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21/01/02

LHC Radiation Hard Voltage Regulator News

This news updates the status of the Voltage Regulators L4913 and L7913 developed and produced by ST Microelectronics. I remind you that ST Microelectronics has decided to offer the L4913 and L7913 only in the adjustable versions to speed up production and delivery and minimize packaging and testing cost. In the following I report the outcome of the Video Conference with ST Catania on the 9th January 2002 and recent results obtained with the regulator prototypes received at CERN in November 2001.

Industrialisation of the L4913 ADJ

The L4913 +ve regulator has been accepted by CERN as mentioned in the November news, and ST Catania and Rennes have internally approved the product to be in conformity with specifications for CERN LHC and Space applications. ST Microelectronics is now proceeding to the industrial qualification of the L4913, which it will be made commercially available in a Power-SO20 plastic package. Because it is not a HiRel product, the Rennes Space division has transferred the responsibility for the industrialisation of the product to ST's Standard Product Division in Catania. Therefore, ST will apply their standard industrial reliability procedures to qualify the L4913 – this requires more complex and longer qualification procedures than for HiRel components; 168 hours and 1000 hours reliability tests, and several other qualification tests will be performed to validate the so-called "product maturity" level before the regulator is officially released to CERN.

The new persons responsible for the industrialisation told us that the ST qualification of the L4913 would be completed the end of March (week 12). I proposed that it would be better to deliver to CERN 3000 pre-production samples of the L4913 as soon as possible and not wait another 3 months - LHC users are waiting for them to build prototype electronic boards. ST agrees to deliver the 3000 pre-production samples mid of February after the maturity level 20 of the product is completed. ST Catania will send to CERN the preliminary industrial data sheet of the L4913 in week 4 (end of January).

Radiation Hardness Assurance of the L4913 ADJ

The first 100 prototype Power-SO20 samples received in November 2001 have been distributed to some LHC users for evaluation. Wafers have been already tested using the MIC group's X-ray irradiator. As already mentioned in the November news, the L4913 turns out to be extremely radiation hard. We have now tried with Bartek to push the radiation testing further in an attempt to observe radiation-induced failures. Up to the huge total ionizing dose of 100 Mrad, no visible degradation has been observed. We therefore investigated the validity of our radiation tests. The result of a second series of X-ray tests being the same, we studied the degradation of individual bipolar transistors placed in the scribe line and irradiated at the same time. As can be seen from the included figure, the current gain decrease of the bipolar transistors up to 20Mrad is about 50%. However, this degradation process saturates rapidly, and thereafter almost no change is observed up to 100Mrad. The explanation of the high level of radiation hardness is that the current gain decrease of 50% is small enough to not affect the performance of the L4913.

Additional radiation tests on packaged samples with Co-60 for TID test and with pions and protons for displacement damage test will be performed in the coming months to complete the radiation hardness qualification for the LHC applications.

The L4913 radiation hardness margin is sufficiently high to avoid problems of radiation damage for regulators placed in the outer detector regions of LHC experiments. However, for regulators exposed to radiation levels higher than 1Mrad, a radiation assurance should be foreseen during production. The component is now being industrialised in a plastic package and ST will not provide radiation assurance as they do for the expensive HiRel components. To overcome this issue, we have asked ST Catania to maintain traceability between the shipments of regulators to CERN and the physical fabrication lots. In this way the radiation-tolerance of shipments of regulators received at CERN can be evaluated by sampling and keeping the correlation to the fabrication lots. ST Catania should propose soon how lot traceability will be organised.

Volume Production and Procurement of the L4913 ADJ

The CERN Stores (SPL Division) are preparing a frame contract with ST that will cover all the needs in radiation-hard voltage regulators for LHC. This document will be presented to the CERN Finance Committee in June 2002, and eventually the first order will be placed to ST Microelectronics just after that Finance Committee approval. The delivery of 50 000 pieces of the first release order to CERN is expected in September 2002.
The CERN Stores will act as a 'distributor' and place release orders directly to ST. This commercial arrangement has the advantage of minimizing administrative costs, and simplifying the procurement procedure for all LHC users. I would like to ask you to send to **Isabelle.Mardirossian@cern.ch** the forecast of the number of L4913 and L7913 that you foresee to purchase (i) in 2002, (ii) in the first half of 2003 and (iii) in the second half of 2003. This information has been requested by ST and is essential for them to be able to organize fabrication of the regulators.

