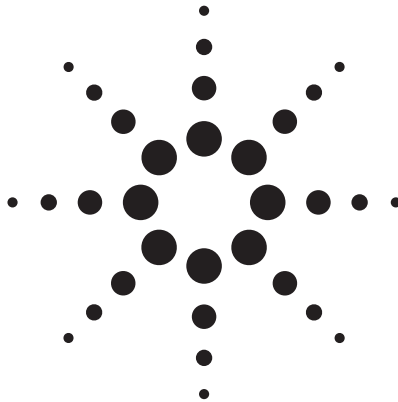


Agilent Technologies 81200 When Digital goes Analog

- **How to deal with signals which have two or more states**

Application Note



Agilent Technologies

Agilent Technologies 81200

When Digital Goes Analog: How to deal with signals, which have two or more states

The digital world is not always just 0s and 1s. Sometimes more than two levels occur. Figure 1 is an example of this in a 5 level signal. These kinds of signals are used in the Gigabit Ethernet over categories 5 and 6. The technology can operate at a relatively low frequency, yet still provide a data rate of 1 Gbit/s. Figure one is the eye diagram of such a signal. The technical benefits, when compared to signals at Gigabit speed include lower emissions and higher noise immunity. The commercial benefit is that one can take advantage of cheaper transmission media. In addition, the cabling infrastructure or 100MBit LAN systems, which are already installed, can simply be re-used, meaning lower upgrade costs.

With help from the E4838A generator front-end, the Agilent 81200 is capable of generating multi-level signals: it supports a mode called 'Analog Channel Add', which allows the generation of signals with more than 2 levels. Figure 2 shows the implementation of such an amplifier along with a description of how this signal is made.

The amplifier consists of a programmable voltage source and two switchable current sources with programmable current values. There are complementary outputs, so the current flows either from the node 'out' or 'nout' through the 50-Ohm resistors. With no current from a node, the output voltage is the same as the voltage source is set to, which provides the high level (V_{hi}) to the output. With the current switched from the node, the drop in voltage across the 50-Ohm resistor lowers the output voltage to the low level (V_{lo}). Therefore, the two current switches can achieve two independently low levels (V_{lo1} & V_{lo2}).

When both currents flow at the same time from one node, a 4th level, which has the lowest output level, occurs. The 4th level can be calculated as $V_{hi} - (I_{lo1} + I_{lo2}) \times 50\text{-}\Omega$. This level cannot be set independently.

For ease of use, the system is operated by programming levels. So there are entry fields for V_{hi} , V_{lo} and V_{lo2} . In this case the 4th level will be calculated as: $V_{lo} + V_{lo2} - V_{hi}$. Figure 5 is a picture of the programming window and is explained a little later in this product note.

Both current sources need independent switching signals. For a 4 level signal one needs two formatted signals. This means that data information from the memory and timing information in terms of format (NRZ, RZ,...), delay and width are available. The Agilent 81200 E4841A module provides 4 formatted signals as shown in figure 3. These are normally the signals, which make 4 channels. Each of these signals is available twice. One goes directly to a front-end generator and is used in normal (not channel add enabled) mode.

