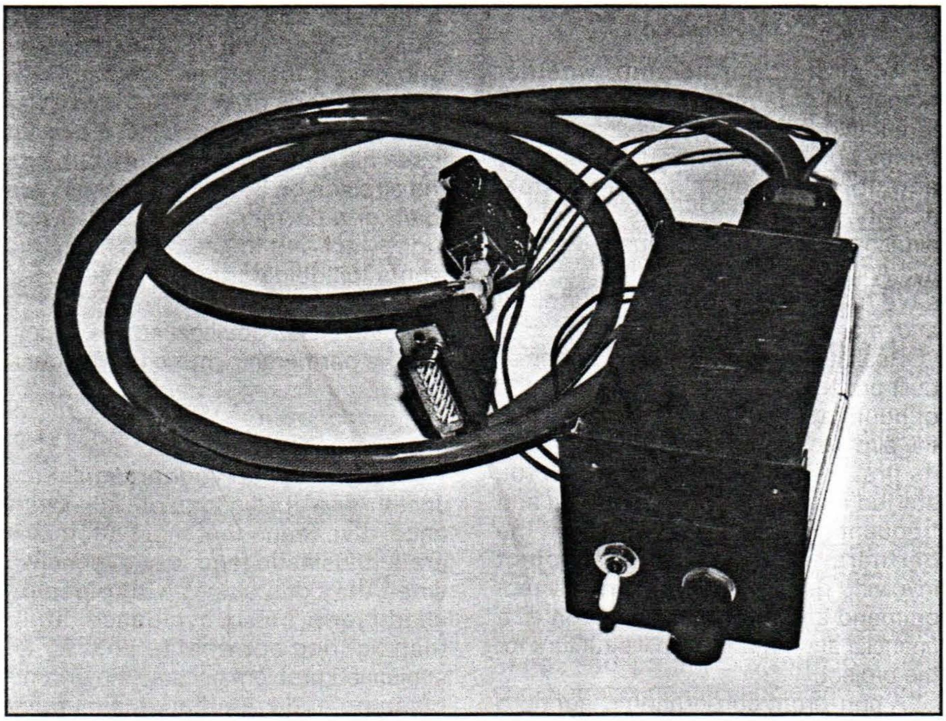

ALTITUDE ENCODERS . . . HOW TO GET SOMETHING USEFUL FROM THEM

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Wow! Heads Up Displays, Glass Cockpits, Lorans that do about everything. If you have been a regular reader of aviation magazines you have probably been amazed and perhaps awed at the innovations taking place in avionics these days. If you have plenty of money, you can go out, buy, and install some of these marvels. But for the majority of us, high cost keeps these instruments in the dream category. However, by experimenting and building with "off the shelf" electronic parts, we may be able to get some of these things (or something just as useful) in our airplanes at an affordable cost.

If you have been carefully studying these articles, you could not fail to understand that many of these electronic wonders are based on some pretty fancy computer technology. To understand how these wonders work, much less build something useful and put it in your airplane, requires somewhat more knowledge than how to screw in a light bulb. And, of course, high tech computer technology equates to EXPENSIVE. So what we want to do is make something low tech, therefore, INEXPENSIVE, but still useful. Keep in mind though, that what is low tech in electronics today can still be pretty snazzy looking stuff to most folks.

Using this approach, I've come up with a "brute force" TRANSPONDER ALTITUDE ENCODER READ-OUT device that you might like to duplicate.

This instrument can be used in several different ways: as test equipment to help you calibrate your altitude encoder/transponder set up; as a cockpit read-out device to verify that your encoder is operating and what altitude it is sending to the ground controller; as a safety device backing up your regular altimeter since it shows what your altitude is, within about plus or minus 50 feet; or if you are in a VFR only homebuilt, I believe the regulations will allow it to be used as your only altimeter. More about this later.

This encoder read-out does not need any calibration, no adjustments, or any test equipment to get it going; it doesn't contain any exotic or expensive parts, doesn't have any critical or high frequency circuits, and doesn't interfere with any of your radios or other instruments. After you build it, plug it in to your encoder and it will just sit there and report what altitude your encoder is broadcasting.

So why else, you might ask, would I want to tackle this project? As I'm sure you know, in July 1989 the FAA started requiring Mode C altitude encoding transponders on almost everything that flies within 30 nm of a TCA. With more TCAs on the way and the requirement to have Mode C around ARSA's, it's going to become increasingly tough to fly without Mode C. Since we're going to have to live with it, we might as well try to make some use of it for ourselves as well as try to reduce its initial and continuing costs. Mode C doesn't add one ounce of lift or make our airplanes fly better or faster, something the FAA just doesn't seem to understand.

