LAB 2

1. AIM

Investigate binary modulation and demodulation techniques.

2. METHODOLOGY

The signals apparatus, has 3 main components, connected by carriers.

The oscilloscope is use to view and measure the signal at given stages in the signals transformation process.

In the modulation sections of a the experiments, a signal is generated in the signal generator,

and it passed though the modulator.

The generated, and modulated signals are observed with the oscilloscope.

In the demodulation section, it is passed onwards through the demodulator,

and that output is also observed.

We also experiment with adding noise.

This is done for Amplitude Shift King, and Phase Shift keying.

3. RESULTS

3.1. **PRN and Spectum of Baseband Binary Signals.** PRN is pseudo random noise

3.1.1. *A).* 10kHz Rectangular singal has period: $T = \frac{1}{10000} = 10^{-4} seconds$

From page 481 of text book:

10kHz PRN single has period:

$T_c = \frac{1}{f} = 10^{-4} seconds$ per pulse

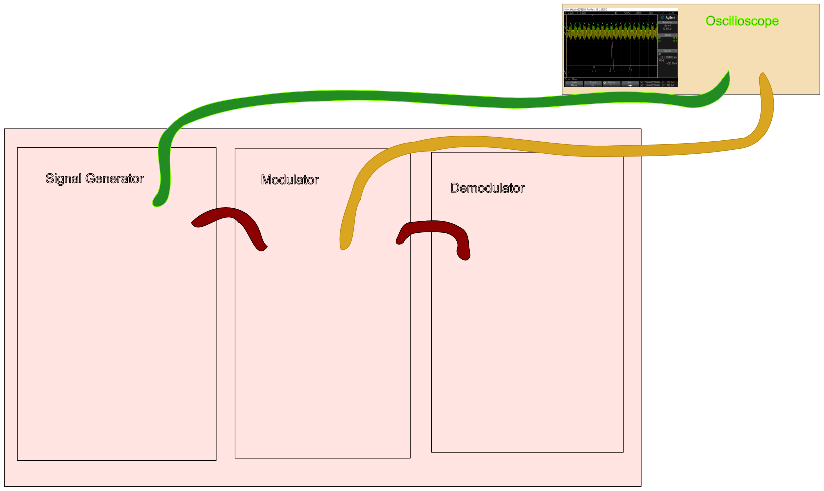


FIGURE 2.1.

$m = 15$, So maximum period is $N = 2^{15} - 1 = 32767$ pulses
$T_b = NT_c = 3.2767$ seconds before it repeats itself.
Explain the effect the period of the PRN has on the spectrum. The period is how many bits the PRN can output before it repeats itself.
Explain the effect the period of the Rectangular has on the spectrum. $m(t) = \sum_{k\in\mathbb{Z}} \begin{cases} 1 & k+0 \le t < k+\frac{T}{2} \\ 0 & k+\frac{T}{2} \le t < k+T \end{cases} = \sum_{k\in\mathbb{Z}} \begin{cases} 1 & 0 \le t-k < \frac{T}{2} \\ 0 & \frac{T}{2} \le t-k < T \end{cases}$

or equivelently: $m(t) = \sum_{k\in\mathbb{Z}} \begin{cases} 1 & \frac{-T}{4} \le t-k < \frac{T}{4} \\ 0 & \frac{T}{4} \le t-k < \frac{3T}{4} \end{cases} = \sum_{k\in\mathbb{Z}} rect(\frac{t}{0.5T} - k)$

By the Linearity of the Forfier tranfrom $M(2\pi f) = \sum_{k\in Z} \frac{T}{2} sinc(\frac{fT}{2}) e^{-j2\pi fk}$

$M(2\pi f) = \sum_{k\in Z} \frac{T}{2} \frac{sin(2\pi f \frac{T}{4})}{2\pi f \frac{T}{4}} e^{-j2\pi fk} = \sum_{k\in Z} \frac{sin(2\pi f \frac{T}{4})}{\pi f} e^{-j2\pi fk} = \sum_{k\in Z} \frac{sin(2\pi f \frac{T}{4})}{\pi f} e^{-j2\pi fk}$

$M(2\pi f) = \sum_{k\in Z} \frac{sin(2\pi f \frac{T}{4})}{\pi f} e^{-j2\pi fk} = \sum_{k\in Z} \frac{e^{j(\frac{\pi}{2} - 2\pi f \frac{T}{4})} + e^{j(\frac{\pi}{2} + 2\pi f \frac{T}{4})}}{2\pi f} e^{-j2\pi fk}$

using $sin(x) = \frac{e^{jx} - e^{-jx}}{2j} = \frac{e^{\frac{\pi}{2}j}(e^{-jx} - e^{jx})}{2} = \frac{e^{j(\frac{\pi}{2} - x)} - e^{(\frac{\pi}{2} + x)}}{2}$

$M(2\pi f) = \sum_{k\in Z} \frac{e^{\frac{\pi}{2}j(1-fT)} + e^{\frac{\pi}{2}j(1+fT)}}{2\pi f} e^{-j2\pi fk} = \sum_{k\in Z} \frac{e^{\frac{\pi}{2}j(1-4kf-fT)} + e^{\frac{\pi}{2}j(i-4kf+fT)}}{2\pi f}$