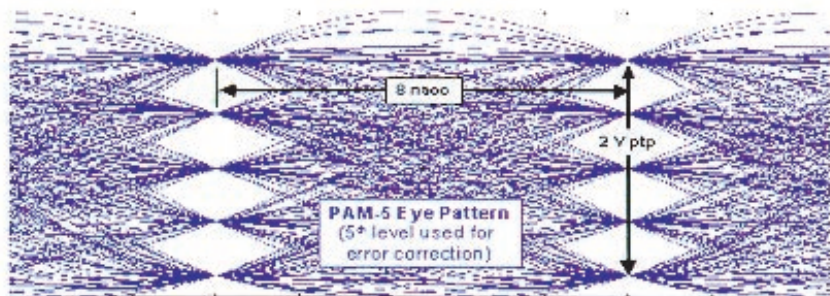


Figure 1: Gigabit Ethernet over Category 5

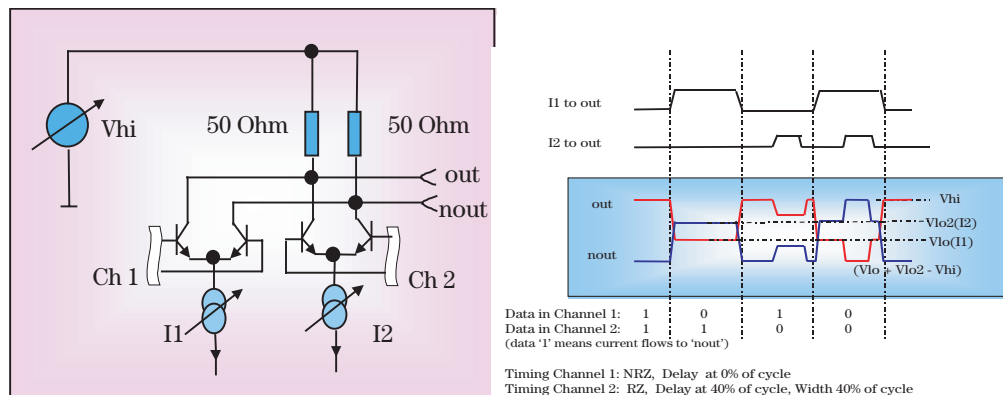


Figure 2: Analog Channel Add, Agilent E4838A Front-end

The second one either goes into the formatting circuitry of the neighborhood channel for digital add or goes to the secondary input of the E4838A amplifier. Of course the E4841A is deskewed for all different signal paths.

So there are two different adding modes: digital and analog. The digital add mode allows the generation of signals with glitches or changes in timing from cycle to cycle, called 'Change Timing On the Fly' (CTOF). Alternatively, it can be used for doubling / quadrupling the memory behind one pin or doubling the data rate to 1.32 Gbit/s. These modes are supported by either the E4843A or the E4838A generator front-ends. Figure 6 gives an overview of the digital adding capabilities.

The Analog Channel Add mode only works with the E4838A front-end. When the Channel Add mode is selected, two formatted signals are provided for the two current sources inside the amplifier. In case of level coding, one would set both to NRZ format. In case of glitch or noise emulation, one of the formatted signals might be set to RZ format, similar to the example in figure 2.

When working with such a signal for the first time it can be a little confusing, as when changing one of the three parameters (high level, low level or low level two), it is always the 4th level (the lowest one) that changes with the parameter being worked on. This is because it is not independent of the other three parameters. As this is the lowest level when looking at normal output, it might appear strange that it is the bottom signal. Always keep in mind, however, that this implementation referring to the high level.

Figure 4 is a screen shot of the signal setup, according to figure 5. First the Analog Add mode (A2) is selected. In this example there is an E4838A installed in front-end slot 4 of module E4841A in slot 2, Digital Add is the only option, the A2 mode is non-selectable. Then the output parameters are entered in the 'Output' and the 'Analog Channel Add' page. The 'Analog Channel Add' page contains the value of the second lowest level and also the control for the transition time belonging to this transition. If the timing parameters for both formatted signals are the

