Approaching the Final Frontier

Near Space

Modifying a PenCam for Use in Near Space Applications

I like to collect data. If I can send a near spacecraft (NS craft) to 100,000 feet and return data on cosmic rays, I'm in heaven (or maybe it's near heaven).

For most people, though, they want to see photographs. To them, your backpacking trip to the bottom of the Grand Canyon isn't interesting unless you can share photographs.

For this reason, you'll want your NS craft to carry a camera. In this month's column, I want to explain how to modify an inexpensive digital camera for control either by a 555 timer circuit or a flight computer. The procedure is the same for other cameras I have modified, so the directions here do not limit you to using inexpensive, low resolution digital cameras.

The camera I modify in this month's column is called a PenCam and is available at Wal-Mart for less than $20.00 (Figure 1). It contains built-in memory and a CCD imager operating at VGA resolution. At high resolution, it has enough memory to store a total of 19 images, but if you set it for low resolution, it then holds a total of 76 images — four times as many. The weight of my PenCam is 1.2 ounces or 60 grams with its two AAA batteries. It's 5" tall, 1-1/4" wide, and 5/8" deep. Its compact design makes it useful for BalloonSats, where weight (and space) is at a premium.

Figure 1. The PenCam (note the AAA cell for scale).

To modify the PenCam, you will need to access the electrical contacts of its two switches and solder thin gauge wires to them. The wires terminate in either a momentary push button switch and NPN transistor or two NPN transistors, depending on your application.

This article will explain how to build a 555 timer to operate the PenCam. An explanation on constructing a flight computer that can operate the PenCam will be covered in a future column.

First, purchase a PenCam and install a set of AAA cells into it. You need to make sure the PenCam works properly and that you can download the images before making this modification.

If the camera does not work, return it because, once you break into this project and violate the camera's warranty, it's too late to return the PenCam if it turns out to be defective.

Now that you know you have a functional camera, it's time to modify it. The function and location of the two switches to be replaced are indicated in Figure 2.

Opening the PenCam

Remove the batteries you used to test the camera and leave the battery compartment cover off. Also remove the pocket clip attached to the camera, since you won't need it. The PenCam body is held together with two small screws and tabs molded into the plastic case. Use a small, jeweler's Phillips screwdriver to remove the two screws located inside the battery compartment. You'll probably want to use a pair of fine tweezers to pick these screws out of the battery compartment.

Set the screws aside where they can't be lost; be careful, they are pretty tiny. Now, work your way around the case and carefully open it without breaking the plastic tabs. I found the top of the case to be the most difficult part to open. When you open the case, you'll see that the camera circuit is contained on a single PCB (Figure 3).

When you open the PenCam, the top button — the shutter button — will fall out. The button is just a chunk of plastic that presses against the micro-switch on the PenCam PCB. Toss the button, as you won't be needing it after this modification.

At this point, you could leave the selector button in place; however, if you do, you must mount the PenCam in such a way that you can access the switch. By installing a remote switch, you have more freedom as to how you can mount the PenCam in a BalloonSat. Next, we'll see how to remove the camera PCB so you can access the selector switch.

There are three small screws holding the PCB to the camera case. The first is located at the bottom-left of the PCB and the remaining two are on the lens casing. Remove all three screws and set them aside. The lens casing comes off when you remove the last two screws; this exposes the CCD imager. It's a good idea to work in a relatively clean area, so you don't get dust on the face of the imager.

After you remove the three screws, the PCB will lift out of the camera case, as will the selector button. Toss the selector button, as it isn't needed anymore. Use a DMM to determine the proper connections on the two switches before soldering wires to them. Set the DMM to continuity check and probe the four pins on the selector switch.

You should discover that the left two pins are connected together and the right two pins are also connected together. When the button is pushed, the top two pins are shorted together, as are the bottom two pins. If your PenCam is identical to mine, solder wires to the top two pins as shown in Figure 4.

There are only two pins on the shutter switch, so there's no need to determine which pins to use.

