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## Conversion of NGP-0 Coordinates to Device

### Specific Coordinates

Conversion of NGP-0 coordinates to floating point PDP-10 coordinates was discussed in RFC #387. In general, however, it is undesirable to convert NGP coordinates to floating point coordinates because real devices require integer addressing. To this end, a means is described to convert NGP coordinates to integer coordinates in the range zero to M, where M is the maximum address of the device screen on a machine using 2's complement arithmetic. It would not, however, be difficult to modify this algorithm to operate on machines using one's complement or sign-magnitude arithmetic.

First consider the NGP coordinate format:

```
+---+-----+
|   |   n   |
+---+-----+
s ^  FRACTION
i
g
n
```

Where the sign occupies the most significant bit of the coordinate followed by bits of numerical information (initial implementation of NGP requires N=15). Negative numbers are represented by 2's complement. Conversion to device coordinates is accomplished by:

$$D = S * f + S$$

Where D => integer device coordinate  
S => scaling factor (typically M/2)  
f => NGP fractional coordinate

Let us rewrite this as:

$$D = S * (2^n * f) / 2^n + S$$

Now factor S into two terms:

$$S = Q * 2^I$$

Where Q is an odd integer and I is an integer.

When:

$$\begin{aligned} D &= Q * 2^{I-n} * (2^n * f) / 2^n + S \\ &= Q * 2^{I-n} * (2^n * f) + S \end{aligned}$$

The factor  $2^n$  is represented in 2's complement form simply by extending the sign bit of f into the upper portion of the computer word, If  $Q = 1$  (as it would be with many devices), it can be ignored. If  $Q \neq 1$ , we may console ourselves that an integer multiply is faster on most machines than a floating point multiply. In fact, on a PDP-10, this multiply can usually be performed with no access to memory since Q is usually small.

We are now left with the  $2^{I-n}$  factor. This can be accomplished with an arithmetic shift left by (I-n) or an arithmetic shift right by (n-I) as is appropriate. The offset factor, S, may now be added using an integer add.

The procedure for converting NGP coordinates to integer device coordinates is then:

1. move coordinate to a register and extend sign
2. integer multiply by Q (if necessary)
3. arithmetic shift left by (I-n)
4. integer add S

This procedure would generally be much faster than:

1. move coordinate to register and extend sign
2. float fractional coordinate
3. floating point multiply
4. floating point add
5. conversion to fixed point

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