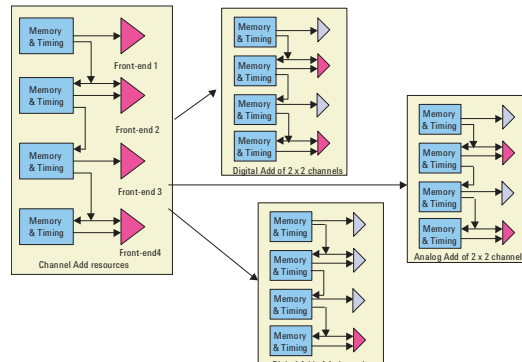


Figure 3: Analog Channel Add, Agilent E4841A Back-end and Generator Front-ends



Figure 4: Analog Channel Add Agilent E4838A Front-end

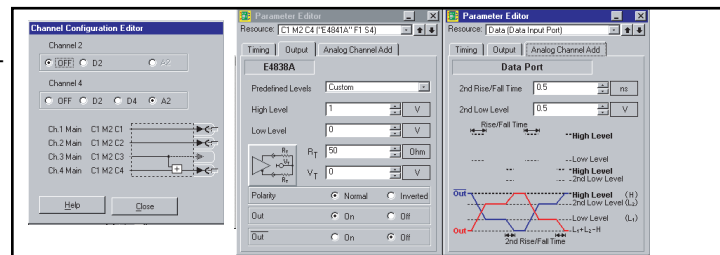


Figure 5: Analog Channel Add Setup the E4838A

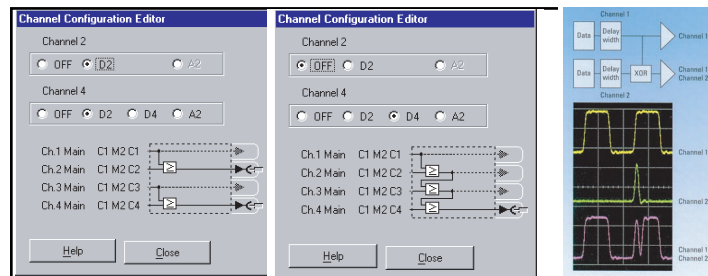


Figure 6: Digital Channel Add

same, then they are entered on the 'Timing' page of the same editor (Resource Field indicates: Data In Port). If format, delay and width need to be different for each channel being added, then the machine editors' channel resources have to be used (Resource Field indicates: C1M2C4, for example).

A few other rules also need to be considered: 'Channel Add' is only possible in slot 2 and 4 of the front-end E4841A module. When 'Channel Add' is enabled, the added signal is available from amplifiers installed in the odd front-end slots. However, there is no need for those front-ends. These slots can be emptied, if they are only targeted to use the 'Channel Add' mode. 'Channel Add' is only possible for generator channels. It cannot be selected if any analyzer channel is in the chain of channel add signals, as shown in figure 3.

Multi-Level Generation

The application given at the beginning requires a 5 level signal. This can be achieved by combining two generator channels as shown in figure 7. This works because each generator itself can act as a terminator at the end of the line. The termination is not perfect and there is a reasonable amount of reflection. But, by playing with the frequency and transmission line length, this reflection can be placed at the transition area in the eye diagram. Therefore, it will do no harm to the eye openings. It is important to consider that there has to be high impedance at the DUT point, which is not a problem as any input pin of an ASIC will do this, providing there are no pull-up/-down resistors on the chip. For the DUT fixture it is important to connect to two transmission lines as close to the pin as possible, any stub has to be avoided. A waveform as shown in figure 9 can be established with proper setup. At the point of DUT there is the superimposition of the two signals coming from the two generators. An Infinium scope with 1.5 GHz bandwidth is connected with 1 Meg input impedance to the DUT point.

Figure 8 shows the configuration of the setup used: one side is the E4838A amplifier in 'Channel Add' mode, the other side is an E4843A amplifier in normal mode. The timing of all three channels is set to NRZ and the delay is adjusted to compensate for the delay due to wiring. Figure 8 gives a detailed overview how the different states are generated in this setup. It is important to understand that there are four parameters to control: Vhi, I1, I2, I3.

