CUSTOM TURNKEY TIME & FREQUENCY SYSTEMS
A STRUCTURED, EXPANDABLE APPROACH

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Abstract

Radiocode Clocks Ltd. have developed a Turnkey Time and Frequency Generation and Distribution System strategy based upon a bus of three, "core" signals from which any Time code, Pulse rate or Frequency can be produced. The heart of the system is a ruggedized 19 inch, 3U Single Eurocard chassis constructed from machined 10mm aluminum alloy plate and designed to meet stringent Military, Security and Telecommunications specifications. The chassis is fitted with an advanced multilayer backplane with separate ground planes for analog and digital signals ensuring no degradation of low noise frequency references in the proximity of high speed digital pulse transmissions.

The system has been designed to be used in three possible configurations:

a) As a stand alone generation and distribution instrument.

b) As a primary distribution unit in a turnkey Time and Frequency system.

c) As a secondary distribution unit at a remote location from the Turnkey Time and Frequency System providing regeneration of core signals and correction for transmission delays.

When configured as a secondary distribution unit the system will continue to provide usable outputs when one, two or even all three of the "core" signals are lost.

The instrument's placement within a system as a possible single point of system failure has required the development of very high reliability translator, synthesizer, phase locked loop and distribution modules together with a comprehensive alarm and monitoring strategy.

INTRODUCTION

The requirements for sources of Precise Time and Frequency have grown substantially in recent years, not just in the number of projects but also in their complexity. An increasing number of users are specifying redundancy, high reliability, expandability and a plethora of Time code, Pulse rate and Reference frequency outputs in their systems. In dual or triple

redundant configurations the switching, monitoring and alarm management of such a myriad of signals can become technically complex, commercially expensive and, in many cases, can reduce system availability. This, coupled with the tightening of international standards with regard to electromagnetic compatibility, electrical safety and product quality, has lead to the development of a new strategy for Time and Frequency distribution.

SYSTEM ARCHITECTURE

Traditionally, when designing a turnkey distribution system, two or three master clocks, frequency standards or time code generators are fitted with one of each required system output. In some complex cases an atomic frequency standard will provide a stable reference frequency to a pair of low noise quartz oscillators via individual frequency or phase locked loops. These oscillators then produce one of each of the required frequency outputs which are fault detected and switched to a frequency distribution unit, while a GPS or Off-air master clock synchronizes two or three time code generators, each of which produces one of every required time or time interval output. These in turn, are majority voted, fault detected and switched to a timing buffer or distribution unit.

The addition of features such as secondary power supplies, alarms and output monitoring quickly make the system difficult to use, very inflexible, costly to manufacture and support and inefficient in terms of spares ranging.

Our solution to these problem has been to reduce the number of switched signals to an absolute minimum and to use these "core" signals as references with which to generate the required system outputs. Using conventional copper or fiber optic technology the minimum "core" signal count is three, a 1 Pulse per second (1 PPS) epoch marker, a 10MHz reference frequency and a proprietary format RS422 time message.

These "core" signals are generated by one or more Time and Frequency Standards such as GPS or Off-Air receivers, free running atomic or quartz clocks or a combination of the above. The "core" signals, plus alarm and status signals from the master time and frequency source are fed to an intelligent monitor and changeover unit which will fault detect, majority vote and switch between sources. This unit also acts as a system alarm manager. The selected "core" signals are then fed to a high reliability, modular distribution chassis based upon a single Eurocard format and fitted with dual power supplies, an alarm management module, an input/expansion module and a backplane accommodating the "core" signals, power lines, alarm signals and inter-module control signals.

Because there are also smaller applications, where a single distribution chassis is sufficient and the use of an external source of time and frequency is not always necessary, a range of "core" signal generation modules, which could obtain time from an external reference, has been developed for the distribution system. These modules now include GPS, Loran, WWVB, MSF and DCF receivers, together with free-running master time and frequency sources.

Historically, the distribution of low noise frequencies and digital signals has been undertaken using two separate chassis. As this approach was considered cumbersome, a single chassis architecture was developed for the distribution of all time and frequency signals while maintaining

the quality of the outputs. This has been achieved by developing an advanced multilayer backplane with high isolation and separate ground planes for analog and digital signals allowing high speed pulse trains and low–noise frequencies to be processed in close proximity without any significant degradation in signal quality.

