

# **Example Specification for a Low Cost Eight Channel Telemetry System for Application in Experimental High Altitude Balloon Flights**

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## **Introduction**

This specification describes a design for a low cost telemetry system for use in many applications, but specifically designed for use in experimental high altitude balloon flights. This design incorporates the ability to monitor and telemeter signal data from eight different analog input channels. The analog data will be converted into digital format for transmission to a telemetry receiving station. The data can be transmitted in two different formats simultaneously. One format is standard AX.25 radio packet format (packet) and the other format is in International Morse Code (CW). The dual format provides convenience for two types of users, those who use a computer and radio packet receiving station and those who prefer a simpler communications protocol without the need for extra equipment for purposes of decoding the telemetry information. In addition to the eight channel analog telemetry capability, this system also includes the ability to provide timing and control signals for up to two digital cameras in the flight payload and also will provide up to 4 bits of digital status information. Additional capability also includes providing two different timed control signals that can be used for such things as payload release or other in-flight control. The time associated with these two timed control signals can be user selected for up to 4 different preset values for each timed signal (independently) via 2 digital inputs for each of the timed signals. A start up security sequence will be required so only authorized users can activate the beacon transmitter(s).

## **Specific Capability**

### **Analog Inputs**

The eight analog inputs will be selected sequentially, one at a time. Each will be sampled for approximately 1 second and the analog signal value will be converted into an internal digital format that can be stored in a temporary memory prior to being transmitted to the receiving telemetry station.

These analog input signals will be designated AnIn1 through AnIn8 respectively.

### **Digital Status Inputs**

Four bits of on/off digital status inputs are provided. These input bits can be in one of 16 different combinations of input. The current state of these status bits will be sampled once prior to each data transmission sequence and their state will be transmitted as a hexadecimal number from 0 to F as appropriate. Active high logic is assumed.

The input status signals will be designated S1 through S4.

## Timed Output Signals

Two independent timed output signals will be provided. Each output independently can have up to 4 different preset values. The specific preset time value will be selected via 2 digital input signals. Two input select bits are provided independently for each of the two timed output signals. All signals for this capability (input and output) are active high logic.

The output signals will be designated TO1 and TO2. The associated input control signals will be designated T1A, T1B, T2A, T2B.

## Telemetry Data Stream Format

The telemetry data will be available for simultaneous transmission via two independent formats. The first format is standard AX.25 radio packet format as is typically seen with GPS/APRS tracking systems.

The specific sequence is as follows: Status code will be sent first as a hexadecimal digit and will be repeated to be sent a total of 4 times. Then Analog Channel 1 value (4 digits), followed by Analog Channel 2, etc through to Analog Channel 8 will be sent. Following that sequence the phrase BALLOON EXPERIMENT will be sent and following that will be the radio transmitter identification callsign sequence which will be in the following format: DE callsign /BCN. This sequence will be sent as ASCII characters in the case of the packet telemetry message and will be sent as Morse Code characters in the case of the CW message. Appropriate spaces will be sent between each item in the message. Minor modifications in the transmitter identification sequence may be needed to meet the standard formatting for packet radio protocols.

```
Status code hexadecimal digit
Status code hexadecimal digit      (same single digit is
transmitted 4 times)
Status code hexadecimal digit
Status code hexadecimal digit
Analog Channel 1 value (4 hexadecimal digits)
Analog Channel 2 value (4 hexadecimal digits)
Analog Channel 3 value (4 hexadecimal digits)
Analog Channel 4 value (4 hexadecimal digits)
Analog Channel 5 value (4 hexadecimal digits)
Analog Channel 6 value (4 hexadecimal digits)
Analog Channel 7 value (4 hexadecimal digits)
Analog Channel 8 value (4 hexadecimal digits)
BALLOON EXPERIMENT
DE callsign /BCN (CW) or DE callsign - x (packet)
20 second keydown for the CW transmitter for tracking
purposes
```

**Figure 1. Data transmission sequence**

## **Operational Description**

The description that follows is for use of this design as part of a high altitude experimental balloon payload. This unit will require a special start up sequence in order to prevent unauthorized users from enabling the beacon transmitter(s) to transmit a signal. This is required to meet FCC Part 97 regulations since the transmitters typically used in amateur experimental flights can only be used as authorized under Part 97.

There will be two general modes, a pre-flight mode and a flight mode. During pre-flight mode, the beacon transmitter(s) will transmit a test sequence that can be used to verify the operation of the beacon and tracking transmitter(s). Remaining functions will not be activated until flight mode is activated.