In my opinion the FARs are a real mess! Full of contradictions and ambiguities that make it difficult to be sure what the regulations really mean. Putting an altitude encoding transponder into my VariEze, I soon realized, would not be simple. There is no legal definition of a VFR altimeter, transponder and encoder set-up. If you have an altitude encoder in your aircraft you must have your static system certified, your pilot's reference altimeter must meet IFR standards (even though the FAA has now ruled that your altimeter doesn't have to be TSO'd), and a data correspondence test must be performed to ensure that your altimeter and the transponder are reporting the same altitude, within certain tolerances. If you don't believe that the FAA has slipped it to us again, please dig out your FARs and carefully read 91.33(b), 91.33(d), 91.24, 91.81, 91.36, 91.171, 91.172 and FAR 43. They all refer to altimeters and transponder/encoder requirements. Depending on how these regulations are interpreted, some of the work must be done by an instrument/avionics certified repair station. You can't just wire up and plumb your static

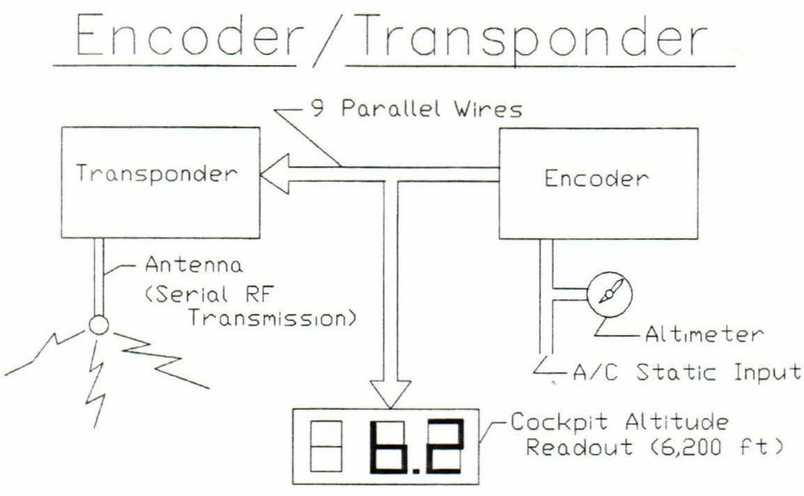

Figure 1

system, transponder and encoder and blast off into the sky.

To get all this work done by a certified repair shop may cost several hundred dollars at best and a whole lot more at worst. And it will be a recurring cost every two years. I decided to search for a way to soften this pain in the pocketbook. If I was able to ensure my set up was functioning correctly, at least I could avoid paying expensive shop time for the technician to adjust and correct problems I could have fixed myself. I found using the read-out device to ground test my encoder to be very useful.

But when I started flying with the read-out installed in my cockpit, that is when its real value became apparent. With it constantly reading out the encoder altitude, it quickly became a prime instrument in my scan. If you try it, I think you'll agree. With the FAA zero tolerance attitude, peace of mind is knowing your encoder is working and what it is reporting. This is particularly true if you are working ATC or are flying around Mode C required airspace. The read-out seemed so useful to me, I decided some of you might like one, too!

