

## LESSONS LEARNT

### TROUBLE-SHOOTING UNIWERSAL DOME WITH VELLEMAN K8055(N) BOARD AND LESVEDOME SOFTWARE

## INTRODUCTION

A word of warning. This is a rather long document.

I wrote it as personal background documentation and developed it a bit so it might help others having one or more of the following components in their dome architecture:

- LesveDomeNet software
- Velleman K8055(N) card
- UNIWERSAL dome

The intent I to help other UNIWERSAL dome owners save time, frustration and money by describing some of the problems I encountered and the solutions I implemented.

This document assumes that you are familiar with LesveDomeNet.

- See Pierre de Ponthiere's LesveDomeNet website for description, downloads and schematics related to LesveDomeNet software:  
<http://www.dppobservatory.net/DomeAutomation/DomeDriver.php>.
- The following webpage by Erik Bryssinck is also useful:  
<http://www.astronomie.be/erik.bryssinck/universal-migration.html>

## CONTEXT

My set-up:

- UNIWERSAL Dome 3.2m
- UNIWERSAL control box with Velleman K8055N card.
- LesveDomeNet software

I encountered lots of problems with the electronics and electrical components of the UNIWERSAL control box. Their dome is mechanically sturdy, but the company has very little expertise in electronics, software and computers. (Even some of the electric wiring of my dome is rather shoddy. I swapped pieces out one piece at a time, as did many others.)

I summarize below the dome's problems, and the solutions I implemented after many weeks of diagnostics and attempted mitigation efforts.

## PROBLEMS AND MITIGATION/SOLUTION EFFORTS

I don't know if UNIWERSAL now ship all domes wired and ready for the LesveDomeNet software.

- The **USB connection** delivered by UNIWERSAL was flaky. Probably some ground wiring fault. LesveDomeNet would drop the connection to the Velleman card at random times. I rewired the USB directly to the Velleman card. Solved.
  - o This was actually difficult to diagnose, as the problems were intermittent. Advice: When in doubt run a USB cable directly to your PC.
  - o *As an aside: I have zero problems running my gear through three USB 3.0 hubs, plus a docking station. I have several 5m USB 3.0 cables in the set-up. I have never seen a problem. This runs counter to other people's experience. I think it has to do with my using:*
    - *A new and relatively speedy PC. (Eagle Pro PC by Primaluce Lab running Windows 10 LTSB.)*
    - *The latest DLLs and drivers for USB, ASCOM, K8055N, SiTech, etc.*
    - *Choosing the best USB cables and hubs I could find. They may cost a bit more, but the difference between investing 50€ or 100€ in USB cables and hubs is pretty irrelevant when the dome, mount, scope, cameras, filters costs upwards of [put your own number here].*
    - *I use LINDY CROMO USB 3.0 cables and IcyBox 12V powered USB hubs. (I stayed away from active USB cables, as they don't mix and match well with other gear.)*
- The original **Azimuth encoder** (optocoupler Vishay TCST2103) of my dome was burned out. UNIWERSAL had omitted to insert a 560 ohm resistor in the photodiode circuit of the optocoupler. (The Charles Harrow schematic shows the resistor.) I replaced the optocoupler (it costs under 2€) and added a resistor. Problem solved, but...
- My encoder was now working, sort of, but it was not really functional. More on this below.
- After implementing LesveDomeNet, my dome rotation was hit and miss. Several underlying issues were compounding the problem:
  - o **Cable shielding and grounding**
    - None of the cables in the UNIWERSAL control box were shielded.
    - The cable from the control box to the motors, the home switch and the shutter limit switches were also unshielded. The cable of the DC shutter motor was shielded but the shield was not grounded.
    - The 3-phase inverter requires shielded cable and grounding. Inverters are known for their EM interference.
    - I installed shielded cables everywhere and grounded them.