Cut four lengths of thin gauge wire, about 12" long. (I used #26 gauge, stranded.) Strip about 1/4" of insulation from one end of each of the four wires. Tin the stripped ends well. Some of the insulation may melt as you tin the wires, so trim the tinned ends to 1/8" after tinning. The ground connection for each switch is the pin of both switches that is located the closest to the center of the PenCam.

Solder each wire by holding the tinned end of a wire in contact with its switch pin and heating it with a well-tinned soldering iron. Solder from the switch pin and the tinned wire will connect the wire to its switch pin. Solder the wires carefully, as the spacing around the switches is a little tight.

To reduce confusion over which wires connect to which PenCam micro-switch, pass the wires for each micro-switch through their respective button holes in the case. So far, you have removed five screws from the PenCam. The longest two mount the lens case to the PCB and the PCB to the back of the camera case. The shortest screw holds the lower-left hand corner of the PCB to the PenCam case.

Before you put the lens case back on, however, take a minute to look at it. From the underside, in front of the lens is an infrared blocking filter. If you remove this thin sheet of glass, the CCD imager will be capable of recording infrared images.

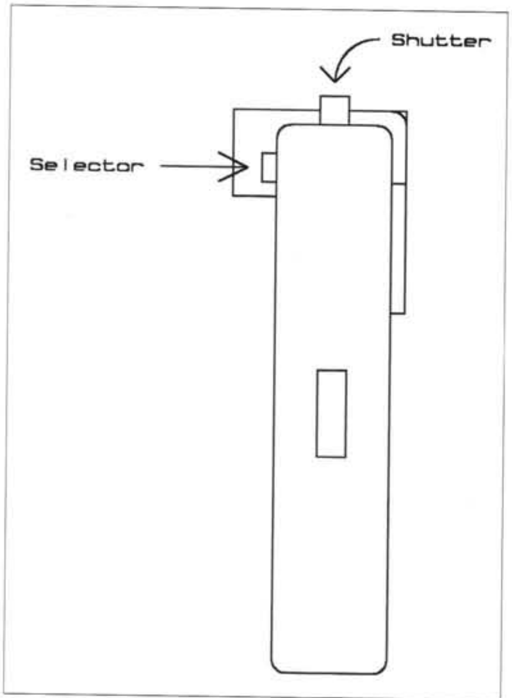


Figure 2. A side view of the PenCam, highlighting the function and location of the two buttons to be replaced.

One experiment you may want to perform in near space is to compare visible and infrared images. Since these PenCams are so inexpensive, you can afford to modify two of them. The first one would have the IR filter intact and the second one would have it removed.

As long as you place the PenCams side-by-side and operate them at the same time, they'll record images of the identical scene. One image would be strictly in visible light and the other image would be in both visible and IR. The differences between the images would be due to IR radiation.

Perhaps the best way to bring out this detail is to invert the visible light image and add it to the IR and visible image. I believe this will subtract out the visible light image from the IR and visible light image, leaving only the image due to IR radiation. How to combine the images and what software

Figure 3. The PenCam on the half shell. The PCB is mounted to the back half of the camera case.

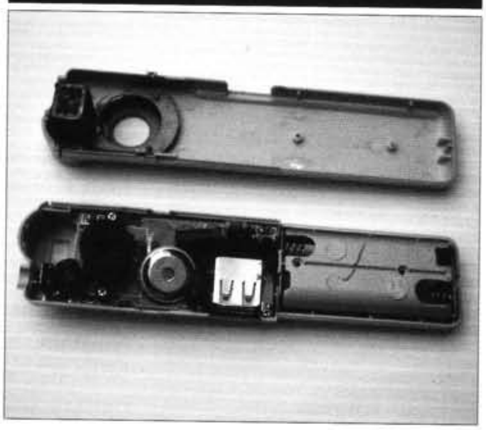
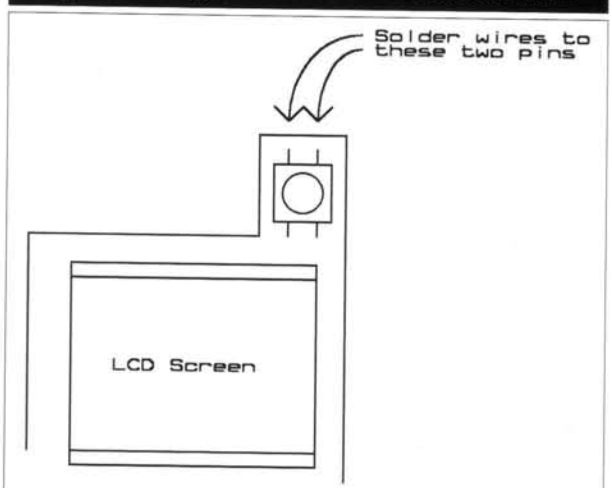