High reliability modules have also been developed which accept the required signals from the backplane and translate, synthesize and distribute virtually any Time and Frequency signal. Most modules are 4E wide and provide five isolated outputs of each signal. The Input module has been developed to provide expansion outputs of the "core" signals so that when the chassis is fully populated, additional modules can be added by simple connection of further chassis allowing virtually infinite expansion capabilities without having to modify or reconfigure all the instruments in the system.

Another important design consideration was the provision of high stability, very low noise reference frequencies within the distribution system. Good long and medium term stability can be achieved by using a Cesium standard or GPS-disciplined Rubidium atomic oscillator but typical specification requirements of 1×10^{-12} over 24 hours, 1×10^{-11} over 1 second, and phase noise below 110 dBc/Hz at 1 Hz offset from carrier could only be achieved by the use of a high quality ovenized quartz oscillator phase locked to the "core" 10 MHz signal.

Our standard PLL module uses a number of novel techniques to implement the well proven second order phase locked loop that has the required characteristics. In the short term, up to some tens of seconds, the phase locked loop's ovenized oscillator frequency can be more stable than the "core" signal; for this reason the phase locked loop is designed to have a time constant of about one minute. For longer time periods the loop holds the oscillator in phase with the 10MHz reference. Time constants of that order can be realized using analog techniques but when the requirement for "holdover" operation on loss of reference is considered the use of digital control becomes mandatory. A microprocessor controlled loop provides sophisticated solutions for all of the control problems but has inferior reliability performance. Worse still, the processor generates a broad spectrum of noise signals which are unwelcome in a module whose primary purpose is to provide high quality, low noise analog signal outputs.

The solution we have developed for this system is part analog, part digital proportional and integral control. The control loop error signal is formed by direct phase comparison of the 10MHz "core" signal and the local ovenized oscillator in a circuit which is effective over more than 320 degrees of phase, almost a whole cycle at 10MHz. The magnitude of the phase difference provides the control signal for a low frequency voltage controlled oscillator which clocks a 16 bit up/down counter. The sign of the phase difference determines the count direction. The counter outputs connect to a 16 bit DAC which provides the integral part of the loop control signal. When the phase difference has been driven to zero in a steady state condition the up/down counter ceases to be clocked and no other clock signals are active in the control system.

The integrator can set the ovenized oscillator control voltage anywhere in it's entire range but the largest proportional control contribution required has only a fraction of the value of the control range. This signal is a fraction of the loop error signal already derived from the phase detector; it is fed through an analog switch and summed with the signal from the DAC to form

the ovenized oscillator control voltage.

The proportional control is immediately active at a low level in response to a loop error; the integral control works to drive the phase to zero in the longer term. If the "core" 10MHz reference is lost then the integrator has the correct value to hold the oscillator at the last best control value indefinitely. The digital parts of the circuit fit readily into programmable logic and the controller adds no clock noise to the OCXO output.

