Problem C, Solution

This is a PWM.

i) If the switch is open, the input to the non-inverting terminal of the comparator is just equal to the output of the Hall Effect sensor.

a) if the hall effect output is 1 V, the v+ is always less than v- so the output of the comparator is always 0.

b) if the hall effect output is 2 V, then v+ is higher than v- for (2-1.3)/(3.9-1.3)=27% of the time. So the output will vary between 0V (comparator output is short circuit to ground) and 12V (comparator output is an open circuit) with a duty cycle of 27%.

c) the duty cycle is now (3-1.3)/(3.9-1.3)=65%.

d) v+ is always greater than v-, so the duty cycle is 100% (the output is always high (12V)).

ii) In all cases v+ is 0.7 volts (using constant drop model of the diode), so v+ is always less than v-, and the output is always low (0V).

We can replace this part of the circuit with a PWM with an “inhibit” input. If we pull the inhibit line low, the output of the PWM is always low.

Note: the PWM output is low impedance for low output, but with a 5k impedance when the output is high.
If the amplitude of the square wave is $V_{sq}$ then the power delivered by the square wave to a resistance $R$ will be $V_{sq}^2 / R$. If this power is to equal that delivered by a sine wave of peak amplitude $V$ then

$$V_{sq}^2 = \left(\frac{V}{\sqrt{2}}\right)^2$$

Thus, $V_{sq} = \frac{V}{\sqrt{2}}$. This result is independent of frequency.

<table>
<thead>
<tr>
<th>Decimal</th>
<th>Binary</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>101</td>
</tr>
<tr>
<td>8</td>
<td>1000</td>
</tr>
<tr>
<td>25</td>
<td>11001</td>
</tr>
<tr>
<td>57</td>
<td>111001</td>
</tr>
</tbody>
</table>

(b) The maximum error in conversion occurs when the analog signal value is at the middle of a step. Thus the maximum error is

$$\frac{1}{2} \times \text{step size} = \frac{V_{FS}}{2^{N-1}}$$

This is known as the quantization error.

<table>
<thead>
<tr>
<th>Input</th>
<th>Steps</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>+2.5 V</td>
<td>+5</td>
<td>0101</td>
</tr>
<tr>
<td>-3.0 V</td>
<td>-6</td>
<td>1110</td>
</tr>
<tr>
<td>+2.7 V</td>
<td>+5</td>
<td>0101</td>
</tr>
<tr>
<td>-2.8 V</td>
<td>-6</td>
<td>1110</td>
</tr>
</tbody>
</table>

1.37 When $b_i = 1$, the $i$th switch is in position 1 and a current $(V_{sqrt}/2/R)$ flows to the output. Thus $i_o$ will be the sum of all the currents corresponding to "1" bits, i.e.,

$$i_o = \frac{V_{sqrt}}{R} \left(\frac{b_1}{2^1} + \frac{b_2}{2^2} + \ldots + \frac{b_N}{2^N}\right)$$

(b) $b_n$ is the LSB  
(b) $b_i$ is the MSB
RESOLUTION OF A/D
3.3V/1024 = 3.22 mV

TEMPERATURE RESOLUTION

VOLTAGE RESOLUTION = 1.5/1024 = 1.46 mV

\[ V_{\text{Temp}} = 0.00355(T_{\text{Temp}}) + 0.986 \]

\[ T_{\text{Temp}} = 281.69 V_{\text{Temp}} + 277.7 \quad \text{if} \quad \Delta U = 1.46 \text{mV} \]

\[ \Delta T = 281.69 \Delta U = 0.4^\circ \]

pbFlag is volatile because, to compiler, it looks like it doesn't change, so it could be optimized away.
main.c

#include <msp430.h>

#define P1LED BIT0
#define P1SW BIT3

/** This program sets up P1.0 as an output (connected
to an LED, and P1.3 as in input with a pull up
resistor, connected to a switch.
On the falling edge of P1.3 and interrupt is generated
that raises a flag.
In the main loop, if the flag is raised, the LED is toggled.
*/
volatile int pbFlag=0;
#define LED BIT0

void main(void) {
    WDTCTL = WDTPW + WDTHOLD; // Stop watchdog
    P1OUT &= ~P1LED; // Turn LED off.
P1DIR |= P1LED; // Make LED an output
    P1OUT |= P1SW; // Add resistor to switch
    P1OUT |= P1SW; // Make it a pull-up resistor.
    PIE |= P1SW; // Make interrupt falling edge.
P1IE |= P1SW; // Enable interrupt on switch.
P1IFG &= ~P1SW; // Clear interrupt flag.
    __bis_SR_register(GIE); // enable interrupts globally

    while (1){
        if (pbFlag) {
            pbFlag = 0;
P1OUT ^= LED;
        }
    }
    // Port 1 interrupt service routine
#pragma vector=PORT1_VECTOR
_interrupt void Port_1(void) {
    pbFlag = 1; // Set flag to signal interrupt.
P1IFG &= ~P1SW; // Clear interrupt flag.