Figure 4. Adding external wires to the shutter switch.



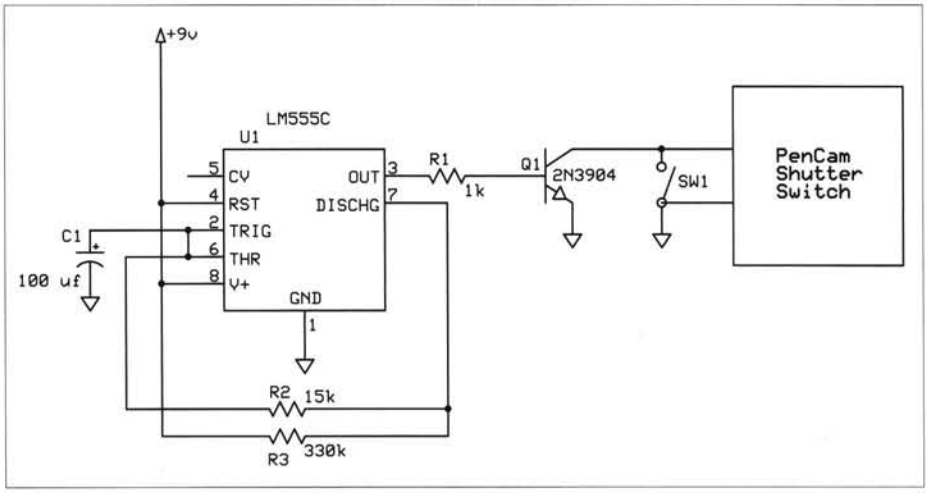


Figure 5. Schematic of the 555 timer-driven shutter switch.

to use I leave as an exercise for the reader. However, if you do work out the details, please contact me and I'll share the process with the rest of this column's readers.

Now, close the camera case. Be careful not to pinch the wires in the case. Test your switch connections once the case is closed. Put two AAA cells into the PenCam. When you tap the two wires from the selector button together, the PenCam should power up and beep.

Assuming this is the first time the camera has been started since the batteries were installed, the LCD should display 19, the remaining number of photographs that can be stored in memory. Next, point the PenCam toward a well-lit scene and tap the two wires from the shutter switch together for about one second. There should be a beep as the camera records an image. Check to make sure that the LCD now displays an 18.

If any of these tests fail, then open the case and look for a loose or misplaced wire. After testing the wire connections, make a strain relief for the wires. Put a small dab of hot glue on the PenCam case and stick the wires to it. Don't place the glue over the button holes or over the seams in the plastic case, as this will make it difficult to fix broken connections in the future.

The shutter button wires will be connected to a NPN transistor. The selector button wires can either be connected to a momentary, normally off switch or to an NPN transistor. If you plan to use the PenCam on a BalloonSat that uses a 555 timer IC circuit to operate the camera, then connect a momentary switch to the selector button wires. If you plan to use the PenCam with a flight computer that will control the operation of the camera, then connect a NPN transistor to the selector button wires.