- The original **encoder and encoder wheel** on the UNIWERSAL dome is inadequate. At least mine was. The wheel rotates too fast and/or has too many holes. The encoder wheel has 32 holes and rotates about once every 1.6 seconds, i.e. 20 holes/s. Furthermore, the holes are very small, the barriers between holes are very narrow, and the holes are round. This makes positioning the optocoupler optimally extremely difficult.
- The encoder problem was compounded by the fact that I was reading hole to no-hole transitions at very high speed. There were only two options: Slow down the dome, or change the encoder. Due to the encoder wheel configuration I would have had to slow down the dome a lot, so I discarded that option. Clearly I needed to modify the encoder wheel and encoder.
- After many hours reading about other people's experience on various astro forums, I became convinced that an **encoder producing Gray code is preferable to a single bit encoder**. The main reason is that 2-bit Gray code can distinguish the direction of rotation (CW vs CCW). Single bit encoders cannot. -- LesveDomeNet supports Gray code mode.
- To cut a long story short: Rather than have a machine shop machine a new encoder wheel and a new support bracket for a second TCST2103 in order to generate Gray code, I decided to look for an industrial encoder where all the electronics, encoder wheel and optocouplers are encapsulated in one piece of equipment.
  - Some people have used the Bourns EM14 encoder with good results. It is quite cheap, too. For my UNIWERSAL dome and motor it looked a bit flimsy, so I went with a different encoder. Still, the Bourns EM 14 may be a good alternative, for less money.
  - In the end I bought and installed a KOYO TRD-NH10-RZWD encoder. Cost: ca. 200€. (Plus the cost of getting a machine shop to adapt the motor shaft and cut a simple mounting plate. Cost: 70€.)
    - This encoder provides totem-pole output and runs off 5-30 VDC, which was perfect for my 12V power supply. Totem-pole output is supported by the K8055(N)'s digital inputs.
    - I used the hollow-shaft encoder version of the encoder, but the KOYOs also come in solid-shaft versions.
    - I bought the 10 ppr (pulses per revolution) version. In hindsight, that was not optimal. I should have gone for the 3 ppr version. More on this below, under "encoder pulse rates".

Encountering ever more frustrating issues, somewhere along the way, I had turned to the LesveDome Yahoo group. Two Steves, one Paul, one Mike, and several others

kindly offered advice. Thank you, guys. I was getting desperate at that point and needed new ideas and moral support.

To anyone using the **Velleman K8055 board**, here is some advice:

- There are two versions of the K8055:
  - The original K8055 kit, or the equivalent VM110.
  - The newer K8055N, or its VM110N counterpart. (I have the K8055N.)
  - Make sure you know which version you have, as the two versions of the board appear to support very different interrupt times. More on this below, where I discuss encoder pulse rates. (The newer K8055N tolerates interrupt times on the order of 1 ms; the older K8055 apparently has trouble going much below 30 ms.)
- For completeness sake, I add a couple of pieces of information on the K8055(N) board, which are hard to find in the documentation:
  - The five digital inputs accept a voltage of up to 30V.
  - I am not sure of their maximum current rating, but GND digital inputs can definitely take 20 mA. (They may be able to take much more, but I could not find that information.)
  - For electronics newbies like myself, be aware that the K8055(N) is using open collector logic. Digital inputs give a HIGH signal when they are grounded (i.e., LOW voltage); while when the input is a non-zero (HIGH) voltage, the K8055(N) reports a LOW signal. In other words, the logic is reversed. This is quite common in electronics, and there are excellent reasons for it, but it confused me initially, and it may not be immediately clear to others not well versed in electronics.

#### Configuring your dome software

I recommend to follow the following steps in that order to save yourself time and grief:

- First download, install and play around with the Velleman K8055(N) demo software. Test the inputs and outputs of your K8055(N).
  - Here is the link for the "N" version's download page: <https://www.velleman.eu/support/downloads/?code=K8055N&type=>
- Next download Steve Hennerley's *K8055 Dome Diagnostics* program: <https://hennerley.wordpress.com/k8055DomeDiags/>
  - This nifty piece of software did not exist until June 2019. To me and a few others, it made all the difference. We can finally see what our encoders and our home switch are doing. (I cannot stress enough how much Steve's free little program has facilitated problem diagnostics. Thank you again, Steve.)
  - *K8055 Dome Diagnostics* displays your encoder's pulses (single bit and/or Gray code) and your home switch pulses on a timeline.

- Take a good look at your encoder pulses. Are they as expected? Regularly spaced? Equal length highs and lows? What interrupt time is recommended by the software? etc.
- This is where I got my next nasty surprise: My dome's home switch was causing sporadic "closed" pulses, when the home switch was *not* closed. These "false" pulses were throwing LesveDomeNet off, as it resets azimuth when it is at the home position. More on this later.
- Once your pulses look good with Steve's *K8055 Dome Diagnostics* program, note the following two numbers:
  - The number "p" of pulses per rotation of the azimuth wheel (i.e. your encoder's PPR).
  - The number "Q" of encoder pulses (of either of your encoder code signals, if you use Gray code) for a full dome revolution. This number is provided by the *K8055 Dome Diagnostics* program.
- Now start up LesveDomeNet, and parametrize it for your dome. I suggest that you input the above two numbers on LesveDomeNet's set-up screen as follows:
  - Dome Diameter = Q.
  - Azimuth Sensor Wheel Diameter = p
  - Azimuth sensor Wheel Number of holes = p (*sic!*)

This works because Q and p are proportional respectively to dome diameter and sensor wheel diameter.

