Time and synchronization formats

F.1 One pulse per second (1 PPS)

The I PPS signal shall be a positive pulse at least 5 us wide and have a rise time less than 50 ns. It shall be capable of driving a 50 ohm load to at least 5 V over 50 m of RG-58 cable.

F.2 IRIG-B format

IRIG-B is fully described in IRIG STANDARD 200-89, published by the Range Commanders Council of the U.S. Army White Sands Missile Range. The minimum format shall be B122, which has seconds through day-of-year coded in BCD and amplitude modulated on a I kHz carrier. Information needed for continuous precision timekeeping shall be added to the code in the control functions as described below. Straight binary seconds may be added as allowed in the standard, but shall not be required by either transmitting or receiving equipment. The amplitude shall be 1-6 V peak-to-peak for the mark (peak), with a mark-to-space amplitude ratio 10:3, as provided in the standard. The time code format is as follows:

<sync> **SS:MM:HH:DDD** <control> <binary seconds>

where

<sync> is the on-time sync marker
SS is the second of the minute [00 to 59 (60 during leap seconds)]
MM is the minute of the hour (00 to 59)
HH is the hour of day in 24 format (00 to 23)
DDD is the day of year (001 to 366)
<control> is a block of 27 binary control characters
<binary seconds> is a 17 b second of day in binary

F.3 Control bit assignment

By using IRIG-B with additional extensions, old and new time sources and time users can be easily integrated. PMUs should be programmed to check the control bit field and use this additional information where it is provided, but rely on user-entered data where it is not. Where possible, these new assignments are made with zero indicating a normal state since unused control field bits are normally set to zero. This will minimize the possibility of creating a false alarm, For example, if a control field was all zeroes, the time quality code would indicate the clock was locked with full accuracy that would not accidentally be interpreted as an error condition.

Virtually every timekeeping system is run by some kind of processor. Since IRIG time code numbers arrive AFTER the on-time mark, the timekeeping system must generate the time-tag based on the anticipated number, rather than on what it just got. Consequently, time counts that are not in exact sequence require advance notice. Non-sequence clock counts include leap year, leap second, and daylight savings time changes. The leap second and daylight savings change bits warn of impending special clock counts, and the last two digits of the year alert the timing system of leap year changes.

As an interpretation of the IRIG standard, BCD time and Straight Binary Seconds (SBS) should always be consistent. If BCD time changes by an hour for a daylight time change, SBS should change at the same time to reflect a consistent count. The year will rollover with BCD time regardless of whether it corresponds with UTC time.

Table F.1-Control bit assignments

IRIG-B Pos ID	CTRLB IT#	Designation	Explanation
P50	I	Year, BCD I	Last 2 digits of year in BCD
P51	2	Year, BCD 2	IBID
P52	3	Year, BCD 4	IBID
P53	4	Year, BCD 8	IBID
P54	5	Not used	Unassigned
P55	6	Year, BCD 10	Last 2 digits of year in BCD
P56	7	Year, BCD 20	IBID
P57	8	Year, BCD 40	IBID
P58	9	Year, BCD 80	IBID
P59	-	P6	Position identifier # 6
P 60	10	Leap second pending (LSP)	Becomes 1up to 59 s BEFORE leap second insert
P 61	11	Leap second (LS)	0 = Add leap second, 1 = Delete leap second
P62	12	Daylight saving pending (DSP)	Becomes 1 up to 59 s BEFORE DST change
P63	13	Daylight savings time (DST)	Becomes 1 during DST
P 64	14	Time offset sign	Time offset sign – 0=+, 1=-
P65	15	Time offset-binary I	Offset from coded IRIG-B time to UTC time IRIG coded time plus time offset (including sign) equals UTC time at all times (offset will change during daylight savings)
P 66	16	Time offset-binary 2	
P 67	17	Time offset-binary 4	
P68	18	Time offset-binary 8	
P 69	-	P7	Position identifier # 7
P70	19	Time offset-0.5 hour	O = none, 1 = additional 0.5 h time offset
P71	20	Time quality	4 b code representing approx. clock time error 0000 = clock locked, maximum accuracy 1111 = clock failed, data unreliable.
P72	21	Time quality	
P73	22	Time quality	
P74	23	Time quality	
P75	24	PARITY	Parity on all preceding data bits
P76	25	Not used	Unassigned
P77	26	Not used	Unassigned
P78	27	Not used	Unassigned
P79	-	P8	Position identifier # 8

F.3.1 Year

The last two digits of the year is in straight BCD in the same format as the rest of the IRIG-B code and follows first after day of year. It will rollover with the day-of-year in the BCD time count.

F.3.2 Leap second

The leap second pending (LSP) and polarity (LS) bits show that one is about to happen and whether it will be inserted or deleted. Leap seconds have only been positive for the last 20 years, so LS = 0 is almost certain. The LSP bit should be asserted at least 1 s and less than 60 s before the hour it is to be inserted. The bit should go to 0 when the second count goes to 00. Leap seconds are always inserted at UTC midnight by altering the second time count only. Thus, in UTC time the time count goes from 23:59:59 to 23:59:60 to 00:00:00 to add the extra second. In another time zone, say Pacific Standard Time, 8 h behind UTC, the same count will be 15:59:59 to 15:59:60 to 16:00:00. SBS should give the count 57 600 (=16:00:00) twice.

