Monday, 08/31/2020

Notes from Mail List

Participants: Dave, Julius, Hyomin, Gil, SungJun

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latest inground temperature stabilized RM3100 results
Julius Madey
Mon, Aug 24, 10:04 PM (7 days ago)
to Hyomin, me, Dave, Nathaniel

Attached is a 0110UTC to 2400UTC, 0823, run with my inground RM3100 mag, compared to data from the Intermagnet.org Fredericksburg, VA observatory data. I used Dave's runMag program with cycle count of 400 but set the average count register to 10, so each one second sample is an average of 10 readings with a 400 cycle count. Each data point represents the running average of the previous 60 seconds.

I did not try to plot delta B, which is the format of the Intermagnet data as but the resolution of the three RM3100 axes is sufficient to show the variation from which the delta B numbers can be derived. Note that the effective noise level of the RM3100 readings is ~5nT pp. JennyJump data is probably a closer match to my location but the comparison with the Fredericksburg numbers is very encouraging and has been consistent since I started the inground temperature stabilization tests.

Regards, Jules - K2KGJ Attachments area

David Witten
Wed, Aug 19, 2:03 PM (12 days ago)
to Julius

Jules,

Sorry to be long-winded.

As I told you, I'm very frustrated trying to get more of my Magnetometer Extender pairs to work correctly. I made and ordered two new sets of simplified local-side only boards. I botched the first set so I ordered an improved second set.

With some blue-wire I have fixed one of the first set of these boards sufficiently to test the local i2c integrity when the board is minimally populated. When I then fully populate the board the I2C bus locks up.

So I have tried removing components, testing as I go, until things begin functioning again. The culprit(s) seem to be the filter/protection chain that connects the 5v on from the Pi to the pins 4 & 5 on the RJ45 jack. This does not make sense to me, but it is undeniably so.

You commented that what I was doing is roughly equivalent to your modifications to the Sparkfun PCA9615 Differential breakout board that you often use.

While I have more test boards coming, I'm not convinced that they won't also have some fatal flaw.

Is it possible that you could explain to me (or mark up SparkFun's schematic) so that I can copy the modifications that you are using.

Thanks!

(OBTW I cut traces to blue-wire the SDA line on the PI to the testpoint marked SCL and the SCL one to SDA. I don't use the JST-sh (Qwiic) connector - Just plug the whole thing into the Pi Bus)

Dave Witten 2 Attachments

Julius Madey
Wed, Aug 19, 10:06 PM (12 days ago)
to me

Dave, that sounds odd to me also. The only variable I haven't had to deal with is the polyfuse ... what happens when you bridge across it? Did you scope all the lines? I've attached the mods I did to SFfun boards at both ends of the CAT5 cable run. Originally, I used your little 0.0.2 board with the 9808 and RM3100 and plugged that in to the remote end SF board Quiic connector. I added a 3.3 volt regulator on that board for supply to the single end side of the 9615, the 9808 and the RM3100. Curiously, the enable pin of the 9615 on the SF boards is left floating to a solder pad on the edge of the board but I am not aware of any problem with proper startup of the board without intentionally adding a capacitor for delay as you did on your later boards which I'm using in the two magnetometer assemblies here.

I don't think 0.1uf is sufficient bypassing for the 5 volt line from the Pi. As you see in my mod description, I'm using 10uf.

Hope this helps.

Jules

David Witten
Aug 19, 2020, 10:13 PM (12 days ago)
to Julius

Jules,

Thanks!

THe enable line on the PCA9615 was a late addition when I was having other difficulties. I do not really believe that it is required, but the data sheet implied that it might be.

I'll think about your other points, and let you know what I find.

Dave

Julius Madey// Aug 20, 2020, 9:31 AM (11 days ago)
to me

Dave, I understand that the current proposition is to essentially use the 10/100 Mode B pinout for the differential i2c circuits. There was also concern about external fields possibly coupling to the twisted pair lines, introducing noise. So, if that is a concern, it would seem that to reduce possible noise coupling to the DC lines as well, having a separate pair for plus and for minus isn't a good idea since there is physical separation within the cable between the two DC pairs.

So, in keeping with the idea of minimum external field interference, it would seem that paralleling the two spare pares with one wire of each as minus and the other wire as plus is the way to go.

Further, although the external B field produced by one pair as plus and the other spare as minus is probably pretty small, if the concern is to minimize B fields local to the RM3100 produced by cabling/circuitry, then it would seem to make sense to run DC lines as twisted pairs as well.

Now, you can do the latter (ie, power on paralleled twisted pairs) and keep signal definitions consistent with 10/100 Mode B pinouts, or, use the SparkFun pinouts with the trivial modification I used to do the same.

Was there some concern that someone may inadvertently plug the differential i2c circuit into a standard ethernet socket ?

Jules

Julius Madey
Mon, Aug 17, 11:21 AM
to me

Dave, This is an aside ... The latest results I just sent out pretty much blew my mind re all of the previous testing.

Two separate runs, one with runMag 0.0.8 and 400 cycles and the cobbed up simplei2c which I set for a cycle of 600 and 10 averages at the same 1/sec polling as runMag, are essentially the same quality, with perhaps slightly less noise at the higher cycle count with averaging.

I can't believe the results and correlation with the Intermag data for the same time period is a fluke; it's got to be valid.

May have to go back and cut the number of variables changed at one time. The first runs after installing the buried unit were temperature stable but still didn't look quite right. Changing the remote regulator to a lower drop out unit AND 3.0 volts seems to have made a major improvement along with the temperature stabilization.

From a testing standpoint, one really should separate the those two variables.

For the time being, I'm going to continue making runs and looking for correlation with reporting magnetic observatories.

Hopefully, at some point, PNI will give a reply on the temperature issue.

Regards, Jules

David Witten
Mon, Aug 17, 1:37 PM
to Julius

Jules,

Very impressive!

At this point I feel very certain of the suitability for purpose of these units. The only odd bit is Hyomin's data from JJ, and there are many more unanswered questions about that than the PNI module.

You have done more to give me confidence in this path than anyone else could.

