Lafayette Instrument

LX4000 and LX5000 EDA Circuit Design and Evolution

The following is the first part of a two part series on the design and evolution of the Lafayette Instrument Computerized Polygraph System. The purpose of these articles is to provide information regarding the EDA circuitry used in the LX4000 and the LX5000.

The LX4000 and LX5000 data acquisition systems have been successful products that have serviced the polygraph profession in both optimal and sub-optimal, and sometimes harsh, environments. The LX4000 and LX5000 are completely safe for both examiner and examinee, and have a proven track-record of being highly functional in field settings worldwide.

The LX4000 EDA Circuit

The LX4000 was introduced to the market in 2002. The original LX4000 data acquisition system (DAS) included both a skin-conductance and skin-resistance circuit on the main board. The skin-conductance circuit was never used. The original skin-resistance circuit featured a subject current of 3.6 microamps (0. 0000036 amperes) and the ability to acquire data across a resistance range of 10 kilohms (kΩ) to 1 megohm (MΩ). Even though the normal range of EDA is limited to the range from 50 kΩ to 500 kΩ in laboratory settings, customer feedback indicated a desire for greater EDA range. A new LX4000 circuit was developed during 2004, increasing the range, and increasing the amount of current used to take the measurement. The measurement range was increased from 1 MΩ to 2 MΩ to more completely accommodate the range of EDA values that can be observed in polygraph field settings. Current was increased from 3.6 µA to 10 µA at that time.

Changing the EDA circuit involved adding new electronic components, resulting in an auxiliary circuit board that was installed as a daughter card inside the LX4000 DAS enclosure. The new circuit was provided to existing customers upon request. To install the new circuit, the DAS unit had to be returned for factory servicing. The EDA daughter card was also added to some DAS devices during new production. Use of the daughter card installation allowed Lafayette to quickly meet demands for new production and servicing of existing units. The latest date of production for devices with the EDA daughter card was 2006. LX4000 DAS units sold after 2006 had the new EDA circuit included on the main board.

No physical mounting was necessary to secure the daughter card in the enclosure because it fit snugly on top of the rubber tubes connected to the cardiograph and pneumograph circuits. Even though the LX4000 DAS units contain only a small amount of electricity, insulation was added in the form of "fishpaper," a common engineering product specially designed for high electrical insulation. The purpose of this was to eliminate any possibility that the daughter card could ever make electrical contact with the main board, enclosure, or the connectors for any of the circuitry. Any contact between the daughter card and the main board, enclosure, or connectors may have resulted in damage to the circuit, but nothing else. Even without the insulation, and even in the most extreme conditions, there has never been any chance that a fault on any LX4000 circuit would present even the slightest danger to a subject or examiner.

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The only difference between a unit that was built in 2004 and a unit that was built after 2006 is that the earlier unit used two boards to implement the circuit while later units used a single printed circuit board. The circuit functions the same, measures the same, and is equally safe. The performance and safety of the circuit are dependent upon the engineering design principles used to create it, not on the number of circuit boards used or how the inside of the box looks when someone takes the cover off. Use of a daughter card may represent an issue of aesthetics, but it is not an issue of performance or safety.

Minor changes were made to the design of the LX4000 in 2009, and the new version is referred to internally as the LX4000A. The design changes were made only to facilitate more expedient manufacturing. No changes were made to the performance specifications of the LX4000A.

Additional changes were made to the LX4000 in 2010, and this current version of the LX4000 is referred to internally as the LX4000B. The exterior connectors were modified so that auxiliary channels now include dedicated circuits for seat, hands, and feet activity sensors. At the same time, the LX4000 EDA circuit was changed to the same skin-resistance circuit that was originally designed for the modular LX5000. This change was largely made to simplify part purchasing and product manufacturing. The LX4000B EDA skin-resistance circuit uses a constant current of 6.7 µA and has a range of 10 kΩ to 2 MΩ.

In addition to hardware changes in the EDA circuitry, firmware changes were also made to the LX4000. At the time, firmware changes for LX4000 units required reprogramming of the microprocessor on the main board, and therefore the units needed to be returned to Lafayette Instrument for factory servicing. Firmware changes allowed the processor to handle the increased range of the hardware and provided version identification to the software. The firmware version can be read from the LXSoftware data acquisition screen. There is no signal processing in the firmware, and firmware changes do not affect the EDA waveform.

