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# IOTA-VTI v1.1.42

## A GPS based video time inserter

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**Preamble:-**

The IOTA-VTI is a video time inserter intended for astronomical occultation work. It takes a PAL (CCIR) or NTSC (EIA) video feed from a camera presumably attached to a telescope, and overlays the image with GPS-derived time and location information. The output video feed is sent on to some form of video recording system.

The unit is standalone, contains its own GPS unit, and does not require a computer to function.

**Box panels:-**

The front panel of the box has the controls as follows:-



The rear panel has the sockets for video cable, power and USB as follows:-

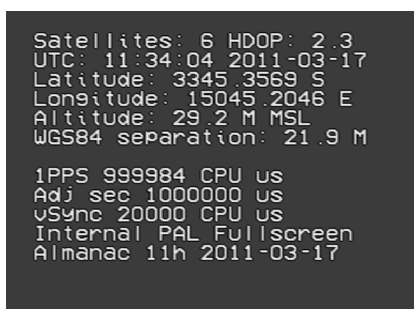


**Overview:-**

The unit displays a splash screen at startup; a Position screen with GPS location; and a Time screen with GPS fix information, UTC, the number of 100 microsecond intervals since last 1PPS signal, and the number of fields counted since power on. Latitude and longitude are given in degrees, minutes, and decimal minutes.



Splash screen



GPS screen



Timing screen

### Using the IOTA-VTI:-

The unit requires clean 5 to 13.8V power (12V is optimal), a video in signal from a camera, and some form of video monitor and / or recorder. A computer connection is not required, but can perform additional function if available. The unit can be powered from the USB socket concurrently with 12V.

On power-up, the unit writes the splash screen to the video output stream, and this should be visible on the monitor regardless of the light conditions. The splash screen displays the unit software version, the unit serial number, and the original owner's name.

The right front panel switch should ideally be in the "Position" position on power up, so that the GPS fix can be monitored. It may take a few minutes to obtain a GPS fix. The time will be longer if you have not used the unit recently, or if the view of the sky is not optimal, or if you have moved large distances since your last use of the unit. Typical first fix can be as little as a thirty seconds, or as long as fifteen minutes.

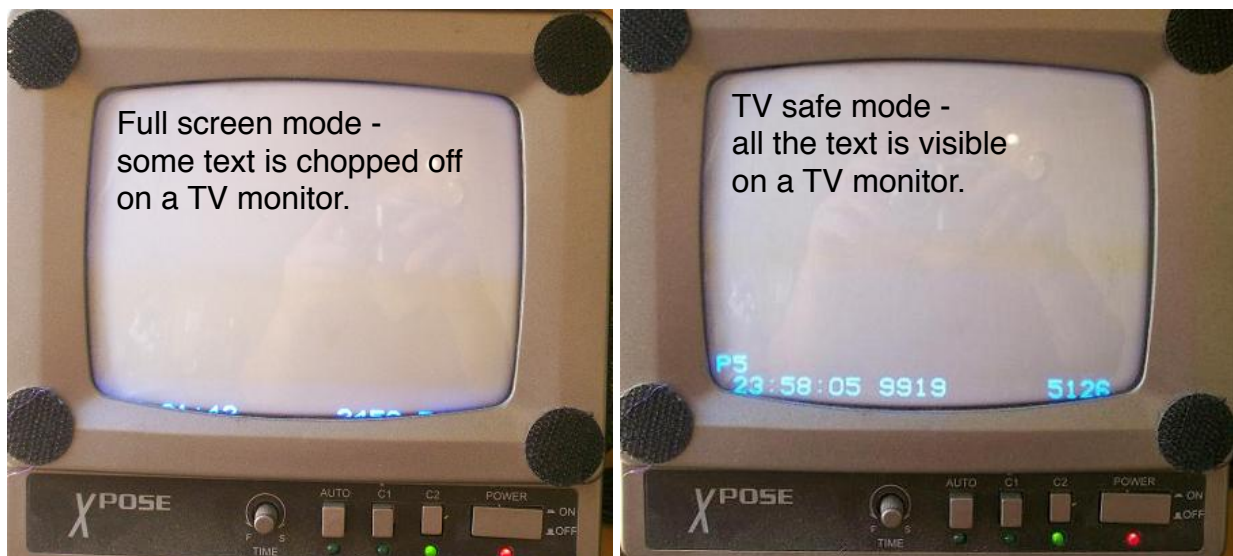
In general, three satellites will give geographic information, and four satellites will provide 1PPS information (including UTC and date). You can switch to the Time screen if you are in a hurry; you won't have UTC until at least four satellites have been acquired, but you can record an imminent occultation event and in your analysis determine the occultation time by working backwards from the first timestamp using the field counter. When 1PPS is working, the 1PPS LED on the front panel will flash at a 1Hz rate.