F.3.3 Daylight savings

The Daylight Savings Pending (DSP) and Daylight Savings Time (DST) bits indicate that a change is about to happen and whether daylight savings is in effect. If DST = 0, then the impending change will be to ON, which will delete I h from the time scale (leap forward I h in the spring) and the Daylight Savings bit will go to one. If DST = 1, the opposite will occur. Daylight time changes will be I h and are asserted at the minute rollover. The DSP bit should be asserted at least I s and less than 60 s before time is to be changed. The DSP and DST bits should change at the same time between the 59 s and 00 s counts. In the U. S., where the time change is put into effect at 2 a.m., the time count in the spring is 01:59:59 to 03:00:00. In the fall, the count is 01:59:59 to 01:00:00.

F.3.4 Local time offset

The local time offset is a 4 b binary count with a sign bit. An extra bit is included for an additional 1/2 h offset used by a few countries. The offset gives the hours difference (up to ± 16.5 h) between UTC time and the IRIG time (both BCD and SBS codes). Adding the offset to the IRIG-B time using the included sign gives UTC time (e.g., if the IRIG-B time is 109:14:43:27 and the offset is -06 given by the code 0110 (.0), then UTC time is 109:08:43:27). The local time offset should always give the true difference between IRIG code and UTC time, so the offset changes whenever a daylight savings time change is made. Keeping this offset consistent with UTC simplifies operation of remote equipment that uses UTC time.

F.3.5 Time quality

A 4 b time quality indicator is used by several manufacturers and is in several existing standards. It is an indicator of time accuracy or synchronization relative to UTC and is based on the clock's internal parameters. The code recommended here is by order of magnitude relative to 1 ns. It is basically the same as used in the HaveQuick and STANAG 4430 (NATO) time codes, but with a more practical scale. The 1 ns basic reference is fine enough to accommodate all present industry uses now and into the foreseeable future. With present GPS technology at the 100 ns accuracy level, a 0000 code indicating locked will go to a 00 11 or a 0100 code at unlock.

F.3.6 Parity

A parity bit is easy to implement by simply adding all the bits in the message from BCD seconds through the time quality control bits. (Straight Binary Seconds would not be included.) It provides some assurance the data is correct and a secondary verification that the control bit field has been implemented. An unused bit could not be mistaken for parity, since parity will change each second most of the time as the second count increments. The last three unused bits are left after the parity for user specific assignment without affecting this code. They could be used for higher order bits in a 4 b parity or LRC.

Table F.2-4 b quality indicator code

Binary	Hex	Value (worst case accuracy)
1111	F	Fault-clock failure, time not reliable
1011	B	10 s
1010	A	1 s
1001	9	100 ms (time within 0. 1 s)
1000	8	10 ms (time within 0.01 s)
0111	7	1 ms (time within 0.00 1 s)
0110	6	100 us (time within 10^{-4} s)
0101	5	10 us (time within 10^{-5} s)
0100	4	1 us (time within 10^{-6} s)
0011	3	100 ns (time within 10^{-7} s)
0010	2	10 ns (time within 10^{-8} s)
0001	1	1 ns (time within 10^{-9} s)
0000	0	Normal operation, clock locked

F.4 High precision time code format

IRIG-B format transmitted using modified Manchester modulation is recommended as an alternative to the AM modulated IRIG-B with separate I PPS sync. This modulation is better adapted for both fiber and metallic digital systems. With the previous control bit assignments, this time code format can serve all power industry requirements now and in the foreseeable future.

Manchester coding provides a 0 mean code that is easy to decode, even at low signal levels. The 1 kHz clock provides a precise on-time mark that is always present. The coding method mimics 1 kHz modulated IRIG with binary 1s and Os in place of high and low amplitude cycles. A Manchester binary 1 is equivalent to a high amplitude cycle in the AM modulation and a binary 0 indicates a low amplitude cycle. Using this modulation, an IRIG-B code "0" will be two 1s followed by eight Os. An IRIG-B code "1" will be five 1s followed by five Os (see figure F.1). This conversion keeps the codes compatible and makes translation or regeneration of the AM IRIG-B very simple.

Modified Manchester modulation is not included in the IRIG standard, so this is not an IRIG code. However, the Range Commander's Council is considering adding a Manchester modulation into the IRIG standard. This or a similar Manchester modulation format may be specified by 1997; users of this standard should consult IRIG and IEEE-PSRC for the most recent recommendation.

F.5 Modified Manchester coding

Manchester modulation or encoding is a return-to-zero type where the pulse transition indicates binary 0 or 1. In this case, a 1 kHz square wave is the basic clock modulated by the data to produce a rising edge to indicate a binary one (1) and a falling edge to indicate a binary zero (0). The transition at every data bit provides good receiver synchronization. Each bit period is half high and half low, so the mean is always half, making it easy to decode even at low levels. In standard Manchester coding, the data edge occurs in the middle of the clock window to indicate a binary one or zero. Since there is a data bit (i.e., transition) every clock period, it is easier to synchronize on the data than the clock cycle. The "modification" moves the data window so the data is at the edge of the clock window that is on time with UTC (see figure F.2). In another view, the modification simply defines the middle of the window as "on time." What is important is that the data edge is the "on time" mark in the code. This simplifies the construction of readers and regeneration of the other IRIG code forms.