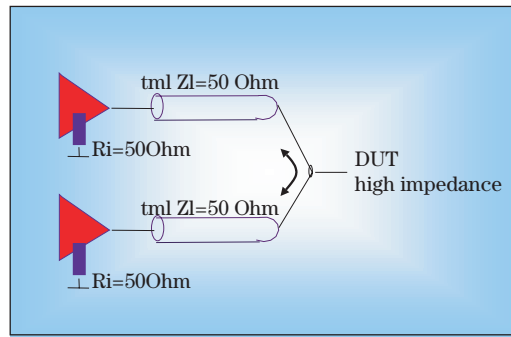


Figure 7: Analog Channel Add, Combination of 2 Generators

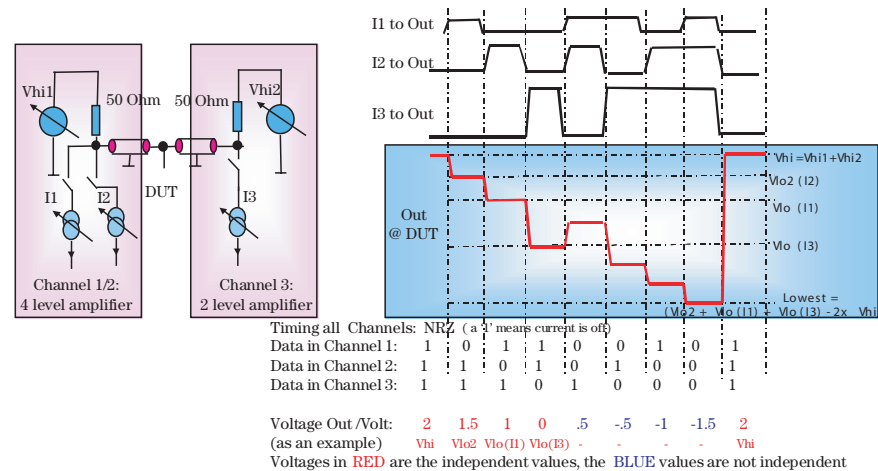


Figure 8: Analog Channel Add, Combination of 2 Generators

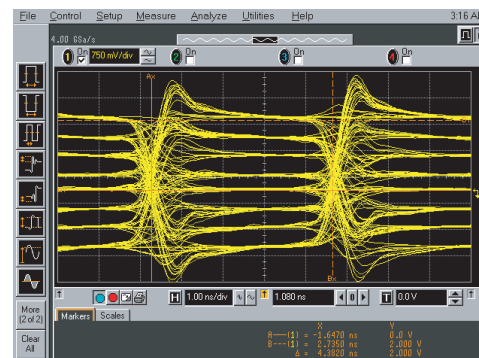


Figure 9: Analog Channel Add, Combination of 2 Generators

As a consequence there are 4 levels in figure 9, which can be set independently, while the other 4 levels are a function of those parameters and cannot be set independently. So if we want more than 4 levels, the combination of parameters must fit the desired levels. But for multi-level signals with equidistant levels, this is not an issue. The picture given in figure 8 uses PRWS based data loaded into the stimulus memory. This makes it possible to see the eight-level eye diagram. For the application requesting a 5 level signal, there are two choices: either the bits used should contain only 5 of the possible

8 states, to avoid using the upper three or lower three level states, or current source I3 would be programmed to be equal to current source I1. In this case, two bit combinations, resulting in a true 5 level picture would generate three level states. This method has the advantage that the complementary signal appears in the same voltage window. The complementary outputs of the E4838A and E4843A generator front-ends are not shown in figure 9, but these outputs are available and the combination of them will work the same.

If normal and complementary output is used, the test fixture will closely match the propagation delay between the normal and complementary path as deskewing between them is not possible. This is only possible for the normal and complementary outputs together. Figure 10 shows the setup on the 81200 Graphical User Interface, which achieves the signal in figure 9. The connection editor (background window) shows the standard dual level generator (machine reference: C1M2C1, model: E4843A) and the added generator (machine reference: C1M2C3 & C1M2C4, model E4838A). The mapping into two ports is done in order to exchange the pattern from static to random data, for deskewing and level setup, quickly and easily. Then there are three windows for the level programming. The left and middle windows are for programming the E4838A. The left window with 'low level' entry, controls current source I1, also referenced as Vlo(I1). In the middle window the '2nd low level' controls current source 2, also referenced as Vlo2. In the right window, the 'low level' controls current source I3, also referenced as Vlo(I3).

The actual programming values differ from the levels desired. Two issues have to be considered: - there are two voltage sources for Vhi. This works as if Vhi were be connected by 25 Ohm (2x 50Ohm in parallel). As a consequence the programming value of Vhi1 and Vhi2 for the two amplifiers is half of the value which is eventually desired for the high level Vh: $V_h = V_{hi1} + V_{hi2}$. Unsymmetrical programming is not recommended: the programming values for Vlo(I1), Vlo2, Vlo(I3) are not directly true. This has to be considered as something different from Vhi1/2, but now appears from Vh. This works as the currents continue to flow from 50 Ohm as in normal operation of the amplifiers. As the combination doubles the high level, the resulting swing is achieved from doubled voltage. Example: assuming the desired levels are $V_h=2V$, $V_{low1}=1.5V$, $V_{lo2}=1V$, $V_{lo3}=0V$, one would set: $V_{hi1} = V_{hi2} = 1V$, $V_{lo(I1)} = .5V$, $V_{lo2} = 0V$ $V_{lo(I3)} = -1V$. These are the levels also used on the following pictures.