Thanks,

Dave

Julius Madey
Mon, Aug 17, 11:00 AM
to Hyomin, me, Dave, TAPR

Hyomin, thanks; whenever you can get to it.

But regarding the attachments yesterday and these today, what is your opinion on the RM3100 data recording?

The correlation between the 1530 to 1400 UTC run yesterday and the Fredericksburg Intermagnet plot seems to be very good. I'm about the same longitude as Fredericksburg but a few degrees difference in lattitude so JJ will be interesting.

Unless my eyes are deceiving me, it looks like the RM3100 resolution is better than 5nT. Keeping temperature variation of the RM3100 within 0.3C during a run seems to have minimized whatever temperature sensitivity of the RM3100 that was previously reported.

I will ask PNI once again about temperature sensitivity but have not heard back since tech support said it would look into the data I provided.

Jules - K2KGJ 2 Attachments

Julius Madey
Sun, Aug 16, 4:17 PM
to me, Hyomin, Dave, TAPR

All, The attached PDFs document a 4.5 hour run with the underground mounted RM3100 to achieve near constant temperature during a run. The voltage regulator on the Dave's 0.0.10 remote adapter board was changed to an AP2210 ultralow dropout type with a 3.0 volt output voltage which matches the specified test voltage in the RM3100 data sheet and is well within both the MCP9808 precision temperature sensor and the PCA9615 differential i2c extender. This modification substantially increases the margin for voltage drop in long cable runs. The modification is trivial and uses the same solder pads as the original 1117 regulator.

The data plots are primarily for Hyomin. There appears to be a correlation between the X and Y axis plots and the reported values for the Fredericksburg magnetic observatory on the Intermagnet site around 0400UTC. Hyomin, can you check Jenny Jump during that same interval; NJ is closer to me than Fredericksburg. I currently have another run going which should show some of the higher dB activity since then if the earlier recording is not just coincidental.

Another question for Hyomin; is there value in doing a test with two RM3100's, perhaps within 100 feet of each other as a check on uniformity of response?

Jules Madey-K2KGJ

Julius Madey
Aug 13, 2020, 11:06 PM
to me

Dave, The direct i2c bus test with my second RM3100 looked normal. Pulled the inground unit and reconnected the weather proof box with the second RM3100 which appears to work normally. Tested the inground unit with its RJ plugged into the Pi diff extender board and everything looked normal. Then did a direct connection with the RM3100 in your small board on the Pi's i2c but and that was normal as well .....

Checked output voltage of LDO reg 3.36V with a min max dropout of 1.3-1.4V, that's 4.76V threshold before voltage sag on the 3.3side. On the adapter board in the inground unit I used your original C values on the LDO but on the first board, which is what's in the weatherproof box that I started testing with, I beefed up the caps to ~47uF, which provides more margin on the transient loading of the differential i2C drivers.

400 feet of paralleled 24Ga on ground and 5V results in 20 ohms round trip resistance and given the margins, the observed behavior fits a classic voltage sag problem.

Also, I don't always use the same Pi 5 volt brick, so that's another contributing factor.

I have SPX1117M3-L-3-3 LDOs with min max of 1.0--1.2V dropout which I'll substitute which, along with larger C, should take care of the problem..

For curiosity sake, I ordered another RM3100 but with attached pin strips just to see if there is any difference between factory attached pins and DIY on the cheaper board.

Jules

David Witten
Aug 14, 2020, 2:26 PM
to Julius

Jules,

It really looks like you have been putting in long hours to sort this all out. Thanks from me and everyone else!

So that you know:

I'm experiencing a problem that I don't remember you mentioning. When I just let the software run for extended periods of time, reading a module in local mode, I consistently encounter a segfault. Probably something stupid I've done in the code, but I hope that it is not interfering with your analysis. I have had many interruptions, so my work on this is inconsistent. I hope to do all the usual methods to track this down over the weekend. But be warned that v0.0.9-master and late v0.0.8 both show this behavior on Ras-Pi 3 and Odroid-N2+. Both running locally and via SSH. I have not been writing logs, which is recent code. The problem could be related to that.

Also, I'm encountering some medical issues that may make it difficult to respond for a short while sometime in the future, perhaps late next week. I will try to put as clean a copy of the code on Github as possible before then.

Dave

Julius Madey
Aug 14, 2020, 3:51 PM
to me

Dave, Just getting the unit ready to place back in the ground. I'm going to use this one for data and repurpose the boards in the wx proof box into a 3 to 4 foot version for deeper insertion. Haven't experienced the seg fault but I'm doing logs for all of the longer runs. While you're at it, check to see if you set defaults in the absence of any user parameters. I note that if I set register 0A to some value other than 0 or 1, it shows up as a multiplication factor in the output. Jules

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David Witten
Aug 14, 2020, 5:43 PM
to Julius

Jules,

Will do.

Dave

Julius Madey
Aug 15, 2020, 5:29 PM
to me

Dave, I decided to change the 3.3 volt 1117 family LDO regulator on the board to a Diodes Incorporated AP2210 family device with 0.25 volts ultralow dropout voltage for more margin in experiments. With a 5.0 volt supply on the Pi, that's almost 1 volt more dropout margin than the 1117 family. Also, since the RM3100 is spec'd with a 3.0 volt supply, even though it's supply voltage range is 2.0 to 3.6 volts, I thought I'd try 3.0 volts, not that I expect to see anything different. The 2210 is rated at 300mA, way more than is needed for the MCP9808, RM3100 and PCA9615 combined. The 1117 provides 10-15db more PSRR than the 2210 but I don't think that is a problem.

It fits very nicely into the existing regulator pad pattern as seen in the attached photo. A short jumper of #32 magnet wire provides the connection from the Vddb pad. The values of C5 and C8 are changed to 22uF for C5 and 3.3uF for C8. Both are MLCC caps rated at 16volts, which means that their actual capacitance at 5 and 3 volts are closer to their marked value with lower piezoelectric effect.

The higher value cap on the Vddb line is to snub 9615 transient currents driving the capacitance of the 400 feet of CAT5. There is very little transient loading on the 3 volt output. Will let you know how this works out. Jules

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David Witten
Aug 15, 2020, 6:57 PM
to Julius

Julius,

I wish I had your advice when I started out on this. You know all this much better than I ever will.