Development of the Low Noise Phase Locked Loop Oscillator Module has provided us with a new time and frequency distribution sub–system, the TFD8000. This is now considered not only a product but a new strategy providing a structured, expandable approach to turnkey system design which has already proved cost–effective, reliable and easy to maintain in applications within the Defense, Security and Telecommunications Industries.
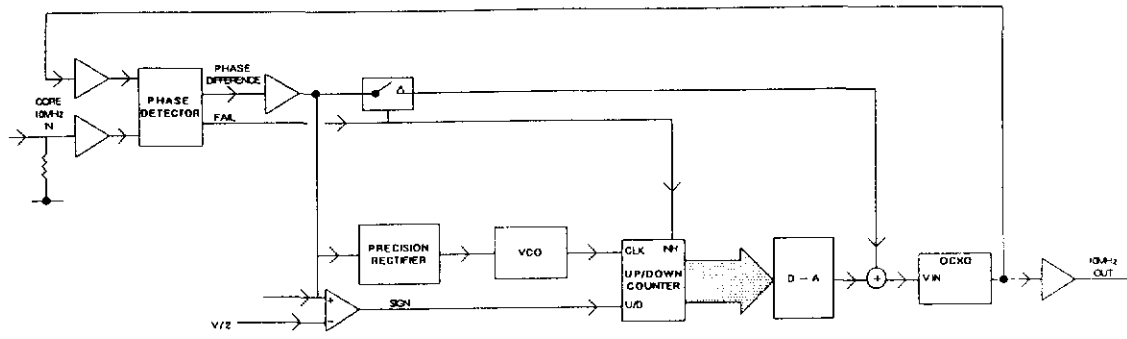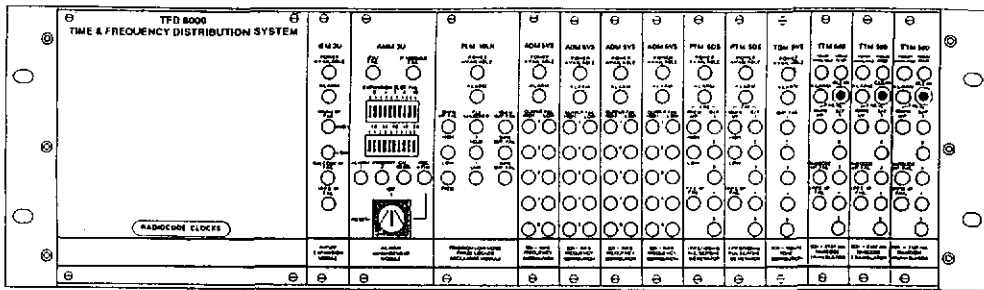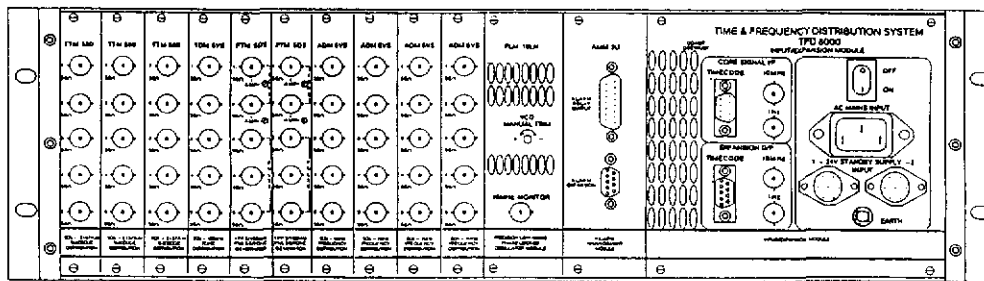
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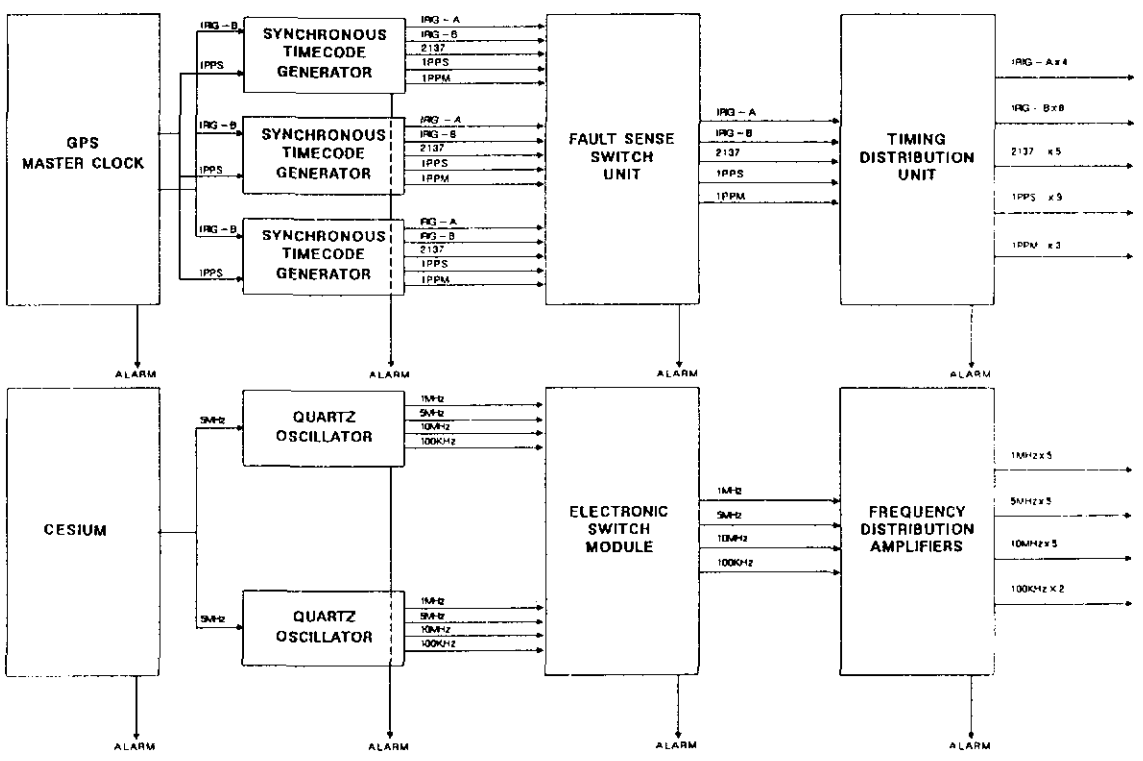
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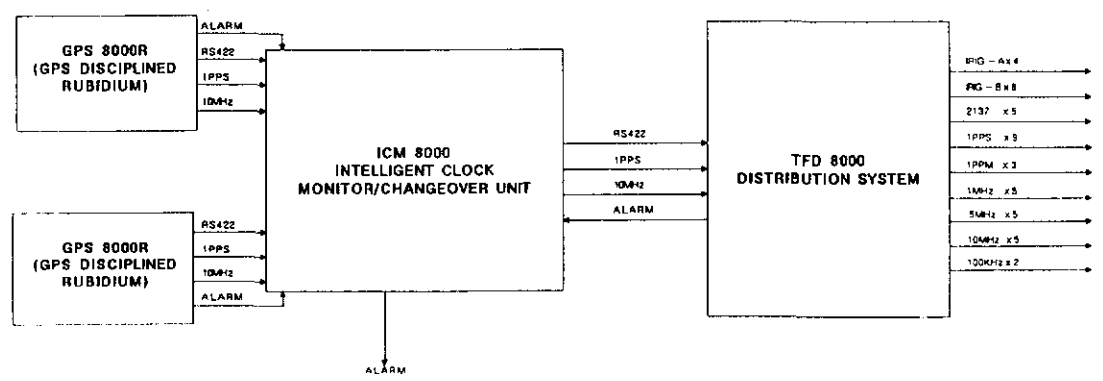
MODERN TIME & FREQUENCY SYSTEM