The LX5000 was introduced in 2008 as a modular system in which sensor modules could be attached directly to the subject or mounted to a central docking station. The modular design was a response to customer interest in the potential for wireless connection between the DAS and the examinee. Customer interest shifted away from wireless solutions, but interest in the LX5000 itself continued. The LX5000 circuits were therefore re-engineered into a single DAS unit. No changes were made to most of the circuitry, though the EDA circuit was upgraded to have the ability to record either skin-conductance or skin-resistance, with a software option for the user to select the desired EDA mode. The LX5000 skin-conductance/skin-resistance circuit was designed and verified to provide linear response in both skin-resistance and skin-conductance modes. The LX5000 skin-resistance circuit uses a constant current of 4 µA and provides a range of 10 kΩ to 2.5 MΩ. The LX5000 skin-conductance circuit uses a constant voltage circuit that is automatically ranged for each subject at the onset of recording, and will employ a maximum current of 10 µA. The circuit is capable of providing a linear response to changes in conductance while recording data from 5 kΩ to 4 MΩ.

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LX4000 and LX5000 Safety

Addressing the safety of the LX4000 and LX5000 requires some understanding of the nature of electrical safety tests. Electrical safety is typically concerned with "line voltage", or the electricity that comes out of a wall outlet. Devices that plug into a wall outlet need to follow specific design criteria to make sure that they are safe, and rightfully so, by preventing the possibility that a person can come into contact with a dangerous voltage level. One international standard for medical equipment, IEC 60601-1, which is the most stringent safety standard, does not consider any voltage under 60 volts (DC) to be a danger. According to this and other standards, if the voltage is less than 60 volts, then engineers are not required to take any special precautions to keep someone from touching it. Although polygraph recording instruments are not actual medical devices, the LX4000 and LX5000 are well within this voltage specification because they are powered by only 5 volts from the USB connector. The LX4000 and LX5000 are thus intrinsically safe to the point where either device could actually be used safely even without an enclosure (although we don't recommend it due to the risk of damage to internal components).

Because the computer that runs the polygraph system is typically plugged into a wall outlet or line voltage, it is necessary to ensure that any electricity that an examinee or examiner could come into contact with does not have any direct path to ground. This safety barrier is accomplished by electrically isolating the EDA electrodes. The EDA is the only sensor that makes electrical contact with the subject. This means that if a subject is wearing the electrodes and happens to touch a high voltage source, there would be no path to ground through the subject and the subject would be safe from potential harm. Isolation is provided in the design of the circuit and is present regardless of whether the circuit resides on one circuit board or two. Again, safety depends on the engineering principles used to design the circuit, not on aesthetics.

LX4000 and LX5000 Stability

Communication from customers indicated some areas for improvement in the LX4000, and changes have been made in response to that feedback. One reported issue was the potential for the DAS unit to become "disconnected" from the computer, resulting in a stoppage of data acquisition. The disconnection was semantic only, as no physical disconnection was reported between the Universal Serial Bus (USB) cable and the computer. Investigation of this condition revealed two causes; one was that the software was initially designed to timeout after approximately 9 hours. This timeout was based on an assumption that the DAS unit and software would not be left in continuous day and night operation. Users who left a computer and DAS unit running overnight may have found a need to restart the software to resume data acquisition. Software changes have subsequently removed the timeout value, and the device can be left in continuous operation if desired.

Static discharge was also found to sometimes affect the LX4000 connection. Measures taken to minimize this included changing the fabricated metallic device enclosure to an anti-static plastic enclosure. (LX4000 units with metallic enclosures have been and can still be returned to Lafayette Instrument for factory servicing.) Separately, a vulnerability to static discharge was identified with

regard to an electronic component within the initial LX4000 design. That component was a serial to USB converter used to connect the DAS to the computer's USB port. The component was subsequently replaced with an electrical component that has been verified as substantially more robust against electrostatic discharge. Additionally, the development of a more effective and more durable activity sensor, using pneumatic sensor technology, allowed the elimination of piezoelectric activity sensors that may have increased the sensitivity of the LX4000 to static discharge in some environments. Finally, both the LX4000B and LX5000 units have passed extensive testing for robustness even when subjected to repeated electrostatic discharge of both the device and the EDA sensor. The result of these changes means that both the LX4000B and LX5000 devices are highly robust against unintentional disconnection of USB data acquisition.

Part II of our series will cover **EDA Signal Processing** in detail. Questions and feedback are always welcome, and we will continue to provide detailed information where needed in response to questions, criticisms, or academic and scientific inquiry.