I made some new boards for the local end only. Basically the same design as before, but without things that seemed non-essential at the local end. And I added some test points to facilitate testing. I put test points on the SDA, SCL, DSCL+, DSCL-, DSDA+, and DSDA-.

There is no voltage regulator on this board, I'm just using 3.3v (and 5.0v) directly from the Ras-Pi.

THis board plugs directly into the GPIO 40 pin bus on the Pi. There is a place for a JST-SH4 (Qwiic) connector and a MCP9808a, but these needn't be populated.

There is probably other stuff that I should have done. I'm willing to make changes and more boards if it seems worthwhile.

These are intended for testing and pretty cheap to make. I'll send you a couple if they seem to work.

I think that I forgot the local I2C pull-ups.

Dave

Julius Madey
Aug 16, 2020, 12:03 PM
to me

Dave, Except for the 9808, that's essentially what I jerry rigged with a piece of perf board and a SparkFun differential i2c adapter for the Pi I'm using at the local end. If you can spare a couple, thanks !

I made an error in my description of the orientation of the rm3100 in the inground mount ... always had some trouble with coordinate rotations in physics !

Rotation of the board is about the Y axis so that the top of the rm3100 board faces magnetic north, which preserves the sign of the Y axis. The Z axis now becomes the X axis but the sign must be reversed because positive was down toward the center of the earth and now positive is toward the south.

The original X axis, which was positive toward magnetic north is now pointing down toward the center of the earth so it's sign is preserved.

Jules

Julius Madey
Aug 16, 2020, 12:07 PM
to me

Forgot, check out this site: https://intermagnet.org/data-donnee/dataplot-eng.php

The Fredericksburg station is the closest to me. Their technical handbook reference is also very handy. Jules

On 8/15/2020 7:57 PM, David Witten wrote:

David Witten
Aug 16, 2020, 7:25 PM
to Julius

Jules,

The results and the Intermagnet site are both very interesting. Unfortunately the nearest sites to me are Stennis Space Science Center or perhaps Boulder. Very far away! Boulder is a 14+ hour drive on I70.

As for the boards I made, I will quickly be ordering another set. The first set is unusable. I make some really amazing mistakes when I work on things like this late at night. I swapped the SDA/SCL lines just about everywhere it was possible to do so. And I switched SDA/SCL with 3.3v and GND on the JST-SH4 connector! Gotta quit doing this when I can't fall asleep...

Dave

Julius Madey
Thu, Aug 13, 7:56 PM
to me

Dave, I'm thinking it might be a good idea to start by setting all RM3100 registers to their default values. I note that if I independently set the 0A register to 10, runMag produces values a factor of 10 high. Jules

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Julius Madey
Tue, Aug 11, 9:49 PM
to me

Dave, I think we're OK operator error here with parameter formats .... Sorry for the false alarm Jules

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David Witten\\
Wed, Aug 12, 9:26 AM to Julius

Jules,

I will look closely at this when I get back from my appointment this am. THere are definitely some untested 'features' here.

Dave

Julius Madey
Wed, Aug 12, 1:21 PM
to me

Dave, Did a 13 hour run from 2300edt yesterday to noon today and then started a second run to complete 24 hours. Seeing a slight 0.3 degree upward shift in temp over the 13 hours. The sensor results are not flat line and still show some drift with an initial relatively rapid change after starting the run ... have to see if the same thing happens on the run in progress now. Some activity around 0400edt to 0900edt which I can't explain as magnetic field shifts, at least according to the data from Intermag. Might be seismic activity related as any movement of the sensor could also create a 'signal' in the low nT range (~50nT). Jules

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David Witten
Wed, Aug 12, 2:14 PM
to Dave, tangerinesdr, Julius

Jules,

Very interesting!

I'm curious what effect we might see burying the sensor completely, say below the frostline:

Frostline Map

This would make deployment more difficult, but would surely provide significant stability.

But what does it do to magnetic field lines? - one more experiment that I would like to try sometime: place several sensors in a vertical column at, say 500 cm intervals in a fairly uniform deposit of soil.

Seismic interaction is something I hadn't considered.

Dave

Julius Madey
Wed, Aug 12, 2:33 PM
to me, Dave, tangerinesdr

Dave, Frost depth varies considerably depending on factors like snow cover, proximity to structures, etc. Take a look at the attached engineering study I found several years ago when setting the foundation for an attached deck. Jules

Attachments area

David Witten
Wed, Aug 12, 3:54 PM
to Julius

Jules,

Interesting! Those frost-tubes interesting. More to read about...

Dave

Julius Madey
Wed, Aug 12, 11:30 PM
to me

Dave, Looks like I have to pull the unit. The Y axis cycle count register appears to have a stuck bit; we had a Tstorm yesterday evening and it might have taken a hit ... seemed to be OK prior to that. Jules

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David Witten
Thu, Aug 13, 8:18 AM
to Julius

Jules,

If you need another PNI module, I can send one. Or of course It might be as quick to get one directly from PNI. Let me know if you need anything.

Dave

Julius Madey
Thu, Aug 13, 8:32 AM
to me

Dave, I have one more module here. Before pulling the assembly, I was going to try the register readback option while monitoring the i2c bus to see the value. Jules

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Julius Madey
Thu, Aug 13, 10:55 AM
to Dave, tangerinesdr, me

Latest results. Attached pdf. Two concatenated runMag runs with beginning of second 15 minutes after end of first with what appears to be a 'startup transient' of approximately an hour at the beginning of each run. No idea what's causing that behavior; more testing under way with local i2c bus connection (no differential extension) on a second RM3100. More testing participants needed. Jules - K2KGJ

On 8/12/2020 3:14 PM, David Witten wrote:

Attachments area

Julius Madey
Thu, Aug 13, 11:26 PM
to me, Dave, tangerinesdr

re_previous 'problem' report: Further testing confirmed problem due to voltage sag at end of CAT5 cable; in retrospect, a 'classic' example .... oops.