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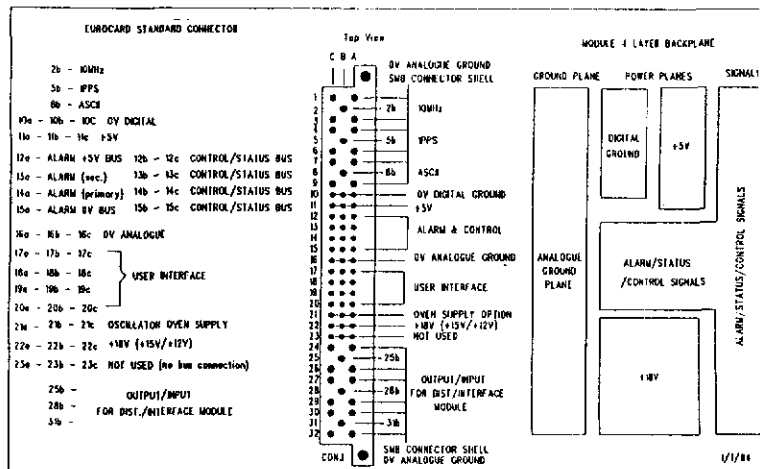**FRONT PANEL TYPICAL SYSTEM CONFIGURATION**

REAR PANEL TYPICAL SYSTEM CONFIGURATION

TYPICAL BACKPLANE CONFIGURATION