- Once these and all other parameters are set, click OK and close LesveDomeNet.
- Reopen it. Now test dome rotation. (After four 90° turns, it should return home. Mine was slightly off, but after fine tuning the Q parameter a bit, it is now spot on.)
- In Gray code mode, you may find that your dome moves CW or CCW as expected, but pay attention to LesveDome's azimuth reading. Do it now, before you go to the next step. (My dome did funny things in POTH when in Gray code mode, but it worked in the other two modes. It took me a while to notice that when rotating CW, the azimuth readings were decreasing, when they should be increasing.) Check this in LesveDomeNet, and, as Pierre de Ponthiere says, just invert input 1 and input 5 cables if azimuth readings and direction of rotation do not coincide.
- Now finally you may sync LesveDomeNet with your mount, using POTH or whatever ASCOM program you use to sync mount and dome.

I am getting to the end of my story.

#### ENCODER PULSE RATES

With Steve's *K8055 Dome Diagnostics* program, I could see my KOYO encoder's Gray code pulses.

In my set-up there remained two issues:

- Sometimes the pulses are not perfectly even in length.
- Sometimes, very rarely now, Steve's program says that the encoder generates poor Gray code.

I believe that both issues are due to the mechanical properties of my UNIWERSAL dome. It is a heavy dome, which rumbles a bit on its sawtooth rail. The vibrations are transmitted to the motor and the encoder shaft. At this stage I see no easy way of mitigating this mechanical vibration.

The uneven pulse issue can be mitigated in software, by oversampling.

- Suppose for a moment that every HIGH pulse lasts 0.5s, followed by 0.5s of a LOW pulse. Then by sampling twice every second, one will always catch the two states.
- If on the other hand occasionally the HIGH pulse lasts 0.25s followed by a 0.75s LOW, then one has to sample at least four times per second to be sure to catch the pulse.
- In my case, the encoder generates about 6 HIGH pulses per second for each encoder input, i.e. 12 state changes per second for each encoder input. As I use 2-bit Gray code, this means  $4 \times 6 = 24$  Gray code state changes per second. So I should sample at least every  $1000/24 = \sim 40$  ms. If I want to catch every pulse twice, to be on the safe side, I should sample every 20 ms or more often. (Steve's program seems to recommend sampling every pulse twice, i.e., in my case it recommends to set the interrupt time to no higher than 20ms.)
- This is where the difference between the K8055N and K8055 boards becomes critically important.
  - According to Pierre de Ponthiere, the K8055 board cannot handle interrupt times much lower than 30 ms. So if your encoder generates too many pulses, you either have to slow down your dome, or change encoders, or swap Velleman cards.
  - The newer K8055N appears to be able to handle interrupt times as low as 1 ms, a significant improvement. I have tested this empirically, and in my case, this appears to be correct. My K8055N runs at 3 ms without any problem. This may be due in part to my having a relatively new computer, too. -- I am running SGP and PhD2 now on the computer, as well as other programs, and I am still not experiencing any problems with interrupt times.
- In my case, for reasons still unknown, my encoder pulses are uneven in length at times. I suspect this is due to the vibration of the dome and motor, which perturbs the smooth rotation of the encoder. To mitigate this, I need to oversample quite a bit. Rather than using an interrupt time of 20 ms, the maximum recommended for my set-up, I sample at 5 or even 3 ms. At these low interrupt times the K8055N is clearly a must.
- This is also where my choice of a 10 ppr encoder was not ideal, for my dome.

- 10 ppr means 40 Gray code state changes per revolution, or about 24 state changes per second for my dome. For my dome and KOYO encoder a 360° dome rotation means 2300 encoder state changes. This precision of 0.16° in azimuth position is overkill. A precision in azimuth of 0.5° to 1° should be more than enough, unless your shutter is very narrow. This represents at most  $2 \times 360 = 720$  state changes per dome revolution. -- I should have bought an encoder with some 3 ppr.
- So, here is my advice: Think about how many encoder state changes (or Gray code state changes, if you use Gray code) per dome rotation you need. 720 state changes or so is enough for most of us. Then look for an encoder which provides no more precision than this. The lower the encoder pulse rate, the better LesveDomeNet and your K8055(N) card will handle it.