The L7913ADJ Negative Voltage Regulator

ST has completed the design of the negative version of the Voltage Regulator (the L7913) and it has been submitted to fabrication in December 2001. Wafers for radiation tests and preliminary electrical characterisation are expected in March 2002. Engineering samples of the L7913 are foreseen to be shipped to CERN beginning of June 2002. ST wants to do internally a full characterisation before releasing samples to LHC users. This negative voltage regulator has already a second signal ground for remote sensing. This will help to validate the double ground remote sensing circuit scheme proposed by ST before launching the L4913 remote sensing version.

Remote Sensing version of L4913 ADJ proposed by ST

The remote sensing version of the L4913 requires a new mask design and an engineering fabrication run. ST has asked CERN to participate financially to this development cost - it should be noted that the Space community does not need the remote sensing feature. The electronics coordinators of the four LHC experiments have already agreed to contribute to the funding of the prototyping of the remote sensing version of the L4913.

The technical details of the remote sensing version are still under discussion with ST, I summarise in the following the status.

The first solution proposed by ST (remote sensing –single ground) is based on a single ended remote sensing scheme as it is currently done for voltage regulators; there is no differential remote input sensing, see Fig. 6. Therefore, the negative sense wire (GNDC) is actually the ground of the voltage regulator (chip) that is used to sense the ground of the remote load GNDL, and is separated from the ground return wire (GNDR). Unfortunately, the base current of the power transistor flowing in the ground return wire GNDR that is load dependent degrades the load regulation.

Then ST has recently proposed another solution (see Fig.7), which consists of separating the regulator ground GNDC into two ground pins:

- a signal ground (GNDS) pin used as sense ground. The small offset voltage drop caused by the offset current of about 1.5mA flowing in the GNDS wire is not anymore a problem for the stability of the load regulation.
- a power ground (GNDP) pin where flows the base current of the power transistor

However, ST mentioned that a maximum of 300 mV of voltage difference between the signal ground (GNDS pin) and the ground (GNDP) pin is authorised to avoid unbalancing the regulation stage of the voltage regulator. To keep the voltage difference low enough, ST proposes to have the 3 separate ground wires connected to the remote load as shown in Fig. 7 in addition to the positive power wire, and the positive sense wire both connected to the positive node of the load.

- ground return wire that connect directly the ground of the power supply GNDR to the ground of the remote load, GNDL. This wire is low resistance, 0.2 -0.5ohm.
- signal ground wire that connect the sense pin GNDS to the ground of remote load GNDL. This wire is high resistance 3 to 15ohm.
- reference ground wire that connects the pin GNDP to GNDL ground load. This wire should have a low resistance, <0.5ohm, or should have a voltage drop lower than 300mV taking into account that the base current is about the load current divided by the power transistor, which is about 40. For a load current of 2A the maximum series resistance would be 6 ohm.

In total 3 low resistance wires are needed for remote sensing, the two power wires Vout and GNDR, and the reference ground GNDP; and two high resistance wires the sense wire connected to ADJ by R2 and GNDS. Sense pin is not used in the adjustable version.

The second remote sensing scheme proposed by ST solves the load regulation problem of the single-ended input remote sensing at the expense of an additional low resistance reference ground wire.

Current gain of 2 sets of npn transistors as function of the radiation exposure is shown in fig.1, 2, 3 and 4.