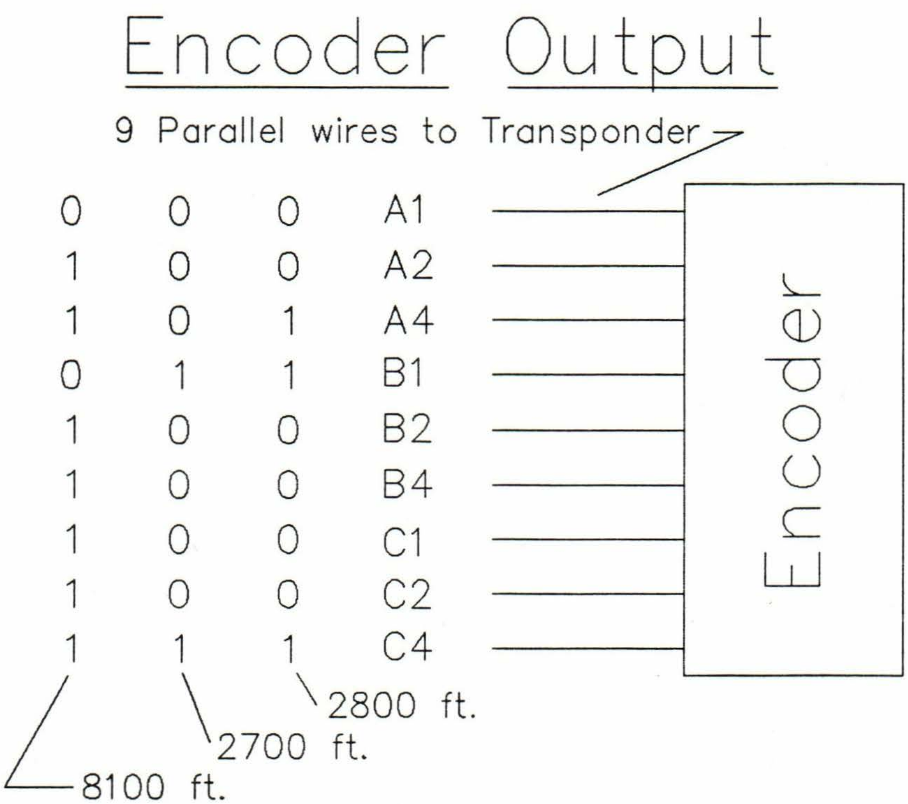

Figure 2.

A basic review of how a transponder/Mode C set-up operates will be necessary for you to understand how the encoder read-out functions. Figure 1 shows an encoder/transponder combined with the encoder read-out. The ambient air pressure goes into the airplane static input. That pressure causes the hands on the face of your altimeter to move in accordance with your altitude and acts on the transducer in the encoder. The transducer puts out an electrical signal that is converted to digital code which is sent to the transponder on a set of parallel wires (parallel format). The transponder is both a receiver and a transmitter. When it receives an interrogation signal from the ground station on 1030 Mhz, it transmits back the reply signal on 1090 Mhz.

The transponder concept and the technology that goes with it is the system that was developed during WW-II to identify friendly versus enemy airplanes. Sort of makes you wonder why the FAA is planning to use technology that is already over 50 years old well into the 21st century. Believe me, folks, there is nothing space age about this system!

The transponder sends out its reply signal that contains your squawk code and your altitude if you are squawking Mode C. The altitude signal it sends is the SAME as your encoder sent over to the transponder. However, the transponder is transmitting on only one frequency and, therefore, must send the data in a serial format rather than a parallel format. Looking a bit closer at the signal the encoder outputs to the transponder (Figure 2), you see the wires are labeled A1, A2, A4, etc. This is a standard designation for all encoders. An encoder only shows your altitude to the nearest 100 feet. For each 100 foot altitude increment the encoder puts out a unique digital code (combination of 1's and 0's) on the output lines. What's really important here is that each 100 foot altitude output has its own code and no code is repeated.

To make our read-out device work, we must connect into each of the wires going from the encoder to the transponder. Figure 3 is a block diagram of what's in the read-out box. The heart of the read-out is something called a Programmable Read Only Memory or PROM. These devices are non-volatile memories that retain the data stored in them even if power is removed. We are going to use the PROM to store a "look up table".

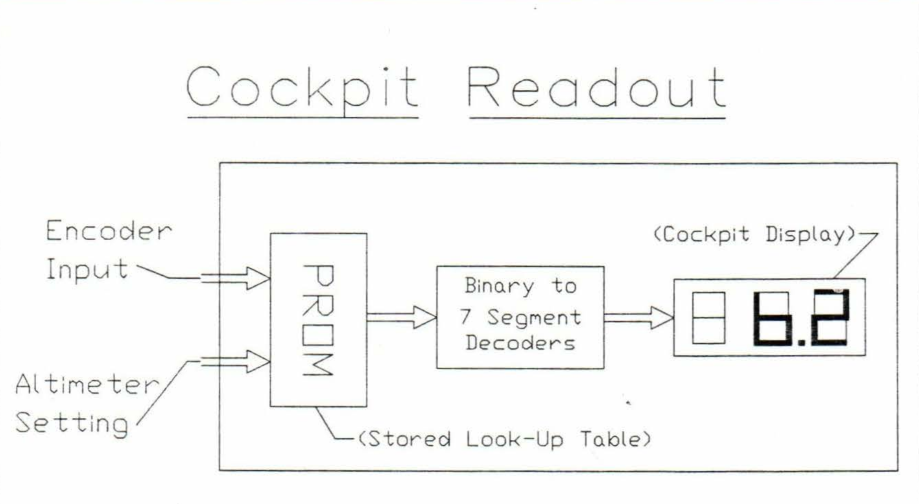

Figure 3.