If you plug in a camera (either NTSC or PAL), the Video Input OK LED will light to indicate a good video in feed, and the video out will carry the camera image as well as overlaid GPS information. The unit automatically switches between NTSC and PAL input.

When there is no video in feed from a camera, the unit chooses PAL or NTSC according to the position of the first DIP switch. This switch is inside the case. If you change this switch, you have to reset the unit or cycle power for the change to take effect.

### TV safe area:-

If your output monitor or recorder records only the TV-safe area of video transmission (such as a regular TV monitor or a video recorder) then you should set the front panel switch to TVsafe. This will put all the information within the TV safe area. A reset or power cycle is required for the change to take effect in the software.



The alternative is Full screen, and is preferred for users with full screen USB or Firewire frame grabbers such as will plug into computers. You get all of the pixels your camera will give you with Full screen. All of the screen shots in this document were taken with a full screen Firewire frame grabber.

**The Timing Screen:-**

The line at the bottom of the Time screen shows you most of the information you need for a valid timestamp.



The first character ("P" in this example) represents the satellite fix.

Item	Meaning	Details
N	No Fix	No valid GPS info, but 1PPS and ZDA continue from internal clocks if previously acquired.
G	2D (Geographical) fix	Valid geo. info (Lat, Long, HDOP)
P	3D (1PPS) fix	Valid time info (1PPS, ZDA), MSL, WGS84

The second character ("6" in this example) represents how many satellites have been acquired. You need 3 satellites for a geo. fix, and 4 for a 1PPS fix (timing fix).

If the unit has recently been powered on, there will be an hourglass symbol next to the satellite number. It does overwrite the second digit of the satellite fix (cough) if you have more than nine satellites in fix.

The presence of the hourglass symbol in the third character position is to remind the user that more than three hours have elapsed since IOTA-VTI was last used and that the GPS internal memory might be out of date, and so, the time displayed should not be relied on. See Almanac Updates - page 7 - for more information. The absence of the hourglass symbol in the third character position means that the time displayed is correct to Universal Time.

The UTC is next ("02:54:45") in this example. It is updated only on receipt of a valid 1PPS and a ZDA NMEA sentence from the GPS.

The "6842" represents 0.6842 sec since the last 1PPS to the vSync field end (when the camera shutter closed on the image). This image is one field of an interlaced image. The next field will have a different timestamp, 20 msec later for PAL, or 16.67 msec later for NTSC. To avoid blurriness in a field-blended image, the next field's timestamp is written in the blank space to the left of "6842".

Lastly we have the field counter since power on, which in this case is 54,617. The counter has been tested to around 6 million counts and can theoretically run to 99 million before the display can't fit all the characters on screen, and 4 billion before it overflows to zero.

The Timing screen updates every vSync period (20msec PAL, 16.7msec NTSC).

**The Position screen:-**

The Position screen shows you useful information about your geographic location and some system values you may find useful. The screen updates every three seconds rather than each second, because more serial information must be sent than with ZDA sentences and this takes more time.

Latitude and longitude are displayed as degrees, minutes, and decimal minutes.

```
Satellites: 6 HDOP: 2.3
UTC: 11:34:04 2011-03-17
Latitude: 3345.3569 S
Longitude: 15045.2046 E
Altitude: 29.2 M MSL
WGS84 separation: 21.9 M

1PPS 999984 CPU us
Adj sec 1000000 us
vSync 20000 CPU us
Internal PAL Fullscreen
Almanac 11h 2011-03-17
```

The UTC is not updated until a valid 1PPS fix (= 4 or more satellites) is acquired. This is important. Without the UTC line showing, the unit will not provide timing information because the internal clock of the GPS unit has not been calibrated against the atomic clocks in the GPS constellation.