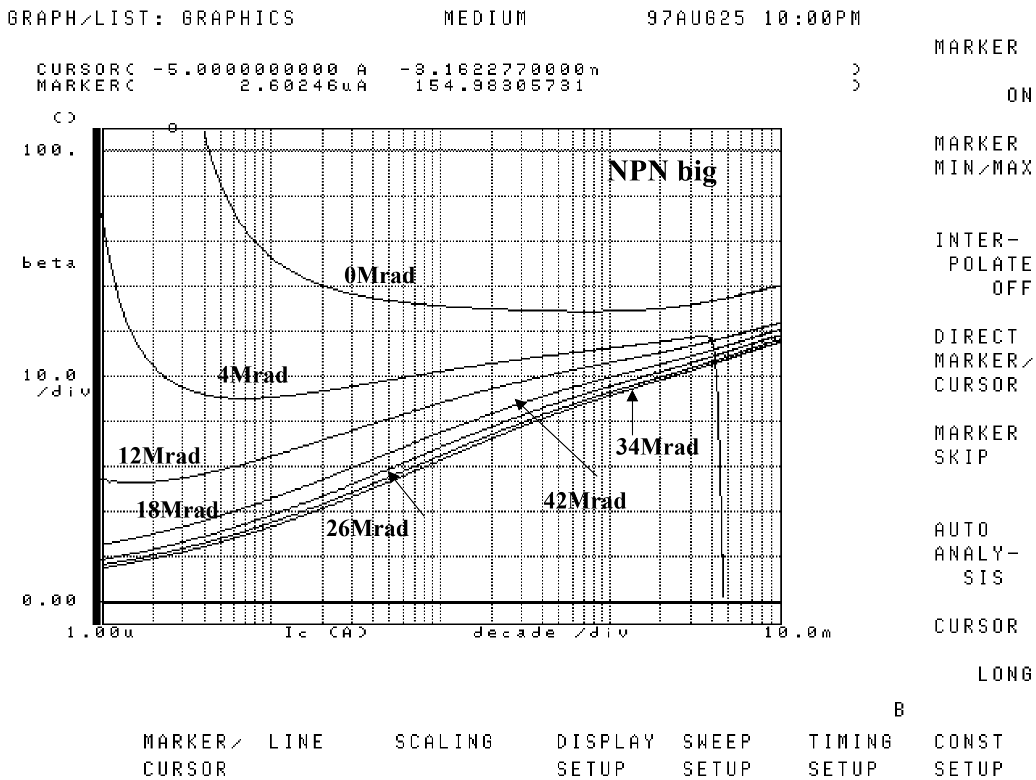

Fig. 1 Current gain of vertical transistor-big, set 1.