Recall that the altitude encoder puts out a unique code or bit pattern for each 100 foot altitude increment. That code will be the memory address. Stored at each address is the binary equivalent of that altitude in feet. The reason for using the binary equivalent is that there is a standard circuit we can buy which will take that binary output from the PROM, convert it (called decoding), and drive a 7 segment numeric display. So by using a properly programmed PROM to convert the transponder code to binary code, some decoders and displays, a read-out device can be built. 11,900 feet will read out as 11.9 on the display, for example. A few support circuits for getting the proper voltages to the chips, a circuit board and a box to hold the stuff in and, presto!, through the magic of modern electronics you, too, can see what altitude your encoder is transmitting.

It seems to me that in a VFR only homebuilt, the read-out device could be the ONLY altimeter required in the airplane. FAR 91.33(b) doesn't require a sensitive altimeter. The 100 foot read-out increment of the transponder encoder is obviously good enough for the VFR requirement. You don't even need to be able to set a VFR altimeter for barometric pressure. The bad thing about that, however, is that you would always be reading your altitude referenced to 29.92 inches of mercury, which is what the encoder is set to. The ground station cranks in the altimeter setting to correct the read-out the controller sees. That could result in some pretty big errors in your altitude. A 0.1 inch pressure difference equals 100 feet. So, if the pressure was, say, 28.92 inches, your actual altitude would be 1000 feet lower than what the encoder read-out would be displaying. That isn't too much of a problem while flying VFR. It would be a problem though when you are working a ground controller and trying to fly to the altitude he assigns you. I can hear it now. "Experimental 1234, maintain 3500." "Ah, roger . . . would that be a little higher, or lower?" Anyway, it turns out we can set the barometric pressure into our device without too much trouble. That makes it a good altimeter for VFR use. Remember that NO VFR altimeter should ever be used for terrain or obstacle avoidance and it's the pilots responsibility to ensure that the proper barometric pressure is set into the altimeter.

In addition, if the encoder read-out is the altitude reference "normally used to maintain flight altitude" (FAR 91.36), then there should be no requirement for a data correspondence test. Actually a data correspondence test isn't even possible because there is nothing to compare. So it would seem that we can eliminate the requirement for a calibrated altimeter (the encoder is already certified and calibrated) and the data correspondence test. You will still have to do a static system test if you have a static system.

So how can we set the barometric pressure into the read-out? To go from -1000 feet (for Dead Sea take-offs?) to 15,900 feet altitude in 100 foot increments requires 170 altitude read-outs or addresses. These 170 addresses form a base table of altitudes referenced to 29.92" hg. For each 0.1" hg change from 29.92" we will program another table just like the base table except it will be changed by 100 feet for each of the same addresses. This means to cover from 28.1" to 31.0" hg (barometric setting range of most altimeters) will require 29 tables to be stored in the PROM. The table we are using to get the read-out will be determined by the position of a knob on the front of the read-out device which manipulates the PROM addresses. It is important to understand that the manipulation of the tables ONLY changes what the read-out is displaying in 100 foot increments. It does NOT change in any way the data the transponder/encoder is sending to the ground interrogator. This way when the controller asks to maintain a certain altitude, what we see in the cockpit will be what he sees on his radar screen.

There are devices on the market that will give a cockpit read-out of the encoder. Admittedly they will do a number of other jobs, like beep when you are 200 feet off your assigned altitude and other stuff like that. Only trouble is, they are priced around $1200 and up. With prices like that I lose interest really fast! So, if you don't have a lot of spare cash lying around, let me assure you that we can build this thing for under 100 bucks. Actually, the electronic parts are the cheapest part of the device. Of course, like most situations in life, there is no free lunch. To program the PROM takes some special equipment that certainly isn't cheap unless you like taking months to squirt in what seems like a hundred jillion bits one at a time into your PROM. And figuring out just how to program the PROM takes lots of time. Specially designed printed circuit boards, connectors, wires, enclosures, hardware, documentation, etc. make up most of the final cost.

For those who may be interested in making this device plans are available for $10 ppd. These cover everything you need to know about how to build, install and use the read-out (it fits in a 2-1/4" instrument hole, 4" deep). Included are full size layouts of the two printed circuit boards, and a list of all required parts and sources. I can supply printed circuit boards, and programmed PROM's if you don't have the equipment or time to do it yourself. A full kit of parts is available for $82 plus $4.50 P&H. Send a self-addressed, stamped envelope if you'd like more details.

About the Author

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