#### SPURIOUS HOME SWITCH PULSES and FLOATING VOLTAGES

The following only applies to dry-contact home switch configurations, such as UNIWERSAL's, or the one in the Charles Harrow schematic.

Steve's diagnostic program identified some odd behavior of my UNIWERSAL dome's home switch. See the red pulses on the attached screenshot. These short "home switch is closed" pulses are misinterpretations by the K8055N card. The home switch is not closed when they occur.

It took me a while to figure out what was happening.

I had shielded and grounded pretty much all my cables. And I still had problems...

According to my multimeter, the chassis and ground of my control box vibrate at 50 Hz. There may also be some harmonics. As a result the dry-contact home switch, when open (!), shows an induced voltage of 0.5 VAC. This is an RMS voltage. Peak voltage would be something like 0.7 VAC.

This should be no big deal, but the K8055's digital input voltage is floating. I measured unconnected digital input voltage at some 1.7 VDC. When I connect the home switch to INPUT-2, I suspect that the open home switch overlays an induced 0.7 VAC voltage over the 1.7 VDC. Every 20 seconds or so, even when the dome is not rotating, this AC component leads to an input voltage of less than 1 V being detected on the K8055N's INPUT-2, which promptly interprets the state as "home switch is closed". (Perhaps an electronics engineer can improve my layman's explanation.)

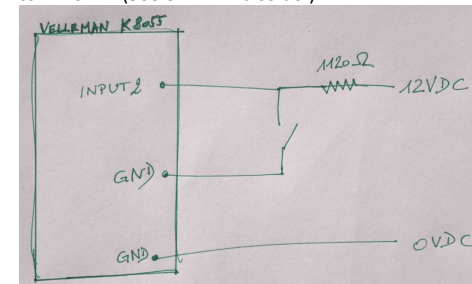
This probably happens because my UNIWERSAL control box generates significant induced EM interference. Other users may not run into this problem.

There are various ways of fixing this.

My solution was to add a pull-up resistor to the home switch circuit, deviating from the Charles Harrow schematic for the home switch:

- My dry-contact home switch runs from INPUT-2 to GROUND, as in the Charles Harrow schematic.
- But I also force INPUT-2 of the K8055N to 12 VDC when the home switch is open. See schematics.

- To do so, I ran an additional cable from +12 VDC to a 1120 ohm resistor to INPUT-2. (560 ohm will also do.)



- When the home switch is open, INPUT-2 sees something like 11-13 V (the range being due to the small induced AC component), i.e., it always provides a HIGH input voltage, i.e., given the open collector logic, a LOW "home-switch-open" signal.
- When the home switch is closed, INPUT-2 is grounded. -- Some minor current (10 mA) then flows from 12 VDC through the resistor to the home switch to ground.

My home switch signal is now perfectly well behaved, at last.

(You may ask why this EM interference problem is not occurring on the K8055N's inputs for my KOYO encoder. It probably would if the encoder provided a dry-contact signal. However, the encoder always provides either a roughly 10 V HIGH signal, or a 0 V LOW signal to the digital input. The small voltage of the EM interference does not significantly affect the 10 V signal.)

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I hope some of this is of use to someone out there.

My heartfelt thanks to Pierre de Ponthiere for his *LesveDomeNet* software, and to Steve Hennerley for his *K8055 dome diagnostics* program.

Clear skies,

Kris

K3055 Dome Diagnostics - ©2019 Steve Hennerley

Dome Diagnostics | K3055 Tester | About

**Sensor 1** Counter: 258 Since last home: 16 Gray Code Indicator:

**Sensor 2** Counter: 257 Since last home: 15

Home Sensor

**Gray Code Pulse Speed Info**

Recommended Max Timer Interval: 21 msec

123.25 pulse/sec (average)

42.8 pulse width (ms) average

**Asimuth Sensor Parameter Calculator**

Gray Code Mode:

Last rotation: Sensor 1: 177 Sensor 2: 18

Rotation speed: 2.88 sec/rev 7507.81 deg/min

Wheel diameter: 5.04 Dome diameter: 14.28

Number of Holes: 6 Dome circumference: 44.86

Card Address

SK5  SK6

Card 0 connected

USB I/O Board Timer Interval in msec: 5

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