EverSet® ES100 Energy Consumption Minimization

SCOPE

This application note provides details and calculations related to the energy consumption of the ES100 EverSet® receiver, and provides guidelines intended to minimize the energy used in battery operated devices. The amount of energy consumed in an initial date and time reception operation, as well as the energy required for a periodic adjustment for drift (tracking operation), depends on the system-level algorithms. The ES100 energy consumption for a single date and time reception attempt in a 3V system is 4.1 W·sec, or 4.1 J (121sec at the Acquisition Mode Current, and 13sec at the Processing Mode Current). The ES100 energy consumption for a single tracking reception attempt in a 3V system is 0.7W·sec, or 0.7 J (22sec at the Acquisition Mode Current, and 1.5sec at the Processing Mode Current). This application note describes energy-conserving algorithms for both date and time reception and tracking reception, which may be modified according to individual system requirements. The host MCU controls the starting and stopping of receptions as well as the antenna selection. Once started, the ES100 will continue date and time reception attempts until the date and time are successfully received, or until stopped by the host MCU. Tracking receptions are initiated one-at-a-time by the host microcontroller (MCU) at the appropriate time to capture the sync word in the WWVB broadcast.

BACKGROUND

The ES100 was designed to receive and decode the 1-minute frame of the WWVB phase-modulated (WWVB-PM) signal that is broadcast from Fort Collins, Colorado. The broadcast format, detailing the assignment of each bit in the frame, is described in the document "Enhanced WWVB Broadcast Format", which is available at the NIST Radio Station WWVB website.

The ES100 supports two antennas mounted perpendicular to each other, and parallel to the floor, so that regardless of the clock's orientation, at least one antenna will be capable of receiving the signal. Being perpendicular, if one antenna is positioned in a "null", the other will be positioned for optimal signal reception. It is likely that in most orientations, both antennas will receive the signal, thus providing the receiver with a degree of freedom that may be helpful in avoiding interference.

A Radio Controlled Clock (RCC) that utilizes the legacy WWVB-AM signal, must re-acquire the signal each night to detect possible Daylight Savings Time (DST) transitions in order to apply the 1-hour correction on the right day. This is not the case with the WWVB-PM signal. The WWVB-PM signal provides advance notice of the date and time for the next DST transition, which is stored in the ES100 "Next DST" registers after a successful date and time reception. This means that most reception operations in the ES100-based RCC are needed only for drift compensation (tracking). The frequency of the tracking operations depends on the accuracy of the clock movement and the performance goals of the end product. It is important to note that the ES100 tracking mode is designed to work only if the clock drift has not exceeded +/-4 seconds.

Every half-hour, for a duration of six minutes, the normal WWVB-PM 1-minute frames are replaced by the WWVB-PM extended-mode time code sequences. The ES100 is not capable of receiving during these six-minute intervals that occur from HH:10 to HH:16 and HH:40 to HH:46 each hour (i.e. HH = 00, 01,…, 23). These times are illustrated by the shaded areas in Figure 1. Before the time is known by the clock, the host MCU cannot know when these six-minute intervals will occur. For that reason, the algorithm defined in this application note recommends initial date and time reception attempts every two hours and fifty minutes. After the initial date and time reception, the clocks host MCU can avoid the extended-mode times for subsequent reception operations (tracking or full date and time). Reception is much better at night than it is during the day (by a factor of up to 100, depending on location). Once the time is known, the host MCU can also choose to start reception attempts at night for a better chance of success.