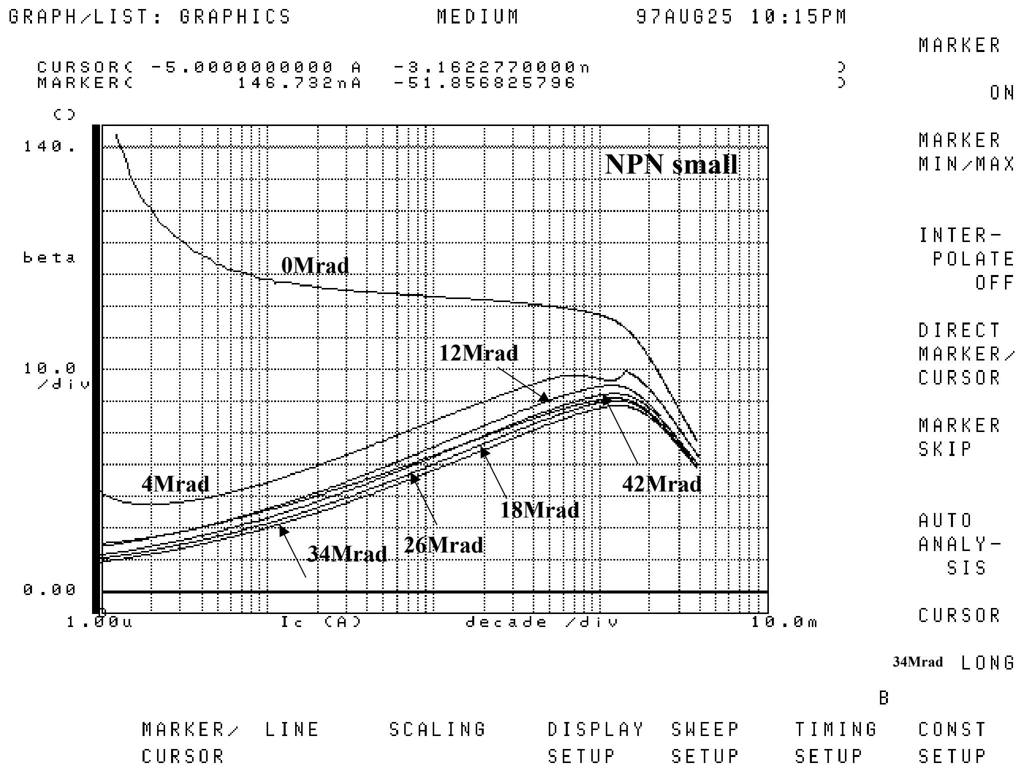

Fig.2 Current gain of vertical transistor-small, set 1.

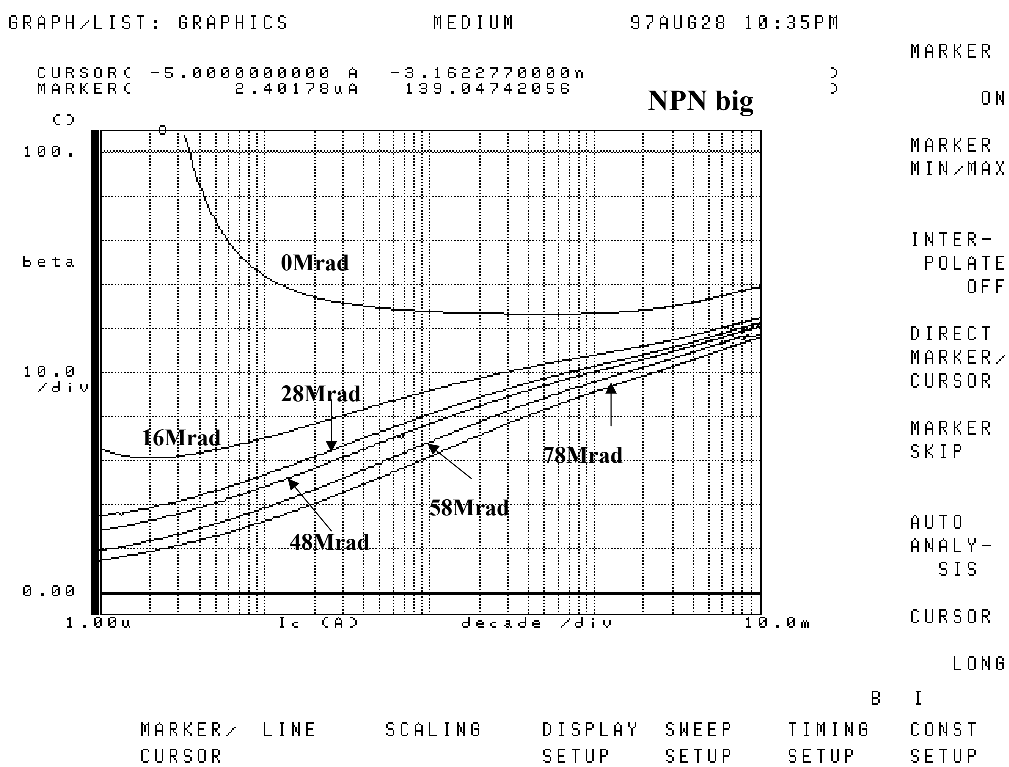

Fig.3 Current gain of vertical transistor –big, set 2.