BalloonSat Connections

Begin by adding the momentary push button. Strip about 1/2" of insulation from the ends of the two selector button wires. Slide short lengths of heat shrink tubing over the wires and then twist the wires onto the lugs of a momentary push button switch. I used a small, RadioShack, normally open, chassis-mounted, push button switch for my remote selector. Solder the connections and cover them with heat shrink tubing.

Next, assemble the 555 timer circuit to operate the camera's shutter button. You'll need a 2N3904 NPN transistor, 1K, 15K, and 330K resistors, 100 µF electrolytic capacitor, 555 IC, eight-pin socket, 9 volt battery snap, and micro-momentary

GPSL 2004

The participants of the Great Plains Super Launch 2004 (GPSL 2004) pose for the camera with their copies of *Nuts & Volts Magazine*. This year, GPSL held two competitions. The first competition challenged participants to reach the highest maximum altitude of GPSL 2004. The second competition required the most accurate prediction for the recovery location of an NS craft prior to launch. Awards for the winners of these competitions were donated by *Nuts & Volts* and Parallax.

First place was awarded to Zack Clobes (W0ZC) of Project: Traveler, whose prediction error was only 5.27 miles and whose balloon reached a maximum altitude of 94,467 feet. Second place was awarded to Rick Von Glahn (N0KKZ) of Edge of Space Sciences for a landing prediction error of 11.44 miles; his balloon reached a maximum altitude of 88,999 feet.

Read more about the participants of GPSL 2004 at their websites:

EOSS
www.eoss.org

HABITAT
http://habtiatskylab.org

NSTAR
www.nstar.org

ORB
http://members.cox.net/hhm_74775/orb/

Project: Traveler
www.rckara.org/project_traveler/

GPSL 2005 will be hosted by Nebraska Stratospheric Amateur Radio (NSTAR) on July 23-24, 2005. All interested individuals are invited to participate. In the meantime, please subscribe to the GPSL Email list under Yahoo Groups for information on this and other amateur near space events.

push button switch (like the ones on the PenCam PCB). I used a 1-3/4" by 3" RadioShack perf board as my circuit board. Figure 5 shows a schematic of the circuit you will build.

Note that both the micro-switch and 555 timer are capable of operating the shutter switch in this circuit. The manual switch allows you to step through the PenCam's menu before you launch the BalloonSat. When you assemble the circuit, use the center two copper strips in the perf board for the power and ground bus. You'll need to cut a few jumper wires to complete the circuit. My layout looks similar to the diagram shown in Figure 6.

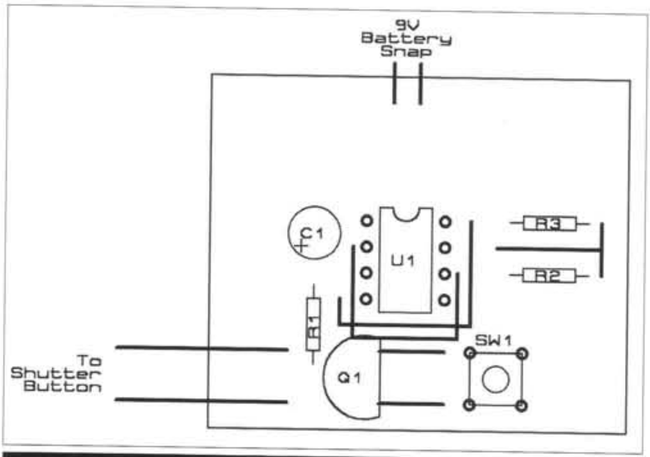


Figure 6. Only electronic components and jumper wires are shown in this diagram. Connections to power and ground are made beneath the perf board.

Check your soldering and make sure there are no shorted traces. Now, attach the PenCam switch wires to your perf board. The ground wire of the shutter switch is connected to the emitter of the transistor (Q1). The other wire of the shutter switch is soldered to the collector of the transistor. This completes the connections required for a BalloonSat.