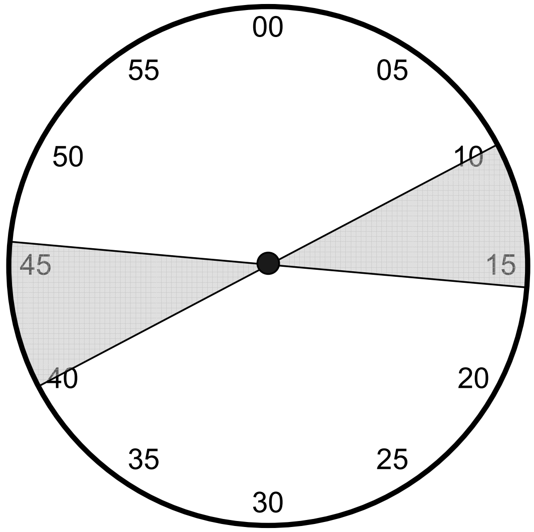

Figure 1 - Extended mode transmission times in each hour

ES100 INITIAL RECEPTION AND DRIFT ADJUSTMENT

The host microcontroller date and time reception flow chart is shown in Figure 2 and the host microcontroller tracking reception flow chart is shown in Figure 3.

The suggested date and time reception routine can run for up to six consecutive 1-minute mode reception attempts. It will terminate when a successful reception occurs, or after the sixth failed attempt, whichever occurs first. The routine alternates between antenna inputs on each attempt. After a successful reception, the antenna input that the reception occurred on should be stored by the host MCU for use as the starting antenna on subsequent reception operations.

For initial date and time acquisition, which would be invoked at power-up, the date and time reception flow chart suggests up to 32 attempts before aborting. This would span about 4 days if reception was not successful. The time gap between each group of 6 reception attempts is set to two hours and fifty minutes from the start of the previous reception attempt. This interval was chosen because the current time is unknown, and waiting two hours and fifty minutes (rather than exactly 3 hours) will avoid the possibility of continually repeating the worst-case situation where the reception attempts occur during the extended-mode time code transmission. A successful reception is likely to occur during the first 24 hours since a number of the reception attempts will happen at night, when the signal is stronger. After four days it can be assumed that the clock is in a location where reception is not possible.

Once the initial date and time have been acquired, tracking mode is used to accommodate drift adjustments. The accuracy of the clock movement and the allowable amount of drift specified for the RCC will determine how often tracking receptions must occur. Since the time is now known, the extended-mode time code transmissions can be avoided and the tracking reception attempts can be initiated at night for the best chance of a successful reception. The first attempt to receive should start with the previously successful antenna input, which is assumed to have maintained the same conditions. However, there is always a possibility that the clock has been moved, or that reception conditions have changed (due to changes in interfering signals in the environment, etc.), for which there would still be the capability of attempting reception from the other antenna.