For the Gigabit Ethernet application, which requires a true 5 level signal, the programming for the Vlo(I3) is changed to $V_{lo(I3)} = +0.5V$. This will raise the three lowest levels in line with the higher levels, shown in figure 11. So the pseudo random pattern can be used without modification and the signal stays within the 0V to 2V window with 5 levels. Figure 12 shows the 5 level pattern at 225MBit/s in eye diagram measurement mode with the help of the Infinium scope.

The total configuration of an Agilent 81200 needed for the generation of such a 5 level signal would be: 1x E4840A, 1x E4805A, 1x E4841A 2x E4838A, 1x E4843A. The second E4838A is not a must, but is helpful for setting signals up before it is added. Along with an Infinium scope this is a viable tool-set for the characterization of the physical layer of Gigabit Ethernet Category 5, 5 Enhanced and Category 6.

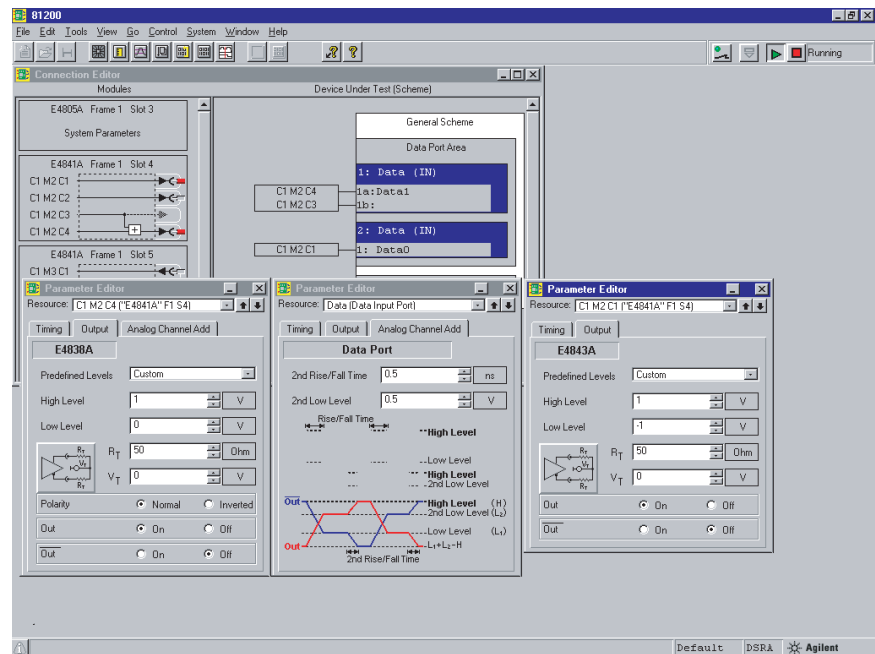


Figure 10: Analog Channel Add, Combination of 2 Generators

Related Literature

	Pub. Number
<i>Agilent 81200 Data Generator/Analyzer Platform</i> , brochure	5980-0488E
<i>Agilent 81200 Data Generator/Analyzer Platform</i> , data sheet	5965-3415E
<i>Agilent 81200 Data Generator/Analyzer Platform</i> , configuration guide	5965-3417E
<i>Data Transfer between Design, Simulation, and the Agilent 81200</i> , product note	5967-6276E
<i>Flat Panel Display Link Test</i> , product note	5968-8028E
<i>How to Use the Agilent 81200 Data Generator/Analyzer Platform Together with Agilent VEE for Signal Integrity Analysis</i> , product note	5968-3857E
<i>Agilent E4839A Test Fixture</i> , data sheet	5968-3580E

For more information, please visit
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