Once a fix is acquired, the internal clock in the GPS can tolerate satellite loss-of-signal for some time. Dave Gault has tested pre-production units and found they held time despite loss of signal to better than a millisecond over eight hours (when referred to a working GPS unit). But you must have the fix first, before you can get this accuracy.

The "1PPS = 999984 CPU us" is a valuable piece of information. It tells you what the clock inside the AVR (the processor in the VTI) thinks one real 1PPS second is worth according to its (slightly) imperfect internal clock. In this case, it counts 16 microseconds too few in every second. Most AVR clocks are out by some (tiny) amount, and this information is used internally to "expand" or "contract" the native clock to the correct time, as shown by the "Adj sec" field. The "Adj Sec" shows you how accurate the expansion or contraction was. It should read 1000000 us or very close to it. The internal clock has a resolution of 4 microseconds (i.e. it counts in 4 microsecond intervals) so the values will vary in amounts of 4 microseconds.

The "vSync = 20000 CPU us" tells you how accurate the clock in your camera is. Dave has tested various cameras and found they generally had drifts of less than 4 microseconds per minute from stated period. This makes the camera clock better than the native AVR clock, and may be the reason why counting frames has long been considered an acceptable method of timing an occultation in the absence of a proper VTI.

The second last line lets you know what the unit thinks about its environment. External means a camera is plugged in. PAL is the video format here. And full screen means that the Timing screen time stamp will be placed at the bottom of the screen, outside the TV safe area. If you are recording to a VCR, you should set the TV safe front panel switch to "On", so the time stamp writes to the next line up and a bit in from the left hand side. If you are recording to a framegrabber, the full screen is available.

The last line tells you when the unit was last operating with a P fix. This is a handy thing to know. If this time / date was less than 3 hours ago, and you have not substantially changed your location, then your unit should have a good almanac and ephemeris, and be unlikely to encounter an almanac update which changes the regular counting of UTC whole seconds. Note that 3 hours is a very conservative estimate, and the almanac in most units is remembered for over a week.

**Camera latency:-**

Not all video cameras are created equal. Some will send video information just as it happens. Some will store a complete frame (2 fields) and then send the picture information down the video line. And some will accumulate several frames before updating the video image.

Your IOTA-VTI does not timestamp the optical image. It timestamps the video transmission from the camera, and is tested to be correct at the Video In plug on the VTI. You must determine how much delay (latency) there is between a known optical event and the appearance of that event on the video stream.

The way to tell what your camera does is to point it at the 1PPS LED on the GPS-VTI and watch the resultant video recording. The LED flashes within 7 microseconds of the 1PPS signal from the GPS, and that's a worst-case scenario; in most cases the LED will illuminate within 3 microseconds of 1PPS. You want to see just when that flash gets to the video in plug. The delay is measured by the subsecond counter on the IOTA-VTI timestamp.