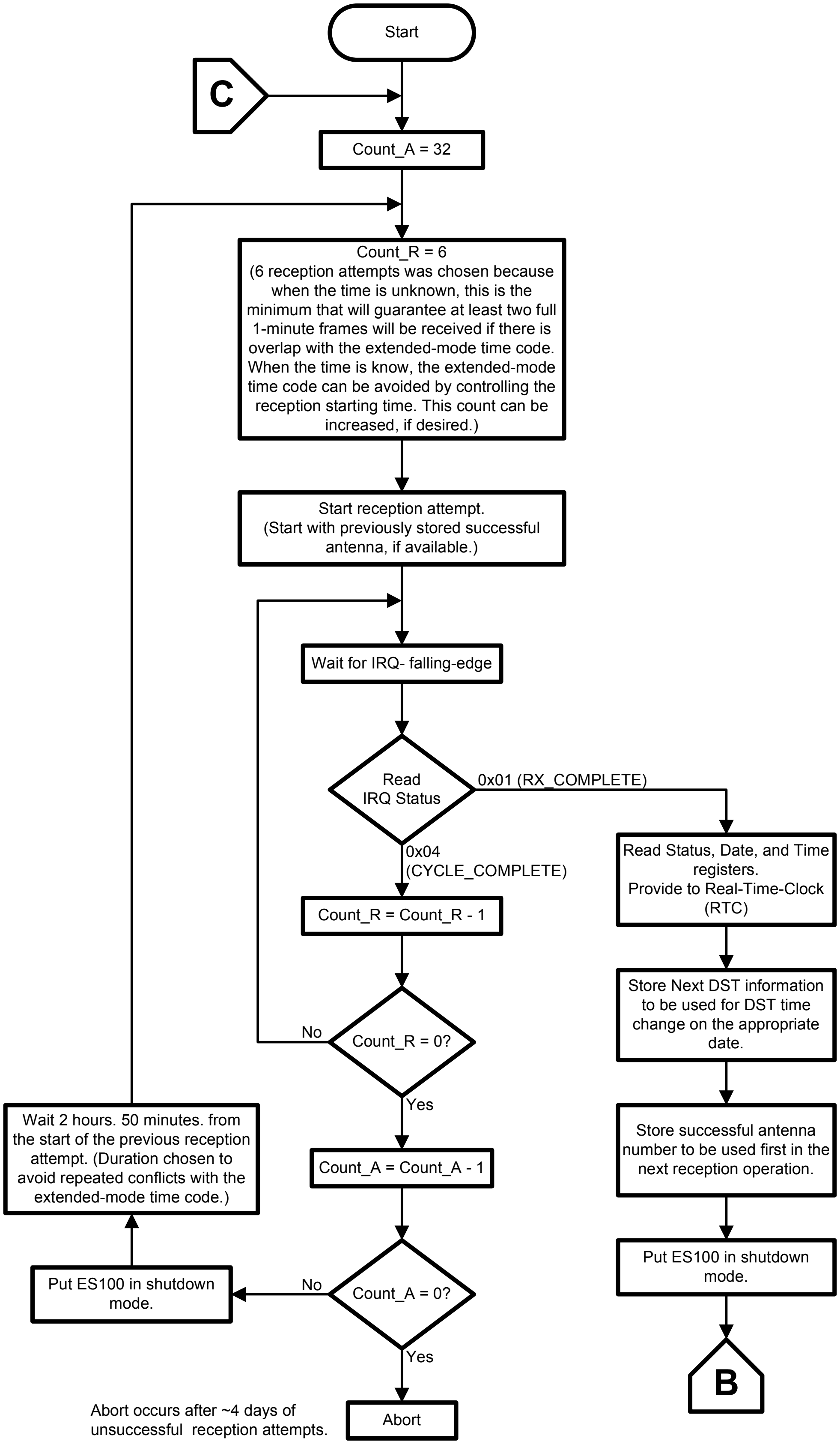

Figure 2 - Host Microcontroller Date and Time Reception Flow Chart

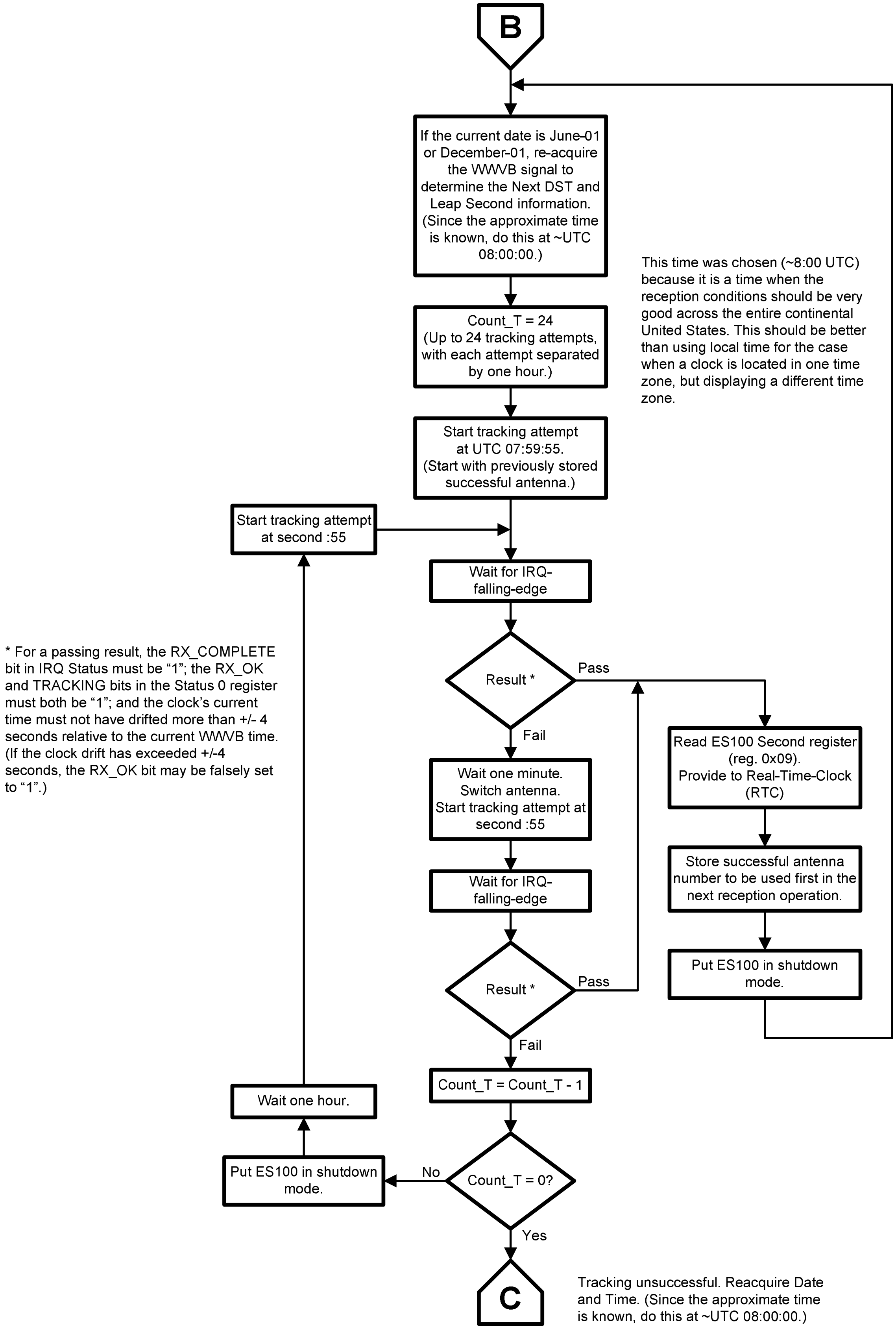

Figure 3 - Host Microcontroller Tracking Reception Flow Chart

ES100 ENERGY CONSUMPTION CALCULATION

The upper bound on the energy consumed for initial reception, assuming that it is successful within the first 24 hours (8 intervals of 2 hours & 50 minutes, each having up to 6 reception attempts), when assuming 4.1 J for a reception attempt, is:

$$E_{init} < 8 \times 6 \times 4.1\ J = 197\ J$$

Assuming the tracking operation takes place only once per day for one year, and is successful on the first reception attempt due to night time reception on a previously stored successful antenna input:

$$E_{drift\_year} = 365 \times 0.7\ J = 256\ J$$

Assuming full date and time receptions are only necessary on June-01 and December-01 (to determine next daylight-saving time transition date and end-of-month leap second warning), and are successful on the first reception attempt due to night time reception on a previously stored successful antenna input:

$$E_{dst\ \&\ ls} = 2 \times 4.1\ J = 8.2\ J$$

The energy used in shutdown mode for one year (365 days x 3V x 86,400sec per day at the Shutdown Current specified in the ES100 data sheet):

$$E_{shutdown\_year} = 365 \times 0.026\ J \cong 10\ J$$

This means that for an entire year the ES100 consumes:

$$E_{total\_year} = 197 + 256 + 8 + 10 = 471\ J$$

The energy available in two new alkaline AA batteries (assuming 2800 mAh available from common alkaline battery specifications) connected in series:

$$E_{total\_2AA} = 3\ V \times 2.8\ Ah \times 3600\ s/h = 30{,}240\ J$$

As shown, the energy required by the ES100 for a year of operation is a fraction of the energy available in the two AA batteries.