**I. Converting Hexadecimal to Decimal**

Many of the elements in each line of WALTA DAQ data are hexadecimal numbers. To understand how the hexadecimal number system works, it is best to start by reminding yourself how the decimal system works. The decimal system has ten symbols (0 to 9) used to designate numbers. In order to express numbers greater than nine, additional columns are used with each column indicating a number zero through nine multiplied by a power of ten. Thus, 782 means 7x102 + 8x101 + 2x100.

Similarly, the hexadecimal system has 16 symbols (0 to 9, A, B, C, D, E, and F) used to designate numbers. In order to express numbers greater than fifteen, additional columns are used with each column indicating a number zero through fifteen multiplied by a power of sixteen. Thus, 7CF means 7x162 + 12x161 + 15x160.

Practice converting the following hexadecimal numbers to decimal.

1. AC 2. 435B 3. F68E163D

**II. Converting to and from Binary**

Some elements of the WALTA DAQ data must be converted to binary numbers in order to interpret them. The binary system has only two symbols (0 and 1) used to designate numbers. In order to express numbers greater than one, additional columns are used with each column indicating a zero or one multiplied by a power of two. Thus, eleven is expressed as 1011, meaning 1x23 + 0x22 + 1x21 + 1x20. Binary digits are called “bits”.

Practice converting the following decimal numbers to binary. Look for a pattern.

4. 12 5. 192 6. 204

Practice converting the following hexadecimal numbers to binary. Look again.

7. C 8. C0 9. CC

10. 4E 11. EF 12. 5A

**III. Representing Binary Flags with Hexadecimal Numbers**

Some of the information sent to and from the DAQ card is binary by nature: the PMT scalers are either on or off; a signal edge is either present or not present. Up to four pieces of this kind of information can be represented compactly with a single hexadecimal digit. For instance, the digit “E” (14 in decimal, 1110 in binary) can be used to indicate that counter 0 is turned off while counters 1, 2 and 3 are turned on. Notice that the counters are represented right to left by the binary bits. The rightmost bit is the 0th bit; the leftmost is the 3rd bit.

Find the single hexadecimal digit that represents each of the following configurations.

12. 0 and 2 on; 1 and 3 off. 13. All on. 14. 0,1, and 3 on, 2 off.

**IV. Mixed Flags and Numbers**

Rising and falling edge data appear as two-digit hexadecimal numbers in the DAQ data stream. When these are converted to binary, the leftmost three bits include two flags and an unused bit. The seventh (leftmost) bit is 1 if this is the beginning of an event record, 0 otherwise. The fifth bit is 1 if an edge is measured for this counter, 0 otherwise. The rightmost five bits represent a number (the number of 0.75 ns intervals elapsed between the 24 ns clock tick and the rising or falling edge). For example, B9 (10111001 in binary) indicates that this is the beginning of an event record, and that a rising edge is detected on this PMT beginning 25 (110012) 0.75 ns intervals after the 24 ns clock tick. [Note that if bit 5 is 0, then bits 0 through 4 are irrelevant. Generally they will read 00001 or 00000 — it doesn’t matter which.]

Practice interpreting the following data.

Binary Start of Event? Edge? Intervals Time

15. A6

16. 3F

17. B8

18. 80

19. 22

**V. The Three Clocks**

The last step in preparing to interpret the DAQ data stream is to understand the three clocks that are used to time events. The first is the GPS clock supplied by government satellites and synchronized with the atomic clock. We use the GPS signal to get the time to the nearest second.

The second clock is in one of the DAQ chips and counts off approximately 24 ns intervals. The chip keeps track of this by incrementing a 32-bit counter, which simply rolls over when it reach 232 (4,294,967,29610). This counter (which appears in the data stream as an eight digit hexadecimal number) is read every time the GPS clock signals one second, and every time an event occurs. By subtracting, we can find out how many 24 ns intervals elapsed between the second and the event.

The third clock ticks every 0.75 ns, and counts the number of 0.75 ns intervals between the last tick of the 24 ns clock and a rising or falling edge from one of the PMTs.

**A. Reading the GPS Time**

The number in the data stream with a decimal point in it is the GPS time. The last number is an adjustment (don’t worry why) in milliseconds. Combine them and round to the nearest whole number. For example:

3DF3D234 36 38 2F 01 00 01 01 2D 3CC24AA6 125850.443 090704 A 07 2 +0344

The GPS time is 12:58:50.443 + 0.344 s rounded to the integer second, 12:58:51.

Find the GPS time for each of the following.

355F168F 00 01 21 2D 00 01 00 01 33776930 210721.183 070704 A 06 0 -0365

AEBB0E41 01 2E 01 3F 00 01 01 00 AECE56EF 021907.194 080704 V 04 2 +0678

**B. Calculating the 24-nanosecond Intervals**

The first 8-digit hexadecimal number in a line of data is the reading on the 24-ns counter at the time the edge data in the line was collected. (Those are the 2-digit hexadecimal numbers. We’ll get back to them.) The second 8-digit hexadecimal number in a line of data is the reading on the 24 ns counter at the moment that the GPS time was recorded. Subtract to find the number of 24-ns intervals elapsed between the second and the beginning of the data. For example:

3DF3D234 36 38 2F 01 00 01 01 2D 3CC24AA6 125850.443 090704 A 07 2 +0344

3DF3D234116 - 3CC24AA616 = 0131878E16 = 20,023,18210 intervals.

If the 24-ns timer could be relied upon to keep a constant beat, this would translate to (20,023,182 x 24 x 10-9) seconds, or 0.480556368 seconds. Unfortunately there is a complication that we will have to deal with in an appendix.

Find the number of 24-ns clock intervals for each of the following lines.

355F168F 00 01 21 2D 00 01 00 01 33776930 210721.183 070704 A 06 0 -0365

014D861A A8 01 2B 35 00 01 3E 01 FFAE431D 162148.090 070704 A 07 2 +0691

Ah oh. The counter “turned over” on that last line. You will have to subtract FFAE431D from 1014D861A. (Note the leading 1.)

**C. The 0.75-ns Edge Timer**

The eight 2-digit hexadecimal numbers represent rising and falling edges of PMT signals on channels 0 through 3. The first is the rising edge for channel 0; the second is the falling edge for channel 0. The third is the rising edge for channel 1, etcetera. They are interpreted as described in section IV of these worksheets.