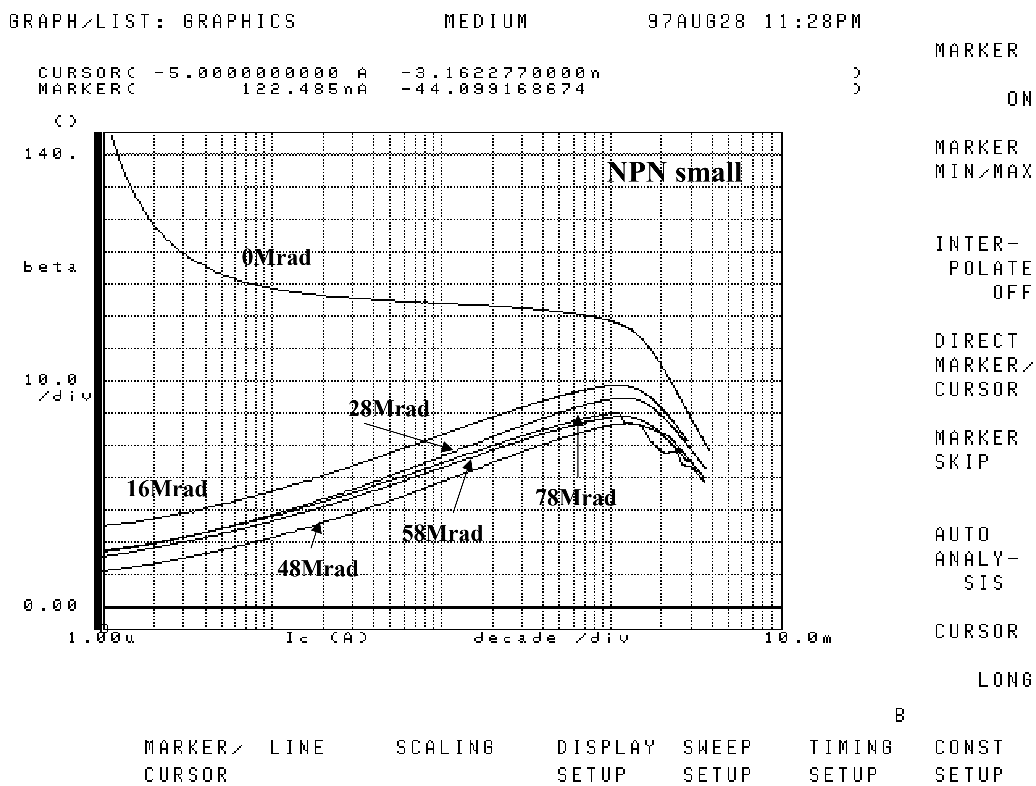

Fig.4 Current gain of vertical transistor-small, set 2.

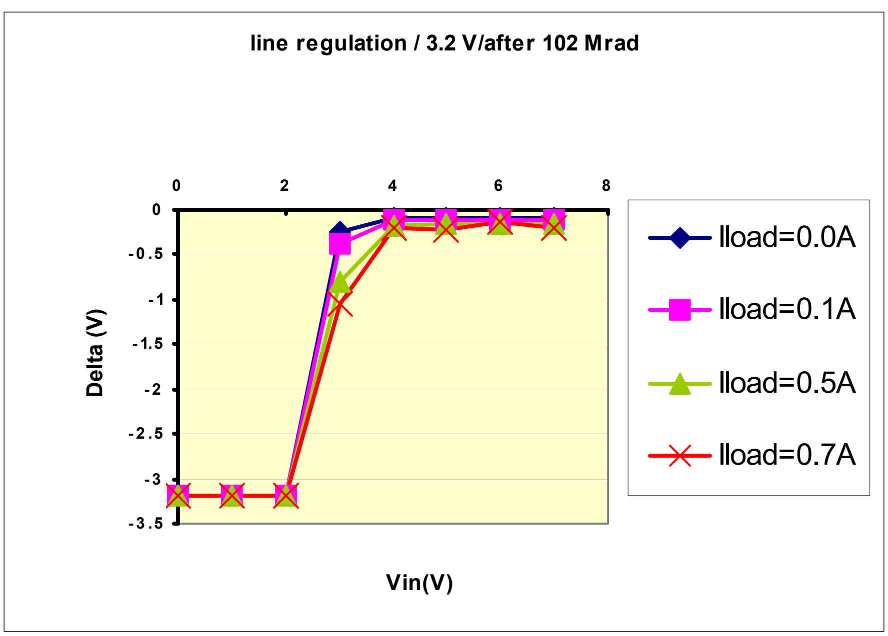

Fig. 5 Line regulation of the L4913 for 4 different load currents after a TID of 102 Mrad. There is no visible degradation when compared to non-irradiated components. The radiation test has been performed on wafer with the X-ray (10KeV) irradiator.

