5510 C system uses named memory sections to organize data and code. The following named sections are used to contain what?

.text _____ .
 .bss _____ .
 .cinit _____ .
 .stack _____ .

59. (4 pts) A waveform is sampled using a sample rate of 8 kHz. How many samples are required in order to have a frequency spacing of 2 Hz in the DFT of the sample set? _____

60. (8 pts) The C5510 C system uses a data structure referred to as a *stack* hold six types of information. List four.

- (a) _____
 (b) _____
 (c) _____
 (d) _____

61. (2 pts each) Assume a 8-bit word size with bits ordered most significant bit left most (bit 7) and least significant right most (bit 0). What is the

- (a) Q7 unsigned value of 1000 0000? _____
 (b) Q7 signed value of 1000 0000? _____
 (c) Q7 unsigned value of 0100 0000? _____
 (d) Q7 signed value of 0100 0000? _____
 (e) Q-2 unsigned value of 1000 0000? _____

62. (2 pts) For proper extended-precision arithmetic in the C5510 the status bit, *satd*, should be set or cleared to prevent the accumulator from saturating during the computations? _____.

63. (2 pts) Given the 16-bit hexadecimal value F237 express its two's complement using hexadecimal.

64. (8 pts) We normally use positional notation when writing binary numbers. Associated with each position is a weight which is a power of two. For the 6-bit binary number $b_5b_4b_3b_2b_1b_0$ (Q0) where the b 's take on values 0 and 1, what is the weight,

(a) for unsigned values, associated with b_2 ? _____

(b) for unsigned values, associated with b_5 ? _____

(c) for two's complement values, associated with b_2 ? _____

(d) for two's complement values, associated with b_5 ? _____

65. (4 pts) Because addition and subtraction in a fixed point computer use a fixed word size there are two situations where one can have arithmetic overflow. These are

(a) _____

(b) _____

66. (4 pts) Assume multiplication of two B -bit numbers with the product being placed into a $2B$ -bit accumulator. When not doing fractional multiplication (frct bit = 0) there is no chance of overflow in the result. When frct bit = 1 it is possible to have an overflow. What values will cause this?

67. (2 pts) When implementing floating point, which operation, addition or multiplication, is going to be the more difficult to do?

68. (5 pts) The arctangent function implemented in class mapped the radian angle range from _____ to _____ into the range from _____ to _____ using units of _____.

69. (4 pts) Polynomial approximations for the arctangent, the base 2 logarithm and square root were discussed. The approximation method of choice was the _____ approximation.

70. (2 pts) The _____ data transfer protocol is used on the C5510DSK to program/configure AIC23 CODEC device.
71. (8 pts) You are given a digital filter described using a biquadratic transfer function of the form

$$H(z) = \frac{b_0 + b_1z^{-1} + b_2z^{-2}}{1 + a_1z^{-1} + a_2z^{-2}}$$

and a sample rate of f_s Hz.

- (a) What is the value of $H(z)$ at 0 Hz?
- (b) What is the value of $H(z)$ at $f_s/2$ Hz?
72. (8 pts) If $*(0x100)=1$, $*(0x101)=2$ and $*(0x102)=3$, what will be the content of AC0 after the following instructions are executed?

(a) MOV #0x100,AR0
 MOV db1(*AR0),AC0

(b) MOV #0x101,AR0
 MOV db1(*AR0),AC0

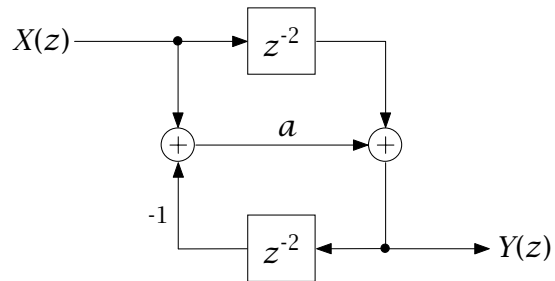
73. (4 pts) Rewrite the following equation using Horner's method/ordering:

$$a_4x^4 + a_3x^3 + a_1x^1 + a_0 = \underline{\hspace{10em}}.$$

74. (2 pts) VHDL and Verilog are _____ languages.
75. (2 pts) “_____ is a high-level design methodology in which the design is described by registers and the necessary of functions describing the transfer of data between these registers.”
76. (6 pts) Given a B -bit A/D converter whose output uses the 2's complement number format. The converter is set so that a zero input voltage corresponds to the mid range of the zero output value. The voltage corresponding to the most negative value is $-V_p$.
- (a) The most positive output value is _____.
- (b) The most negative output value is _____.
- (c) The voltage change which precisely produces a change of one count in the A/D output is $\Delta V =$ _____.
77. (4 pts) In many instances it is useful to have a nonlinear relationship between the voltage at the input of an A/D converter and its output values. This is particularly true in the telephone system where a compression technique called _____ is used with an 8-bit A/D converter to give a perceptual quality of a _____ bit linear A/D converter.
78. (2 pts) Given the z -transform of a filter transfer function the associated frequency response can be determined by evaluating the transfer function where in the z -plane?
_____.
79. (2 pts) A finite response filter uses the current input sample and the M
_____.
80. (2 pts) An all-pole filter uses the the current input sample and the N
_____.

81. (4 pts) Write a line of MATLAB code to generate a table, `sine_table` of N samples of one period of an unit amplitude sine wave.
-

82. (4 pts) For the filter shown below draw its transposed form.



83. For the above filter:

(a) (4 pts) what is the transfer function, $H(z)$?

(b) (3 pts) what are the values of $H(z)$ at $f = 0$, $f_s/4$ and $f_s/2$?

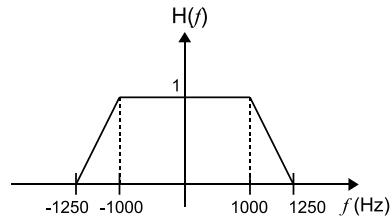
84. (8 pts) A set of measurements is made in order to estimate the group delay through a reasonably broad band measurement system.

Hz	phase (degrees)
1000	-120
1250	90
1500	-60
1750	150

What is the group delay? Hint: plot the data then think about it.

85. Let $x(t) = 3 \sin(2\pi f_{c1}t) + 2 \sin(2\pi f_{c2}t)$ where $f_{c1} = 800$ Hz and $f_{c2} = 1200$ Hz. We sample the signal at $f_s = 2500$ Hz.

- (a) (2 pts) Before we sample the signal, we pass it through an anti-alias filter. The filter response looks like the following



Can this filter prevent aliasing?

- (b) (6 pts) Next we take $N = 100$ samples at the anti-alias filter output, and take a N -point DFT using the “non-standard” definition by multiplying the forward DFT with $1/N$. What does the spectrum look like? Specify the magnitude of the DFT and the range AND the resolution in frequency that can be observed. Is there any leakage?
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86. (4 pts) The following code is used to generate a DTMF signal. Will the code work as desired? If not, what is the problem with this code?

```
#include "McBSP_452.h"

int SineTable[256] = { ... };

int LeftInput, RightInput;

void AIC23_IO(unsigned port, int LeftValue, int RightValue)
{
    ...
}

void main()
{
    int index1, index2, output;
    long ac1, ac2, ftv1, ftv2;

    setup_codec();

    ftv1 = 62366504;
    ftv2 = 108179488;

    while(1){

        ac1 = ac1 + ftv1;
        ac2 = ac2 + ftv2;
        index1 = ac1 >> (32-8);
        index2 = ac2 >> (32-8);
        output = SineTable[index1] + SineTable[index2];

        AIC23_IO(2,output,RightInput);
    }
}
```