

5. (50 points) **Arithmetic on an 8-bit processor.** We have a really \$#!tty 8-bit processor that only has an adder and a bit shifter. It has no ability to perform multiplication or division. We need to compute $(100_{10} - 18_{10})/2$ using only addition and bit shifts.

(a) (15 points) First we're going to calculate the 2's complement representation of -18 . In the box below, write out the binary representation of $+18$, then take its two's complement. Also convert the binary to hex in the boxes at right.

	Binary	Hex									
+18	<table border="1" style="width: 100%; height: 20px; border-collapse: collapse;"> <tr> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> </tr> </table>									<table border="1" style="width: 100%; height: 40px; border-collapse: collapse;"> <tr> <td style="text-align: center; vertical-align: middle;">0x</td> </tr> </table>	0x
0x											
1's(18)	<table border="1" style="width: 100%; height: 20px; border-collapse: collapse;"> <tr> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> </tr> </table>									<table border="1" style="width: 100%; height: 40px; border-collapse: collapse;"> <tr> <td style="text-align: center; vertical-align: middle;">0x</td> </tr> </table>	0x
0x											
2's(18)	<table border="1" style="width: 100%; height: 20px; border-collapse: collapse;"> <tr> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> </tr> </table>									<table border="1" style="width: 100%; height: 40px; border-collapse: collapse;"> <tr> <td style="text-align: center; vertical-align: middle;">0x</td> </tr> </table>	0x
0x											

(b) (15 points) Now add the two's complement of 18 to 100. The result should be the same as $100-18$.

	Binary	Hex									
2's(18)	<table border="1" style="width: 100%; height: 20px; border-collapse: collapse;"> <tr> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> </tr> </table>									<table border="1" style="width: 100%; height: 40px; border-collapse: collapse;"> <tr> <td style="text-align: center; vertical-align: middle;">0x</td> </tr> </table>	0x
0x											
100_{10}	<table border="1" style="width: 100%; height: 20px; border-collapse: collapse;"> <tr> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> </tr> </table>									<table border="1" style="width: 100%; height: 40px; border-collapse: collapse;"> <tr> <td style="text-align: center; vertical-align: middle;">0x</td> </tr> </table>	0x
0x											
$2's(18) + 100_{10}$	<table border="1" style="width: 100%; height: 20px; border-collapse: collapse;"> <tr> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> </tr> </table>									<table border="1" style="width: 100%; height: 40px; border-collapse: collapse;"> <tr> <td style="text-align: center; vertical-align: middle;">0x</td> </tr> </table>	0x
0x											

(c) (10 points) Now divide the result of the addition from part 5(b) by 2 using a bit shift.

	Binary	Hex									
$2's(18) + 100_{10}/2$	<table border="1" style="width: 100%; height: 20px; border-collapse: collapse;"> <tr> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> </tr> </table>									<table border="1" style="width: 100%; height: 40px; border-collapse: collapse;"> <tr> <td style="text-align: center; vertical-align: middle;">0x</td> </tr> </table>	0x
0x											

(d) (10 points) Convert the result from part 5(c) to **decimal**.