Fig. 6 and Fig. 7, example of the remote sensing voltage scheme in the case of ATLAS TRT

Low voltage distribution of the ATLAS TRT detector has a 10 meters sense wire resistance of 13 ohms, and a 10 meters power wire resistance of 0.3 ohm. At the maximum load current of 3 Amp, the base current of the power device is about 60mA.

For the simple-ground scheme (existing version), the voltage drop of the negative sense wire is large 780 mV for a base current of 60mA and a series resistance of 13 ohm. This large load dependent voltage drop prevents a good load regulation. However, this problem could be solved in using sufficiently low resistance sense wire. We are checking it with the final version L4913.

For the double-ground scheme, there is a drop voltage of 18mV in the series resistance 0.3 ohm of the ground wire (connected to pin GNDP). The voltage drop in the series resistance of 13 ohm of the negative sense wire (connected to pin GNDS) is about 25mV constant (Is= 2mA). ST specifies a maximum of 300mV between GNDS and GNDP. The voltage drop in the series resistance of the return power wire GNDR is 0.9V.

GNDC - ground chip

GNDL - ground load

GNDC - ground return

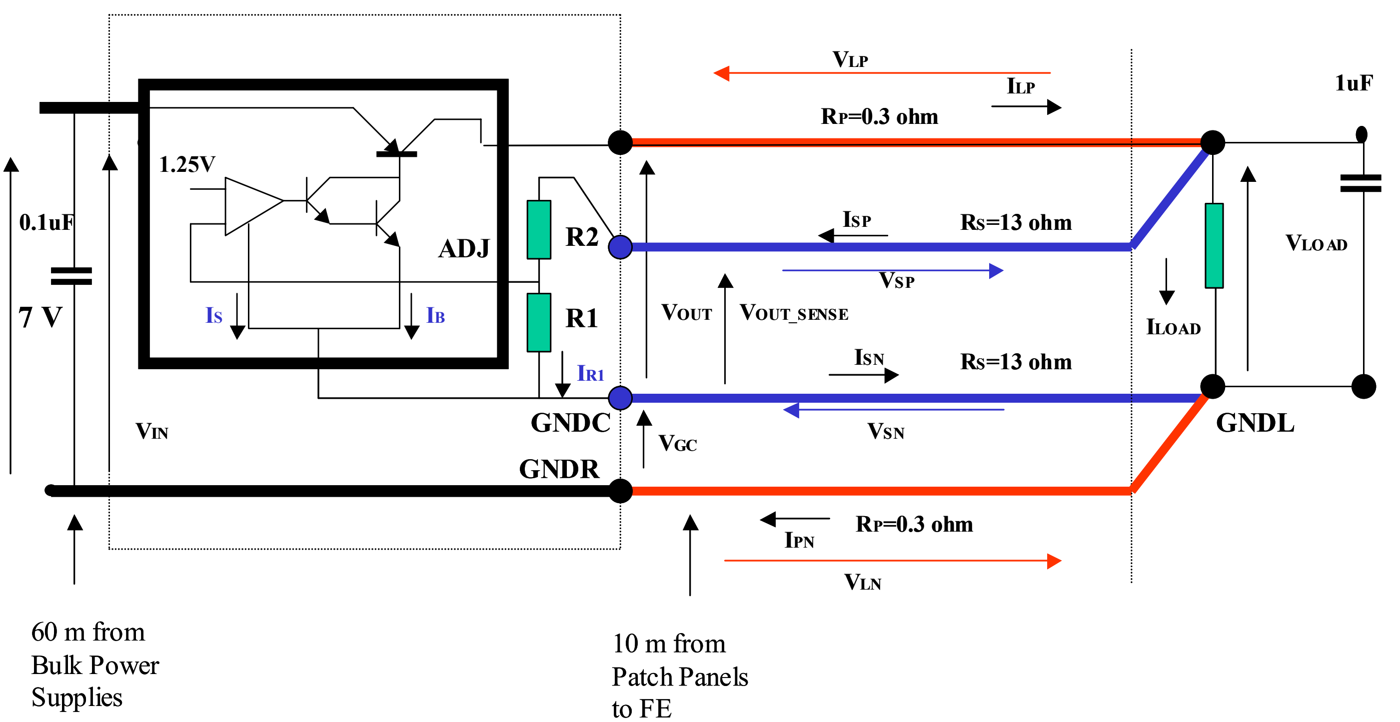

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Fig. 6 Remote sensing single-ground scheme