I designed this circuit to operate the shutter switch every 43 seconds because the PenCam shuts down if it is not used within a minute of power-up. Check the period of the 555 timer circuit to ensure it pulses in less than 60 seconds. I found that my capacitor was sufficiently different from its printed value that I had to change my R3 resistor (Originally, I wanted to use, 15K, 600K, and 100 µF.).

Your final component values will depend on the variations in the values of R2, R3, and C1. If you look at the output from this circuit, you'll find that the output is high for about 50 seconds and low for about 1 second. This means the PenCam sees its shutter switch pressed for 50 seconds and released for 1 second. My tests show that this is acceptable to the PenCam.

Test the 555 timer circuit and PenCam by first pressing the selector button of the PenCam (to power it up). Next, power-up the 555 timer circuit; this has to be done in less than 60 seconds. You should hear a beep from the PenCam every time the 555 timer circuit goes low.

If the PenCam doesn't record an image (The count on the LCD will decrement every time an image is recorded.), then check that you didn't switch the wires on the shutter switch (ground wire to emitter and other wire to collector). Also, check that pin 3 of the 555 is connected to the base of Q1 and that ground from the 555 timer circuit is connected to the emitter of Q1. Be sure there is sufficient light, otherwise the PenCam will not record an image (but it still beeps).

To change the resolution of the PenCam from high to low, start the PenCam by pressing the select button. Now, press the button an additional seven times. On the seventh press, you'll see a tiny "LO" displayed on the left side of the LCD. When you see that, press the shutter micro-switch on the 555 timer circuit to change the PenCam to low resolution. Afterward, the LCD displays a 76 — the number of images that can be stored in the PenCam's memory.

If you do not remove the

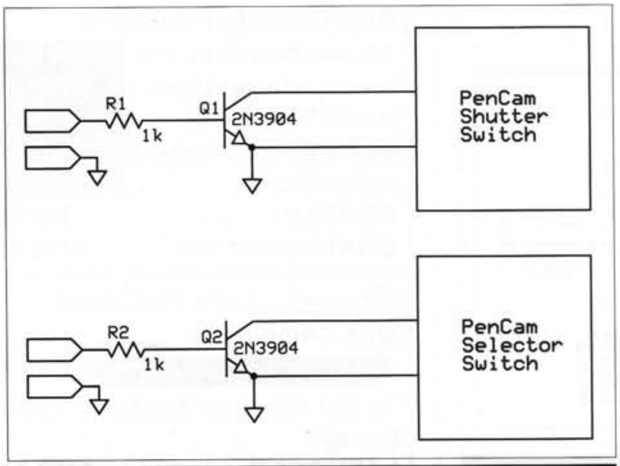


Figure 7. Using transistor switches controlled by the BS2P.

PenCam's battery, then it will remain in low resolution mode the next time it powers up. You can force the PenCam to shut down by pressing the select switch once after the PenCam powers-up. The LCD will display "OF" for off. Press the shutter micro-switch once to shut off the PenCam.

Alternately, you could just wait a minute and the PenCam will shut itself down. Skip to the section "Installing Remote Batteries" if you're not interested in driving the PenCam via a microcontroller.

Flight Computer Connections

I want to thank my student, Jeff Eggebrattan, for testing this modification for the PenCam; originally, I was using reed relays to operate the PenCam. For operation by a flight computer, each switch is connected to a 2N3904 transistor. You need two 2N3904 transistors and two 1K resistors for this circuit (Figure 7).

Connect the grounded wire of each switch to the emitter of a transistor and remaining switch wire to the collector of the transistor. From the flight computer side, connect the flight computer ground to the transistor emitters and an I/O pin to the base of each transistor. Place a 1K resistor in series with the base of each transistor to limit the current to the base to 5 mA.

Terminate these wires as appropriate for your flight computer. Double check that you connected the emitter of each transistor to ground on the flight computer and the base of each transistor to an I/O pin of your flight computer. Now, when the I/O pin of the flight computer's microcontroller is set high, the transistor saturates, shorting the connections of the switch connected to it.