I did not take time to measure dropout voltage on this unit before installation as I did on the first board used in a weather proof above ground box install. Changing to an SPX1117M3-L-3-3 LDO regulator with 250mV additional dropout margin as well as larger filter caps.

From a voltage drop viewpoint, 400 feet of CAT5 or CAT6 24Ga solid copper wire and a well regulated 5 volt supply for the microcomputer represents about the practical limit in cable length. Standard i2c signalling rate of 100KHz presents no problem at that length.

Jules Madey K2KGJ

Julius Madey
Tue, Aug 11, 9:34 PM
to me

Dave, I don't think it's a software bug. Started with a fresh copy of 0.0.8 from GitHub. Did a power off power on reset which cleared all rm3100 registers. Then just ran the c option for 200, 300 and 400 with no problem.

If I want to use the c parameter and the S parameter, what is the proper order? Jules

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Julius Madey
Tue, Aug 11, 8:17 PM
to me

Dave, Running version 0.0.8 of runMag. Tried the c option with the S option for labeling the log file and kept getting segmentation faults.

Then simply tried the c option with 300 and 400.

Then tried the default and also tried c with 200. The gain divisor appears to be stuck.

For a cycle count of 200, the Z field should be ~51uT and I get 71uT .... for a c=400, I get 75uT.

Will do a make again to restore. Haven't checked GitHub lately; is there a newer version?

Jules

Julius Madey
Tue, Aug 11, 4:47 PM
to me

Dave, photos attached of basic assembly and completed install N-S reference is red line visible on top of 90 degree PVC elbow.

The RM3100 has been rotated 90 degrees about the Y sensor axis so the North mark on the RM3100 is pointing straight down; most convenient for assembly since the adapter board cable comes off the 'south' end and runs up the PVC pipe to the waterproof connector.

The plane of the 90 degree PVC elbow is perpendicular to the plane of the RM3100, placing the waterproof RJ connector toward the bottom of the RM3100 board, which means the top of the RM3100 board is pointing North.

So the original X sensor is now Z and reads the correct sign for the B field pointing down toward the center of the earth.

Original Z is now X and the sign is correct. Original Y is still Y.

Over a 24 hour period, temperature at ~ 18 inches below ground has remained between 18.7 and 18.9 C. Max air temp here this afternoon was 30.5 C

For year round service, frost depth becomes a factor and for general use, soil type, including underlying bedrock, may make such an installation impractical.

Still waiting for feedback from PNI but in the meantime, I can do some measurements which hopefully eliminates temperature as a variable.

Regards, Jules K2KGJ

Julius Madey
Tue, Aug 11, 9:21 AM
to me

Dave, I managed to get it in the ground late yesterday afternoon. Interrupted by a downpour and Tstorm which wet things down a bit but made digging the last few inches easier. Ran for two hours last evening ... temp 18.7 C +/- 0.2 but all three axis slowly changed by about 1% which I think was 'settling' in to a stable position as I only filled the hole part way to get a test underway. Finishing up a 12 hour run to see what it stabilized at then have to go back out, finish filling, levelling and adjusting the N-S orientation, then let it sit for another 24 hours to stabilize.

Jules

Kim, Hyomin
Sun, Aug 2, 7:53 PM
to me, Nathaniel, Gil

Hi Dave Gil suggested a good idea - he could move the magnetometer very close to the existing science magnetometer to minimize any possible environmental differences. Also, he suggested that the magnetometer is powered by a battery (this is solely because the cable penetration around the observatory is not easy to accommodate at the moment). Could you estimate the current draw of the system? Also, what is the operating voltage? 3.3?

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David Witten
Sun, Aug 2, 11:01 PM
to Hyomin

Hyomin,

Placing the remote module physically close to the reference magnetometer certainly sounds like a good idea.

It was my original intention that the remote unit could be powered independently from a battery if desired. But I may have lost sight of that objective with all of the other issues that were under discussion. It certainly has not been tested that way, and there might be some danger to the electronics if the device is misconnected. There may be a safe way to do it, but I will have to look again at the schematic.

The operating voltage for the sensors is 3.3v. The signalling across the Cat 6 cable is at 5v. It is critically that the RM3100 module is not exposed to any more than 3.3v on any pin or it will be destroyed.

I'll try to look at this more closely tomorrow.

Dave Witten

David Witten
Sat, Aug 15, 7:06 PM
to Hyomin

Here are some useful Official Ras-Pi power consumption numbers:

https://www.raspberrypi.org/documentation/hardware/raspberrypi/power/README.md

Is this what you need?

Dave

Julius Madey
Fri, Jul 31, 10:19 AM
to me, Hyomin, tangerinesdr

Good morning all. Betty Zhang at PNI is responding to the request and has asked for more information which I have supplied, including some of the JJ test comparisons, how I ran the calibration runs I did, data reduction, etc.

I would suggest one further item for consideration in getting to a useable solution. If RM3100 temperature turns out to be a concern, place the sensor in a small foam insulated box with a proportionally controlled heater which maintains the temperature at something just above what would be considered the highest environmental temperature around the sensor. That should be relatively simple to do without introducing an interfering magnetic field local to the sensor. Some power would be required but with careful design, I would think well within 1 watt.

Another possibility would be using peltier effect heat pumps to do the same thing, although the technology would probably result is stronger local B fields from the peltier device and require more power. The insulated foam box and proportional heater is also probably the cheapest approach considering the need to keep overall costs for the expected users low.

Regards, Jules

Julius Madey
Fri, Jul 31, 10:45 AM
to me, Hyomin, tangerinesdr

One more thought. I've asked PNI for information both on temperature and supply voltage sensitivity, the only two variables I could think of besides the need to minimize local B fields due to currents in circuit board traces, nearby wiring, etc.

I did not find data on the temperature stability of the 3.3 volt regulator Dave's JJ board is using but the regulator I used with the original adapter board Dave sent me has about 5 millivolts of change out of 3.3 volts between 25 and 50 C and Dave's is probably similar. That doesn't seem like enough change to produce the observed variations but that information was given to PNI as well.

