illustrates communications failure, and FIG. 4G illustrates a subroutine for reading external reference time).

In the start-up phase of the device, shown in FIG. 4A, three comparisons, each separated by a time τ_{min}, are made between the internal time of the device and the time of the external reference. The initial time between measurements is set to be long enough so that the measurement noise is small compared to an initial estimate of the capabilities of the device. The internal time can be set correctly after the first measurement, the first estimate of the frequency is made after the second one, and a first estimate of the drift in frequency can be made after the third measurement. Since only three measurements have been made, the device is not yet able to estimate the other parameters.

The algorithm continues with its steady-state phase, which is shown in FIG. 4B. At the start of the steady-state phase, the predictive power of the model is still relatively poor and the time interval between external calibrations is accordingly relatively short. This initial interval is estimated from the stability characteristics of the oscillator, from the maximum allowable error for the device, from the uncertainty in measuring the external standard, and from the cost of each comparison.

When this interval has elapsed, a comparison between the internal time and the external standard is initiated. If both the current measured difference and the previous one are statistically acceptable, then these data are used to update the model parameters and the model is used to compute the correction to the free-running time and frequency of associated oscillator/clock unit.

As the predictive power of the model improves, the time between comparisons can be increased (while maintaining the same average error) or the average error of the device can be reduced (by maintaining the same time between comparisons). The choice between these two possibilities is governed by the balance between desired accuracy and the cost of external comparisons. When the specified delay has elapsed, the process is repeated.

If either the current or the previous measurements were rejected, then rejection tests are commenced. If the current measurement was rejected, but the previous measurement was acceptable (See FIG. 4C), then a second "quick" comparison is immediately initiated and the statistical tests are repeated. If the second "quick" comparison is accepted, then the rejection of the first current measurement is modeled as a transmission error. The second "quick" comparison is used as a valid estimate before returning to the steady-state loop.

If the previous measurement was acceptable but both the current measurement and its "quick" repeat are rejected, then there are two possibilities. If the current measurement and its "quick" repeat agree in a statistical sense, then both measurements are modeled as valid and the associated oscillator/clock unit may have experienced a step in time and/or in frequency with respect to the external reference. If so, the time of the clock is reset, and this fact is stored before returning to the main loop.

If the current measurement and its "quick" repeat disagree in a statistically significant way, then a serious error has occurred in the device or the noise in the transmission or comparison processes is too high to support the desired accuracy. If so, a flag is set to indicate this, followed by a return to the start-up mode to try to re-initialize the device. If this problem re-appears, then either the device has failed or the specified tolerances are inconsistent with the fundamental noise of the device or of the transmission and comparison procedure.

If the current measurement (or its "quick" repeat) is acceptable, but the previous measurement was rejected (See FIGS. 4B through 4E), and if that previous rejection was modeled as a time step, then that assumption is now confirmed since the reset of the clock restored the device to statistically acceptable behavior. The time step is incorporated into the time of the device and the normal operating loop is resumed.

If the current measurement and its "quick" repeat are consistent, and both rejected, and if the previous measurement and its "quick" repeat were consistent, and both rejected (See FIG. 4D), then the local device may have experienced a frequency step (in addition to a possible time step). New estimates are computed for both the frequency and the time of the local device using the previous and current measurements.

If the performance of the device is acceptable at the next measurement, then the steps are incorporated into the model and the operation returns to the normal loop. If the performance cannot be made acceptable using both a frequency step and a time step, then a serious error has occurred. A flag is set to indicate this, followed by a return to the start-up mode to try to re-initialize the device. If this problem again reappears, then the device has failed. At this point it is possible to fall-back to a free-running mode (as is currently available on the market) and set an unhealthy flag to inform the user. In any case, the time can be reset, which will provide some time accuracy enhancement.

A similar situation can arise if the external calibrations become unavailable (See FIG. 4F). As shown in FIG. 4G, the algorithm will also enter this mode if the external calibration data repeatedly fail format, checksum or other checks for internal consistency.

The device of this invention has been implemented in a small computer and has been used to correct the clock in the computer. This internal clock was implemented as a crystal-controlled oscillator connected to a counter. This oscillator initially exhibited a frequency offset of 4.022 seconds/day and a drift in frequency of 0.6% per day.

If the time of this clock was corrected using only the parameters in equation (1), the flicker and random-walk frequency modulations results in residual root-mean-square (RMS) time errors of 122 milliseconds after 1 day. When the device and method of this invention were used, however, the RMS time error was reduced to 5.3 milliseconds after 1 day, and the average error was 3.1 milliseconds. As discussed above, a tradeoff could be made between desired accuracy and the time between external calibrations.

As can be appreciated from the foregoing, this invention provides an improved device and method for enhancing the accuracy of the output of a unit, and particularly for enhancing the frequency and/or time output of an oscillator/clock unit.

What is claimed is:

1. A method for enhancing accuracy of an output of a unit utilized with a utilization network, the output of the unit having an accuracy which departs over time from a predetermined standard, said method comprising:

receiving the output of the unit;