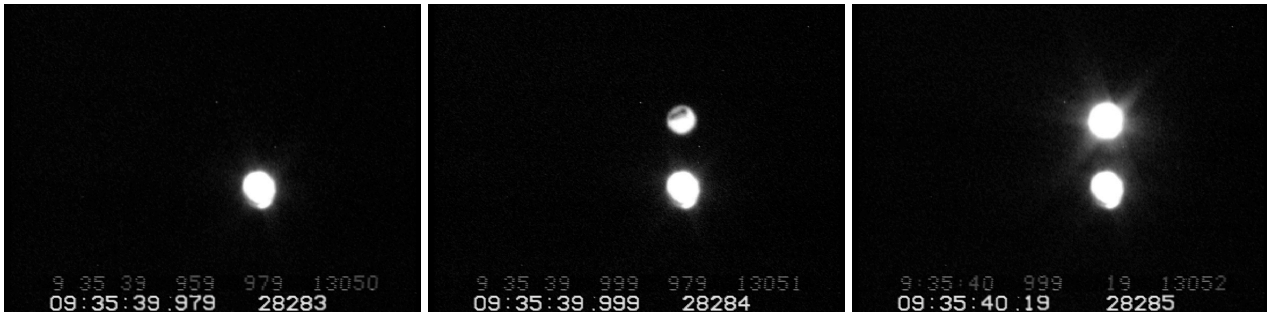
In the two images below, a GStar-EX PAL camera (an accumulating camera) is viewing the 1PPS LED of a pre-production IOTA-VTI. The camera is set for "no accumulation". On the left-hand image, the timestamp is at 14:22:00.053, and the 1PPS LED is still dark. On the right-hand image, the timestamp has advanced to 14:22:00.073, and the 1PPS LED is now lit. We can safely say that the camera, although set to not accumulate, still has a one-frame (two field) delay between optical event and video timestamp. This does not mean the camera is useless! It simply means that there is latency in the system, and any UTC times reported must include the known camera latency. Thus, if you determine an event occurred at UTC 01:23:45.500 according to the end image timestamp on the video, then for this camera, the actual UTC is 01:23:45.460 end image time.



If you see the LED illuminate within one field of UTC change, then your camera sends video as it happens. If the LED illuminates two fields or more after UTC change, then the camera is an accumulating camera. You NEED to know this information; how much time (fields) the camera accumulates before sending the image.

**Optical postfetch:-**

Your camera may be a "just as it happens" camera. If so, you may find that the CCD actually ceases acquiring optical information less than one msec after vSync asserts. This "postfetch" is best seen when the field updates very near to when 1PPS updates. You will see a timestamp of UTC 01:23:45.999 (implying that 1PPS is about to occur, but hasn't actually happened) and the 1PPS LED appears on the screen as faintly lit. The following video stills show this in a pre-production version of IOTA-VTI:-



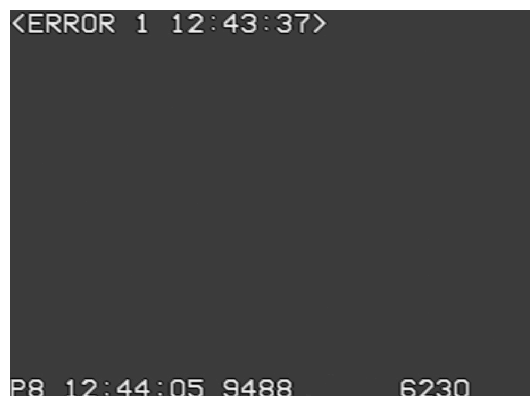
The left-hand image shows a dark 1PPS LED. The middle image shows a faintly-lit LED, even though according to the subsecond display, the LED ought not to be lit yet. The LED is lit because the camera has not yet finished acquisition from the CCD, even though it has put out the vSync signal. This is postfetch, and for cameras which show this phenomenon, it represents less than one msec in timing.

**Errors:-**

The VTI engineering was designed to provide good quality timekeeping with minimal fuss, but to let you know if errors occur. If you lose fix after some period of normal operation (perhaps due to the unit being shielded by some moving metal part), the unit will continue to keep good time. But the Time screen will show you that you have No Fix and no satellites (as shown below). At this point you may wish to take your aluminium eyepiece case off the top of the VTI and allow it a more unobstructed view of the sky :-)



There are six more serious errors, and they are entitled on the screen on the top visible line as follows:-



The error message begins the line with the word ERROR and the error type (here it is type 1). Finally is the UTC (here 12:43:37) when the error occurred.

This message will hang around on screen until you switch to the Position screen. This action will clear the error text off the screen.

If you are doing a recording, you can scroll through and discover when it happened and make decisions about your recording.

If there is more than one error, they are appended on to each other. If the screen gets full, it starts from the top again.