Julius Madey
Thu, Jul 30, 12:13 PM
to me

Dave, This is the best data I have yet to demonstrate possible temperature effects on RM3100 measurements. I had planned to stabilize temperature at near 0 C by mounting the 3100 adapter board on an aluminum block immersed in an ice/water mix, sitting in a foam box but a run this morning at 0500 to 0700 produced a variation of less than 0.5 C.

The attached pdf includes a 2 hour run from yesterday night, 2100-2300 edt, where temperature had not yet stabilized for the night but which , I think, clearly shows what appears to be consistent temperature related measurement effects.

All measurements were made with a cycle count of 600 and a 0A register value of 10, which amounts to averaging 10 successive readings. Status register query was held off until the reading was complete to avoid any possible effects of i2c bus activity.

I am also sending this to PNI for their comment.

Hope you don't mind using you for a post to the group.

Jules Attachments area

David Witten
Thu, Jul 30, 12:24 PM
to Julius

Jules,

Thanks!

This work is really great!

I don't mind being the go between at all. Don't feel that you need to go through me, but sometimes it is good to have a relay.

Dave

Julius Madey
Sun, Jul 26, 11:11 PM
to me

Dave, Will distribute results tomorrow but thought you'd like to know that driving the rm3100 with a known field (using a helmholtz pair) and wave shape at three different levels from +/-50nT to +/-2890 nT (sine wave period of 30 minutes) gave results within 5%. Since runs took at least an hour each, I only tested one axis but based on other work, have no doubt that the other two axis would provide the same results. Jules

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David Witten
Mon, Jul 27, 11:12 AM
to Julius

Jules,

Thanks for the report! That is good news.

Dave

Jules Madey, K2KGJ
July 18, 2020

Attached photos are inside of weatherproof box with Dave's adapter board fastened to two wood cleats with brass wood screws. Cleats are glued to box. Mounting is quite rigid. The box rests on a leveled concrete block and was initially oriented to magnetic north with a Brunton compass, then fine positioned to a zero Y offset of near 50nT, which from the expected value of the EMM model horizontal intensity at this location, is about 0.2 degrees from magnetic north.

For all runs prior to today, a small rock on the closed lid provided enough weight to keep the box in a stable position.

Prior to today's comparison run, two aluminum angle strips were glued to the concrete block with Silicone adhesive and positioned firmly against the sides of the box to prevent movement during the exercise.

1- The weight rock was then removed and the first 30 minute run commenced
2- At the completion of the run, the 400 foot CAT 5 calble was disconnected at the Pi
3- The box was opened and the first RM3100 was removed
4- The second RM3100 board was plugged into the adapter board, making sure it was fully seated
5- The CAT 5 cable was reconnected and a second half hour run commenced
6- At the completion of the second run the cable was again disconnected
7- The second RM3100 board was removed and the first reinserted, again making sure it was fully seated.
8- The cable was again connected and a third run commenced
9- A the end of the run, data was transferred from the Pi to my desktop for analysis.
10- All runs were made with an RM3100 cycle count of 400 with an on-board average of 10 measurements per measurement group and a measurement rate of 2 per second.
11- simple averages were taken for all readings in a run

Results:

NCEI EMM model predicted field values for the box location at 42deg 15min 41.41sec North and 73deg 32min 32.46W and 1100 feet elevation:

Horizontal intensity 19.9926 mT
Vertical component 48.1023 mT
Declination 13deg 33min 1sec W

RM3100 #1 X= 19.769 mT Y= 0.0817 mT Z= 45.511 mT
RM3100#2 X= 21.281 mT Y= 0.9837 mT Z= 48.449 mT
RM3100#1 X= 19.899 mT Y= 0.2145 mT Z= 45.476 mT

2nd run

The shift in Y value between runs 1 and 2 of RM3100 represents an angular shift of ~ 0.2 degrees and the difference between RM3100 #1 and #2 is ~ 2 degrees.

Alignment of all three axis is affected by care in attaching and soldering pin plug strips to bare boards as these two were purchased. The precision of alignment of the sensor elements on the 3100 board could be another factor. Even though the aluminum angles holding the mag box in position were snug, only a small fraction of a degree offset can produce the error between runs 1 and 2 of the first device.

Jules Madey, K2KGJ Hillsdale, NY

Julius Madey
Sat, Jul 18, 9:38 AM
to SungJun, Hyomin, Gil, Nathaniel, me

What is everyone using for time reference with the RM3100 / Pi? Mine is a DS3231 with battery backup. Jules Madey

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David Witten
Sat, Jul 18, 1:05 PM
to Dave, Tom, Julius, Hyomin, Gil, SungJun, Nathaniel

I believe that Hyomin's Pi is justaking Network time via NTP. For units in the field I have purchased a few Adafruit Ultimate GPS Hats https://www.adafruit.com/product/2324. I am using these not because of their precision but because they have performed well in projects like this and fit into the test lash-up easily. I intend to run gpsd to keep the clock in line. They provide GPS time, 1PPS signal, known GPSD compatibility, and Real Time Clock with backup.

I am also looking into Solar powered battery backup for the entire SBC + 2 sensor board unit. Suggestions are welcome

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Julius Madey
Wed, Jul 15, 12:08 PM
to HYOMIN, me

I don't think there is a problem with the accuracy of the RM3100. At the end of April, I did some testing using a single axis Helmholtz pair I built several years ago for calibrating a low frequency B field search meter. Field accuracy at the center of the pair was within 5%.

The procedure was to place the RM3100 axis to be tested aligned with the center of the Helmholtz pair, which fed with 5.75 amps DC generated a calculated field at the center of 5.61mT.

Two series of measurements were taken with local field + Helmholtz and local field - Helmholtz. RM3100 cycle count was 200 and an average of 20 readings was taken for each direction. The the two measurements were then subtracted, divided by two and compared with the computed Helmholtz field. Error was <5% with the measured field less than the calculated Helmholtz pair field by no more than 5%.

Until more accurate calibration fields are available, I think we can trust that the RM3100 data is good to at least 5%.

Regards, Jules

Julius Madey
Jul 15, 2020, 9:34 PM
to Hyomin, HYOMIN, me

Same here.