Operating the PenCam With a BASIC Stamp

I programmed my flight computer to power-up the PenCam and then run through the PenCam settings (Listing 1). After "scrolling" to low resolution mode, the flight computer operates the shutter button to change the camera resolution. (In this program, I'm assuming the batteries were initially removed from the PenCam.) One minute after recording an image, the PenCam shuts down. From there, the flight computer only needs to turn on the PenCam and then make it record another image.

You can modify this code to order the PenCam to shut down, rather than wait for it to time out. To do this, operate the selector button once, followed by the shutter button after recording an image.

Listing 1. A simple image acquisition sequencer.

```
'{$STAMP BS2p}
'****************************************
'* Program selects the low resolution  *
'* mode of the PenCam and then records *
'*          three images               *
'*                                     *
'*    L. Paul Verhage 22 Jan 2004      *
'****************************************

powerSwitch   CON 0          'I/O pin of power switch
shutterSwitch CON 1          'I/O pin of shutter button
pushButton    VAR Nib        'Counter to control number of button pushes

Digital_Camera:
  PAUSE 2000
  DEBUG "Select Camera Setting", CR
  FOR pushButton = 1 TO 7    'Push power button seven times for low resolution
mode
    HIGH powerSwitch
    PAUSE 1000
    LOW powerSwitch
    PAUSE 1000
  NEXT

  DEBUG "Take Three Photos", CR
  FOR pushButton = 1 TO 3
    HIGH shutterSwitch
    PAUSE 1000
    LOW shutterSwitch
    PAUSE 5000
  NEXT
END
```

Installing Remote Batteries

The final modification is only necessary when the space available for the PenCam is tight or if the PenCam is to be exposed to cold temperatures and you want to keep the battery warm. In this modification, the battery compartment is cut off (Talk about really violating the warranty!) and a remote AAA cell holder is attached.

You can use any battery combination to operate the PenCam, as long as it has a voltage of 3 volts. I stayed with AAA cells because my BalloonSat doesn't have the room or weight allowance for AA cells. I used a RadioShack two AAA cell holder for remote power.

Remove the two AAA cells from the PenCam. With a small saw — like a coping saw or Exacto saw — cut the bottom of the PenCam case off. Leave the top of the battery case and the two metal contacts in place on the PenCam case. This modification shortens the PenCam by about 2".

I recommend re-tinning the bare ends of the AAA cell holder's wires. Tin the positive power pad of the PenCam. Solder the red and black wires of the new cell holder to the metal contacts of the shortened PenCam. Connect the cell holder's red wire to the flat contact in the PenCam and the cell holder's black wire to the spring contact of the PenCam.

I twisted the black wire around a wire in the spring of the negative power coil and then soldered it in place. Install the PenCam's battery and test it again.

For strain relief, I recommend using a little hot glue to glue the wires of the remote power to the body of the PenCam. Don't apply glue to the soldered contacts, as that will make it difficult to fix a broken solder connection should it happen in the future.

There's one warning about the PenCam. Do not remove the battery from the PenCam before downloading

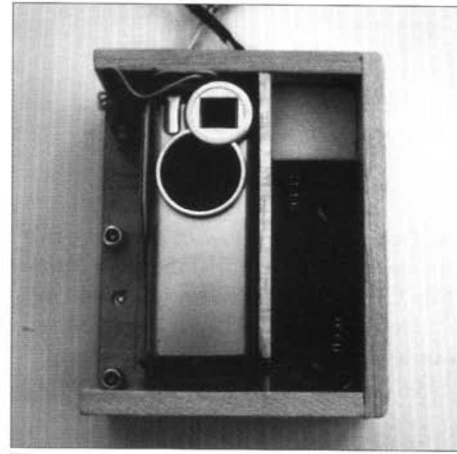


Figure 8. The PenCam pallet of my BalloonSat. Note that the battery holder for the remote power is located to the lower right of the shortened PenCam.

its images. The PenCam does not have a non-volatile memory, so removing the battery erases your images from the PenCam's memory.

Onwards and upwards,

Your Near Space Guide NV