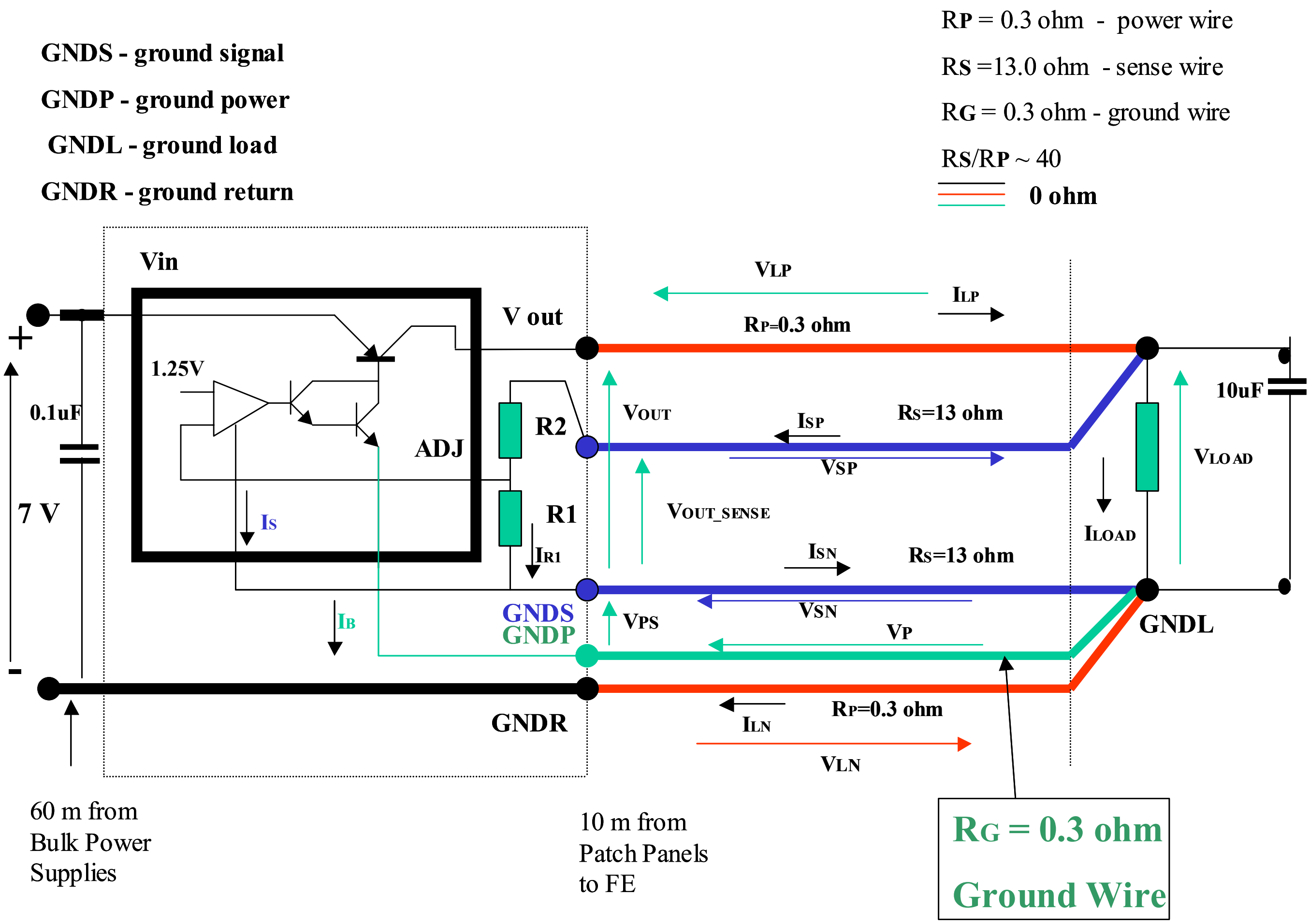

Figure 7 Double ground remote sensing scheme