I know JJ is about 120 mi south south west of here but did the file I just sent compare with the station trace during the same time period today?

So you have another RM3100 board you could plug into the support board to replace the current unit? Jules

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Julius Madey
Jul 15, 2020, 10:57 PM
to Hyomin, HYOMIN, me

I just plotted the 6/30 RM3100 data you sent to Dave, using open office calc.
1- took simple average of the full run for all three axis
2- subtracted that from each 1 second reading to obtain dB
3- performed a sliding window average of the previous 10 seconds on that data
4- plotted the resulting data
Doesn't match the JJ plots nor does it match the RM3100 plots in the power point slides except it's closer in basic shape if you invert the Bx curve and adjust some vertical offsets ..... ??????????

I must be doing something wrong ...

But the line width of the plots of the data I collected today with 400 cycles and 10 averages is somewhat less than 1/2 that of the 6/30 GTJ 0630 data plots

Jules

Julius Madey
Tue, Jul 14, 5:00 PM
to Hyomin, HYOMIN, me

Hyomin,

According to sensor data provided by PNI in April, (attached) the sensitivity (field magnitude resolution) is 6.667nT with a cycle count of 400 as opposed to recording at a cycle count of 200, which yields 13.33 nT field magnitude resolution. As you will note, PNI suggests that increasing the cycle count runs into diminishing returns due to instrument noise.

However, a single measurement at a 400 cycle count takes only 17ms to complete. You can, in theory, improve magnitude resolution further by using the built in averaging function of the RM3100 sensor. Since we're dealing with noise that is both instrumental and field related, and, assuming approximately a more or less 'white' noise spectrum, signal to noise ratio can be improved by averaging with a square root relationship; that actually improves magnitude resolution as well if the noise amplitude is greater than 1/2 the magnitude resolution.

Using the built in averaging function, for example, with a count of 10, and a 400 cycle count, a single measurement is completed in ~170ms with a theoretical magnitude resolution of ~2nT. You could increase the average count to 25 with an theoretical improvement over 6.667nT by a factor of 5 and still manage 2 readings per second.

I am currently running a 2 hour test at 5 measurements per minute with a 400 cycle count and 10 average for evaluation.

I am not familiar with the processing of magnetic field magnitude data to provide delta B values. That implies either a delta between successive samples or a delta relative to a mean or average value. My question was how the delta values were derived from the RM3100 data. If I use an average of the full 24 hours, I see something similar to the plots you sent to Dave.

Regards, Jules

Julius Madey
Jul 14, 2020, 11:31 PM
to Hyomin, HYOMIN, me

Hyomin and Dave, Attached is a 2 hour run with my RM3100 located 350 feet away from my house, road and power lines in a woodlot with nothing but wooded hills behind for at least 1/4 to 1/2 mile. The mounting surface is a spirit leveled 50 pound concrete block set on a gravel bed.

The y value is about as close as I could get to magnetic north orientation of the Y axis without substantially more care.

Using a severely cobbed version of Dave's early simple i2c program with communications between the Pi3B+ and the RM3100 in sealed weatherproof plastic box verified with oscilloscope measurements and an i2c code tracer, measurements were taken at ~ 2 per second.

The RM3100 cycle count was set to 400 with a gain correction of 150 per PNI specifications and an additional gain correction factor of 10 for the 10 sample average per measurement using the RM3100 built in average feature. For each measurement, the RM3100 was not queried for data ready until the expected time of completion of the measurement in order to avoid any possibility of interference from activity on the i2c communications bus and / or associated power conductor transients.

Start time is within 20 seconds of the quoted UTC time. Lat/Long coordinates of the magnetometer are from Google Earth. Elevation is 1220 feet.

Delta B magnitude is referenced to the 2 hour average of all measurements for any particular axis. Note that difference between successive measurements is indicative of the minimum field magnitude resolution and appears to be better than the expected 2nT resolution for the cycle and average settings used. But 'noise'. whatever the origin, appears to be ~10nT peak to peak.

I am not familiar with typical temporal field variations in this area nor what happened locally in the time period recorded but hope this may help to get a better idea of the RM3100 capability. Dave and I have been discussing RM3100 parameter options and his new software should make it possible to try any of the combinations used herein.

Hope this may be of assistance.

Regards, Jules Madey

P.S. Always wanted to build a proton precession mag since about 1961 when my brother and I saw a simple quart water bottle version at Fairleigh Dickenson U at the lab of a geologist who had been in Antarctica during the IGY and whom we met via ham radio, but somehow I never quite finished the project !

Julius Madey
Tue, Jul 7, 11:06 AM
to me, HYOMIN, Hyomin

This is the response from PNI re my question about possible interaction of the i2C bus with measurement during a measurement cycle if the data ready state is determined by repetitive querying of the DRDY state. If you're doing general analysis you might want to check that as well. I had asked Dave if a delay could be added to the code after commanding a measurement cycle and he said that

could be done. There may be no relationship but if you're looking at the basic noise level of the device, you may find something. Unfortunately, I have not had time to do those checks myself in the past month due to other pressing matters. Regards, Jules Madey

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Betty Zhang (PNI Sensor)
Jun 3, 2020, 3:07:30 PM PDT

Hi Julius,

The I2C or SPI bus communication should not affect measurement. The noise level should be the same regardless which bus to use. However, we don't have any data to prove or disprove.

Using DRDY interrupt pin is a good way to retrieve data. It makes the bus less busier than polling data, and should be helpful to minimize the noise from the bus.

Thanks for your good questions.

Stay safe and all the best, Betty

Julius Madey
May 28, 2020, 9:49:35 AM PDT

Jonathan, Many thanks for the note. Ham Radio is a good hobby; I'm still learning things. New digital based tools like the WSJT suite originally developed by Joe Taylor, K1JT, permits more use of bands during low solar activity and provide better understanding of HF propagation. In the US, the ARRL is considering modifications to the volunteer examiner program to allow testing to go forward during the COVID epidemic. On line testing has been used in Alaska where travel to a test location is a problem.