Error	Name	Details
1	UTCdidNotChange Correctly	A 1PPS was detected, and ZDA information described it, but the description was not what was expected.
2	NoPPS	The subsecond timer went over 1.000 099 seconds without a 1PPS detected. xxxx is written to the screen in the msec position as well.
3	NoZDAmsg	The NMEA sentence did not contain the characters "ZDA" where they should have been. Parsing aborts, UTC is not changed.
4	LoopTookTooLong	The main loop took too long to write the Time message properly on screen. This is set at 15 msec (PAL) and 12.5msec (NTSC).
5	FailedBoardTest	The memory check routine detected memory contents were not what they should have been. This also puts a message across the centre of the screen. If this error appears, the most likely cause is ionising radiation (gamma rays) or particle strike on one cell of the controller memory.
6	PPStooQuick	A 1PPS was detected within 0.999 900 sec of a previous 1PPS. This will cause the subsecond counter to reset in the middle of a UTC second. You also get an error 3 because there was no ZDA to describe the 1PPS. The field counter will not be affected.

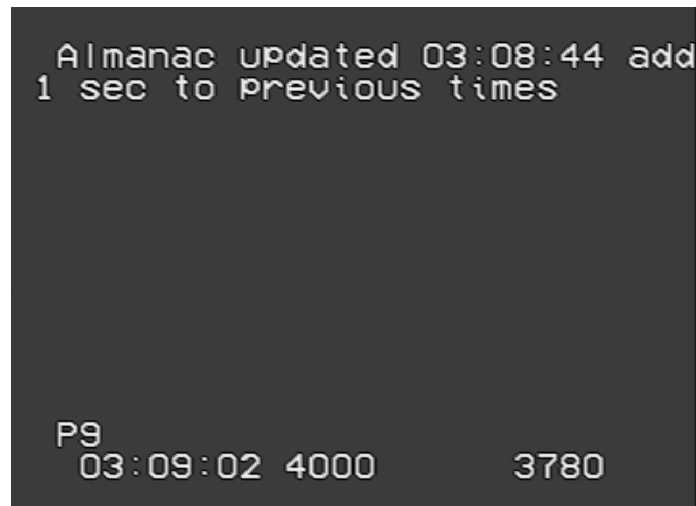
These errors mainly refer to problems in communication between the GPS unit and the microcontroller. Operation in an electrically noisy environment, or with a rubbishy power supply, will cause these errors to be more frequent.

### Almanac Updates:-

Error 1 (UTCdidNotChangeCorrectly) is handled as an Almanac Update rather than an error if it occurs within the first fifteen minutes after P fix.

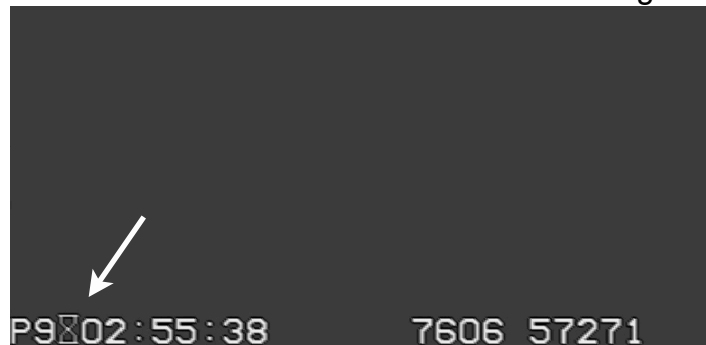
If you have left the unit unpowered for some time (the exact amount of time varies between three hours and a week, depending on your particular unit), the GPS unit internal gold capacitor runs out of power, and the unit forgets the expected satellite positions, extra leap seconds, etc. On power up, the unit takes longer than normal to acquire a fix, and then presents what seems to be a reliable time stamp. It is correct as far as fractions of a second are concerned, but the whole seconds are "out" by some integer offset. This is properly called GPS time rather than UTC, and it takes some time (a minimum of 12 min 30 sec of continuous P fix) for the offset data to come down from the satellites.

When the almanac eventually gets loaded, the UTC may change by an unexpected number of seconds at once. The update indicates that UTC has changed from the logical progression begun at initial acquisition, and is at last, suddenly correct. If this occurs then you can figure the UTC adjustment to give you the correct time "before" the update if this is necessary.