Once flight mode is activated, the beacon transmitters will begin transmitting the sequence described above. Packet information will be sent first in a single packet stream. The packet data stream will have its own independent data output signal which can be used to modulate a packet dedicated transmitter. The CW message will begin immediately following the packet message and will have its own independent data output signal that will be used to on/off key a CW mode transmitter. In flight mode, the analog inputs will be sampled and the digital status signals will be sampled once for each data transmission sequence. A transmission sequence is defined as sending one complete packet message and one complete CW message. It is expected that one complete sequence will require approximately 60 seconds of time. Following the CW message identification, the CW transmitter will be keyed into the on state for 20 seconds to provide a continuous signal to assist with conventional radio direction finding tracking. One camera power on sequence and one camera shutter sequence will occur at the end of each transmission sequence. This will result in one picture taken (on each camera) for each full transmission sequence. The two timers (payload release and extra timed signal) will be updated once each transmission sequence. The timers will thus have a resolution on the order of about 1 minute. The payload release and extra timed signal will be normally in a low state, but will enter a high state when their respective timers have reached their preset time. The timers will be based on pre-loading a register with a count value and the respective signals will be activated when the time count reaches zero. The timer counters will be decremented once for each transmission sequence. Two input pins are provided for each timer so that each timer can be selected to use one of 4 different preset time values.

Once in the flight mode, the beacon transmitters will continue to transmit their message sequences until the power is turned off or the controller is reset. The camera activations will stop after 75 (or some other appropriate value) of pictures have been taken. This is because the typical low cost cameras used in this application will only hold about 75 pictures.

## Security Sequence

The security start up sequence is as follows. A special jumper must be in place when the processor is reset. If the jumper is in place, the unit will enter the pre-flight mode. Once in pre-flight mode, if the jumper is removed, the unit will enter flight mode. If the special jumper is not in place when the processor is powered up or reset, then the unit will simply enter a locked up mode that will not activate any functions.

## Optional Features

Additional optional features may be included. An example optional feature is an LED that is toggled in some fashion to indicate current mode of operation. Another possible optional feature is an audio tone (square wave) provided that matches in time with the CW message.

## Processor

Due to the need for analog signal sampling, the PIC16F877 processor will be used for this project. The PIC16F877 has more than adequate memory and more than adequate I/O signals to meet the needs for this project. The clock frequency will be set at 4 MHz using a quartz crystal to provide consistent timing which is needed primarily by the packet message feature.

## I/O assignments

I/O assignments are as follows for the PIC16F877:

PORTA –0	AnIn1	Analog in
PORTA –1	AnIn2	Analog in
PORTA –2	AnIn3	Analog in
PORTA –3	AnIn4	Analog in
PORTA –4		
PORTA –5	AnIn5	Analog in
PORTB –0	S1	Status In 1
PORTB –1	S2	Status In 2
PORTB –2	S3	Status In 3
PORTB –3	S4	Status In 4
PORTB –4	T1A	Timer 1 preset LSB in
PORTB –5	T1B	Timer 1 preset MSB in
PORTB –6	T2A	Timer 2 preset LSB in
PORTB –7	T2B	Timer 2 preset MSB in
PORTC –0	CW audio out (optional)	active high
PORTC –1	LED out (optional)	active high
PORTC –2	TO1	Timed Out 1 payload release

PORTC -3	TO2 Timed Out 2	extra timer output
PORTC -4		
PORTC -5	Packet Data Out	active high
PORTC -6	CW Data Out	active high
PORTC -7		

PORTD -0	Security startup sequence input	
PORTD -1		
PORTD -2		
PORTD -3		
PORTD -4	Camera 1 power control output	
PORTD -5	Camera 1 shutter control output	
PORTD -6	Camera 2 power control output	
PORTD -7	Camera 2 shutter control output	

PORTE -0	AnIn6	Analog in
PORTE -1	AnIn7	Analog in
PORTE -2	AnIn8	Analog in

### **Other**

The system is expected to be operated from a 6 volt DC power source (typically lithium battery pack) at temperature and altitude extremes up to 120,000 ft and temperatures as low as minus 50 degrees F. It is desirable for total system battery life to be as much as 7 days in the event of a lost payload. Normal flight times will not exceed 4 hours.

The beacon transmitters and camera systems are defined and described elsewhere and are beyond the scope of this document.