Another question about the 3100 I have for you and Betty regards use of either the i2c or SPI buses during a measurement cycle. Is there potentially any difference in 'noise' between, for example, starting a measurement with a write to the POLL register and then repetitively reading STATUS until bit 7 goes high or writing to POLL, waiting for 7 to 10ms (cycle count 200), then reading STATUS, which should be ready by then?

Regards, Julius Madey

Jonathan Olesik (PNI Sensor)
May 26, 2020, 10:12:04 AM PDT

Hi Julius, I have been following the thread here, sounds really cool the project your working on. I will add that personal space weather station to my list of projects to try in my lab at home. We can get even better than ~10nT sometimes but you have to get lucky to get a particularly sensitive magnetics and sensitive ASIC. We know how to build them more sensitive but the cost is much higher and production yield lower. Too bad I missed the HamSci workshop! I have been studying for my HAM exam (I am in Canada) but seems like the testing is not going on right now with Covid. Thanks, Jonathan

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Julius Madey
May 22, 2020, 2:00:10 PM PDT

Dear Betty, This link is probably the best description of the project.

https://www.hamsci.org/basic-project/personal-space-weather-station

In addition to ionospheric condition sensing by measuring the small doppler shift of frequency stable radio signals like those from the National Bureu of Standards time and frequency broadcasts on several HF frequencies carries by sky wave propagation to a monitoring location, local geomagnetic field strength and orientation is another data input.

Before I joined the development and test effort, someone in the group had identified the RM3100 as a device that potentially satisfied sensitivity needs (~10nT) at a reasonable price to integrate into a radio amateur's 'personal observatory'.

I've been interested in geomagnetic field measurement but never found the time to build my own instrument. More time to do things in retirement and when I heard about the candidate RM3100, I volunteered to assist in the integration and testing.

On an historical note, in the mid 60s -70s, I was working with human electroencephalograms (EEG) as a biomedical engineer in San Francisco. At the time, my brother was completing his Physics PhD at Stanford and one of the labs was working on measuring the weak magnetic fields associated with the EEG potentials I was recording and I was able to visit their setup which used a superconducting Josephson Junction (SQUID) for field detection and a person sized Liquid Helium dewar for external field shielding .... the heart's magnetic field is stronger and can be measured without shielding using a gradient magnetometer.

Then after moving here to NY in 1977, I did some consulting for the Lamont Doherty paleomagnetics lab and interfaced their SQUID and spinner magnetometers to an Apple II personal computer.

My oldest son is a physics and math teacher in a local High School and I thought the RM3100 might be useful for him as well.

Have a good Holiday weekend! Julius Madey

Betty Zhang (PNI Sensor)
May 22, 2020, 1:09:45 PM PDT

Dear Julius,

Wow, solute to a true lifelong engineer !!!! I wish I can keep going to reach the goal you have set up there.

Just curious, what project you are working on ? What kind of application it is with RM3100 ?

Thanks and have a good long weekend, Betty

Julius Madey

May 22, 2020, 11:27:07 AM PDT

Betty, Many thanks ! Stay well ... so far so good here; I'll be 80 in June. Julius Madey

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Betty Zhang (PNI Sensor)
May 22, 2020, 10:44:21 AM PDT

Hi Julius,

Thanks for your update on the NOS finding. I searched the older versions of RM3100 and RM3000 user manuals, and did not find any info mentioning this NOS 0x0A register.

After talking to sensor engineer, I understand, the NOS exists and is useful for development purpose. However, there is no further information on how to utilize it for customers or what is the best way to use it.

Thank you for finding it, you are an excellent RM3100 detective! If you find it's working for your application, it's ok to use it.

Have a nice day and stay safe, Betty

Julius Madey
May 21, 2020, 5:18:04 PM PDT

Dear Betty, I ordered two of the RM3100 breakout boards on April 2 of this year and have been working with them. They clearly have an NOS register at address 0X0A which I can write to and read from. The default value is 0. If I write the value 0X0A (decimal 10) and then poll for a reading, I get the sum of 10 consecutive readings. Address 0X0A lies between the 2nd byte of the CCZ register and the address of the TMRC register. A member of the group I'm working with has been developing a C program for testing and I first saw mention of the NOS register there but haven't found any documentation on the PNI site.

So it is definitely there and seems to give the expected result. Could it be an inadvertent leftover from an earlier firmware version? Perhaps one that didn't function as intended or perhaps used by you for test? Any enlightenment you can give me would be greatly appreciated as, if the 'feature' works as it appears to, it could be useful.

Best, Julius Madey

Betty Zhang (PNI Sensor)
May 21, 2020, 4:19:44 PM PDT

Hi Julius,

Thanks for contacting PNI. RM3100 doesn't have multiple sample register NOS. Following is RM3100 register map FYI.

RM3100 Sensor Suite User Manual https://www.pnicorp.com/download/rm3100-user-manual/

RM3100 Eval Board User Manual https://www.pnicorp.com/download/rm3100-testing-boards-manual/

It's ok to do over sampling on RM3100, the host needs to initiate a measurement every time in single measurement, and add each measurement N times to get a sum. At the end, do (sum/N) to get average.

Hope I have answered your questions. Let me know if you need clarification.

Thanks for using RM3100, Betty Betty Zhang | Field Application Engineering Manager PNI Sensor T/F: 707-566-2973 E: bzhang@pnicorp.com W: https://www.pnicorp.com/support/

Robin Stoecker (PNI Sensor)
May 21, 2020, 10:28:08 AM PDT

PNI Product: Geomagnetic Sensors

Comments: I'm looking for information on the multiple sample register NOS in the RM3100. Trying some values indicates that the result read from the X,Y,Z registers after the successive samples complete is simply the sum of all of the samples. So that in order to get a correct reading, if N is the sample number, I have to divide the result by N*gain.

What is the dynamic difference between using NOS for multiple successive samples and polling N times, then averaging the N values ?
Thanks,
J. Madey

Julius Madey
Mon, Jun 8, 10:42 PM to me

Dave, I've managed to completely suppress the strong burst of RFI the perimeter electric fence was radiating with FairRite 75 material plus a small series resistor at the output terminal of the charger. The charger still puts out an 11 to 12 amp pulse into the 3000 pf of the fence wire which results in an estimated magnetic field 30 to 40 feet outside the perimeter of ~0.3uT ... enough to contaminate the reading if taken at that time.