Unfortunately, there is no way to know if the almanac in the GPS is current, except by running the device with a P fix for at least fifteen minutes, before you need it. While this might seem a bit tragic, consider this - the almanac is correct until you get a new one from the satellite. Only with a new almanac can you know that the old one was right (or not).

To help you work out if you have a current almanac, at power on you may get an hourglass displayed next to the satellite fix indicator on the Timing screen.



This hourglass appears if the unit has been unpowered for more than three hours, this period of time being a very conservative estimate of the length of time the GPS unit can support its internal memory without external power. After fifteen full minutes of P fix (or an almanac update), the hourglass goes away. If you haven't had an UTC whole seconds unexpected change by the time the hourglass disappears, you're not likely to get one.

If a type 1 error occurs after the Almanac Update time period, it is seen as a communications error and not an Almanac update. This is probably due to interference on the serial comms lines between the GPS unit and the microcontroller within IOTA-VTI. This corruption is transient and will be rectified in the next second, by a correctly formed ZDA. You will get two type 1 errors in this case, they will be one second apart.

The error line is the top most line in a field, and must be written very early in the vSync cycle to be formed correctly. For this reason, you may find that some error notifications actually appear on the next field after the error occurred.

### NMEA output:-

If you have a PC or Mac, you can get the raw NMEA sentences from the USGlobalSat EM406A GPS inside the VTI. Very handy for debugging GPS almanac bugs. Was the glitch due to the GPS getting an update? This will help tell. Errors are also written to the serial stream as they occur.

You will need a USB port available on your PC or Mac, and the FTDI USB-serial driver installed on the PC. You'll also need Hyperterminal (Windows) or Zterm (Mac OS) or some other serial utility to read the bitstream.



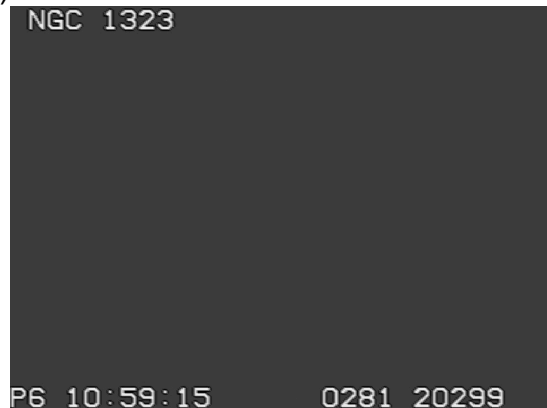
Turn on the third switch on the DIP switch. This switch is located inside the case.

Serial data from the GPS is echoed to the USB line. Settings are 57600, 8N1. Yes, the NMEA standard is 4800 8N1; but we recode the transmission up to 57600 within the microcontroller in IOTA-VTI.

You also get errors echoed to the USB line if the DIP switch is ON.

### Title:-

If you have the computer plugged in, you can title your Time screen. It's limited to a length of 28 characters, and it always happens on the top visible line of the screen. But if you can read NMEA sentences from the GPS, you can entitle your video. Note that you have a reduced set of characters [A-Z, a-z, 0-9, (, ), ., ?, :, ;, /, - < > @] and to erase you send a carriage return (ASCII 13) alone.



If you switch from Time to Position, you will overwrite the title, and it will NOT be replaced when you switch back. If you get an error, it will overwrite the title. That's a consequence of the error reporting philosophy - to squawk loudly on errors. If you reset the unit or power off, the title will be removed. The rationale here is that a "wrong" title is worse than no title at all, so it is quite easily removed.

### Dark Frame:-

A request was received to be able to "hide" the VTI display while taking a "dark" frame for astrophotographic purposes. This has been implemented as follows -

The fourth DIP switch inside the case is now the Dark switch. If you turn it on while in the Location screen, it will blank all of the on screen display. The Dark switch has no effect while in the Time screen.

### Conclusion:-

IOTA-VTI will provide you with good, accurate timestamps if you take the time to set your system up beforehand, and measure your camera latency at the accumulation settings you use on the night.

Clear skies!

Tony Barry and Dave Gault  
Western Sydney Amateur Astronomy Group