I'm looking at other ways of generating the ~11KV fence pulse with longer charge times that reduce surge current to an amp or less. The other strategy would be to detect the 1 per second pulse (quite easy) and use that to start a reading perhaps 100ms later ... everything calms down within 10ms.

Jules

David Witten
Tue, Jun 9, 8:35 AM
to Julius

Sounds like good progress. An 11KV interferer makes a challenge.

I was set back on working on the software by a problem with my Odroid N2 + extender board. I seem to have damaged the N2 and at least one of the PCA9615 chips while manhandling the combo to make photos for documentation. I am back up and running using a RasPi 3, but lack extender functionality.

Time to get out the soldering iron.

Dave

Julius Madey
Sat, May 30, 11:49 PM
to me

Dave, From now on I think I'm also just going to report results and not engage in any discussions about EMI, RFI, remediation / prevention, etc. In over 55 years of engineering practice I've dealt with everything from contamination of microvolt level physiological signals by 60Hz electric and magnetic fields to trucker's 1KW dirty CB 'linears' and 100 watt UHF radios in state trooper cars in toll lanes on the NY State Thruway plus other hairy environments. I'm comfortable with the problem and have working experience with equipment and techniques to measure and observe. Measurement is key to repeatability.

Stay well ... get enough rest. Best, Jules

Julius Madey
Sat, May 30, 11:12 PM
to me

Dave, I'm keeping this off line for now. The rig I'm setting up at the end of the 400 feet of CAT5 is a polycarbonate box with gasketed latching lid and no ferrous hardware. Latches are plastic as well. The sealed panel mount RJ connector is a molded plastic assembly, metalized probably with a zinc based spray as I think it was meant for a metal box for complete shielding, but serves nicely to bring the CAT5 shield inside the enclosure.

On the inside of the box, the panel mount RJ looks like an RJ jack. So, for simplicity of wiring, I'm going to take one of the PC boards you sent and instead of mounting the Amphenol RJ Jack with the stainless shield (which is definitely magnetic !), I'm running about an 8 inch jumper of shielded CAT5 from the board to an RJ plug which is then inserted into the inside jack of the panel connector, carrying the shield wire through if I want to use it.

I'll send a photo of the full setup which I hope to have ready in a couple of days.

I'm doing it this way to give me the best chance at this stage of the game to get some good data in what I hope is going to be as close to an environmentally noise free location as I can get here. My interest now is in testing the mag and not in debating the particulars of any specific design with the group. Your board design is nicely suited for that testing and the Spark Fun stuff with your original simple board gave me a good start.

The runMag program is looking good; hope I can continue to be of service.

Best regards, Jules

Julius Madey
May 30, 2020, 10:31 AM
to me, tangerinesdr

Dave, I hadn't either until I saw the note from Phil. I've been using your original small adapter board with the Quicc connectors so haven't run into the issue yet.

Two shielded RJ45 PC through hole jacks in my parts drawer, made by BERG, have non ferrous shields. Couldn't find the BERG part on line but DigiKey carries several candidates. One is AMP 5558342-1, the data sheet for which shows phosphor bronze as the shield material. Since the shields on the RJ jacks of the three SBC's I have are all non-ferrous, it may be that for RJ45's, non-ferrous construction is the usual.

With regard to the shielded RJ plugs on the extension cable, since the current recommendation seems to be to only tie the shield to ground at the 'local' end, it's possible to remove the shield on the plug at the remote end; just did that with one of mine.

Jules

**Tom McDermott **
May 30, 2020, 10:46 AM
to TAPR, me, Julius

I have no idea where the idea that the shield should be unconnected at the remote end came from. In my opinion this is contrary to what probably needs to be done. I think Scotty put a jumper on that line so it could be tried both ways. Normally one floats a shield if ground return currents from some external path are expected. I don't see where those would come from in this situation.

-- Tom, N5EG

David Witten
May 30, 2020, 11:04 AM

Tom, I believe that I tried to follow your guidance on this. I remember asking you about this specifically. In any case, I did place a jumper for this purpose o

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**Julius Madey **
May 30, 2020, 12:59 PM
to TAPR, Tom, me

Tom, From a 5/4 email from Scotty explaining the design of his new board:

"JMP6 allows us to ground one side of the shield only to minimize noise pickup and ground loops. Note that the CAT5 cable is shielded. "

If I interpreted that as a 'recommendation', my bad ...

Molex has at least one RJ shielded plug using brass .... mine were cheap eBay stuff ... so there appears to be no problem.....just have to order the good stuff....non ferrous metal construction is available on both RJ45 jacks and plugs.

Jules - K2KGJ

David Witten
May 30, 2020, 1:21 PM
to Julius, TAPR

Jules, et. al.:

FWIW: The Amphenol drawing w/details for the RJ45 that I used on the prototypes is attached. It indicates that the shield is tin coated stainless steel. Depending on the alloy it may exhibit some degree of ferromagnetism.

Dave

2 Attachments

Julius Madey
May 30, 2020, 4:27 PM
to me, TAPR

Dave, I specifically note the change of shield material from copper alloy to SS.

I just ordered the AMP jacks and Stewart plugs in the attached data sheets. Jack shield is plated phosphor bronze and plug shield is plated copper. I don't know if other vendors are changing shield material re EMI performance (meaningful at GigE speeds but not at 100KHz differential i2c) and since magnetic properties of SS can vary greatly depending upon specific alloy and cold working, it's probably a good idea to stay away from them if at all possible if the RM3100 will be mounted in close proximity to the SS part if the hope is to see signals well below the microTesla range.

Perhaps Hyomin could provide some guidance on that ?

Jules

Delays in 1000 meters of twisted pair cable are, of course, too long for 100KHz rate i2c exchange protocol, but

2 Attachments

David Witten
May 30, 2020, 4:34 PM
to Julius, TAPR

Jules,

This will have to come to the attention of Scotty. I am now completely excluded from the design process for the magnetometer implementation.

Dave

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