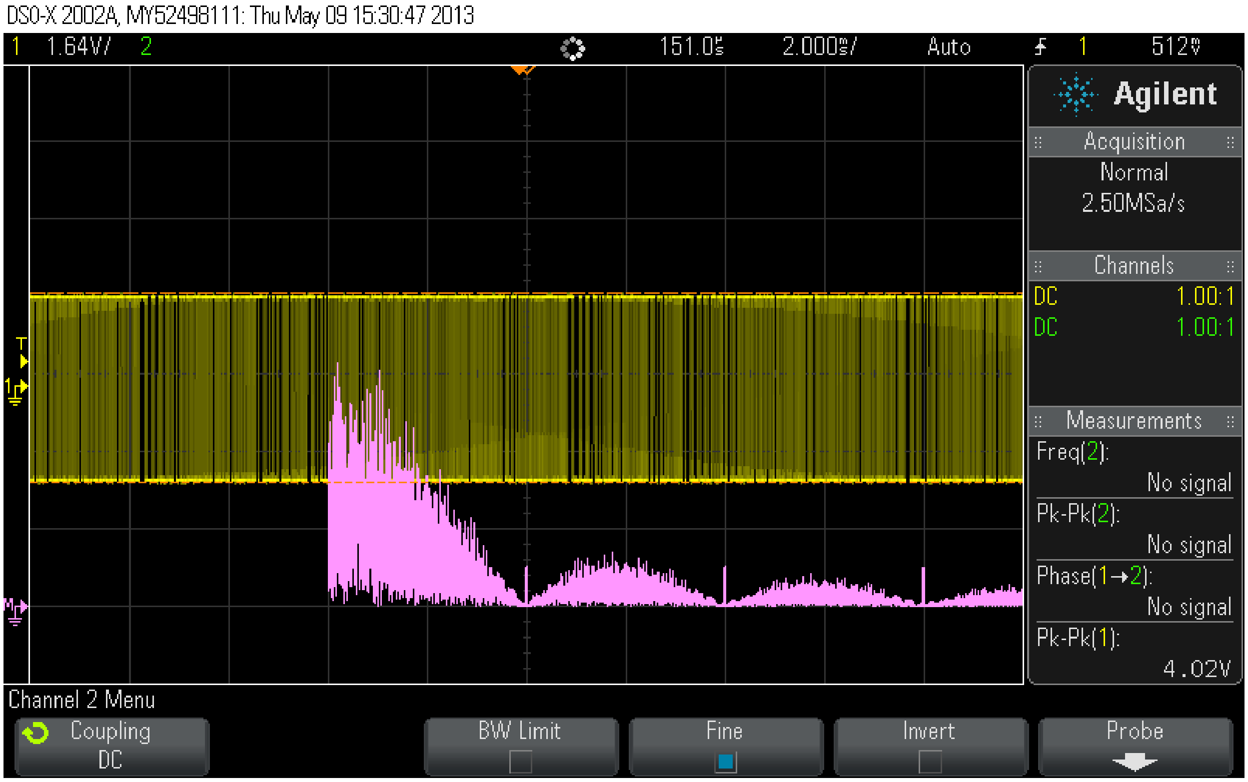
$$M(2\pi f) = \sum_{k\in Z} \frac{e^{\frac{\pi}{2}j(1-f(4k+T))} + e^{\frac{\pi}{2}j(1-f(4k-T))}}{2\pi f}$$

Changing the Period dilates the frequency spectrum.

3.1.2. *b.* $-2V$ to 2V, $100kHz$ PRN binary polar basebane signal.
Sketch specturm:
0 to 4V, $100kHz$ PRN binary unipolar baseban signal.
Sketch specturm:
What differences observed between spectrum? We can't see difference because of a flaw in the hardware, but there should be a DC component at zero frequency for polar.

3.2. **Binary Amplitude Shift Keying (ASK).**

3.2.1. *A) Generate ASK signal.* Modulating Signal 10kHz $1V_{p-p}$unipolar periodic rectangular signal
Carrier 100kHz $2V_{p-p}$sinusoid
Case) a Zero is modulated $\Longrightarrow 1$
Case) a One is modulated $\Longrightarrow 2cos(2\pi 10^5 t)$
Explain form of spectrum. The spectrum of the output ASK signal: $Y(2\pi f) = M(2\pi f) * C(2\pi f)$
since the Carrier single is just a Cosine, $C(2\pi f) = \delta(f - 10^5) + \delta(f + 10^{-5})$
So by the replication property of the Dirac Deltat:
$Y(2\pi f) = M\left(2\pi(f - 10^5)\right) + M\left(2\pi(f + 10^5)\right)$
$y(t) = m(t) \cdot 2cos(2\pi 10^5 t)$
correlate the powers in the carrier and first sideband with that predicted by theory.
Measured:
$C(f = 100kHz\, Carrier) = 297.4mV$
$C(sideband) = 203.5mV$
Calculated:
Carrier $Y(2\pi \times 10^5) = \sum_{k\in\mathbb{Z}} \frac{1}{2\times 10^4} \left(sinc(\frac{0}{2\times 10^4}) e^{-j2\pi k \times 0} + sinc(\frac{2\times 10^5}{2\times 10^4}) e^{-j2\pi k(2\times 10^{-5})} \right)$



DSO-X 2002A, MY52498111: Thu May 09 15:30:47 2013

Acquisition: Normal 2.50MSa/s

Channels: DC 1.00:1, DC 1.00:1

Freq(2): No signal

Pk-Pk(2): No signal

Phase(1→2): No signal

Pk-Pk(1): 4.02V

Channel 2 Menu

Coupling: DC

FIGURE 3.1. Bipolar PRN Signal (Yellow)
and It's frequency spectum (pink)

$$Y(2\pi \times 10^t) = \sum_{k\in\mathbb{Z}} \frac{1}{2\times 10^4}\left(1 + sinc(10)e^{-\frac{4\pi}{10^5}kj}\right)$$

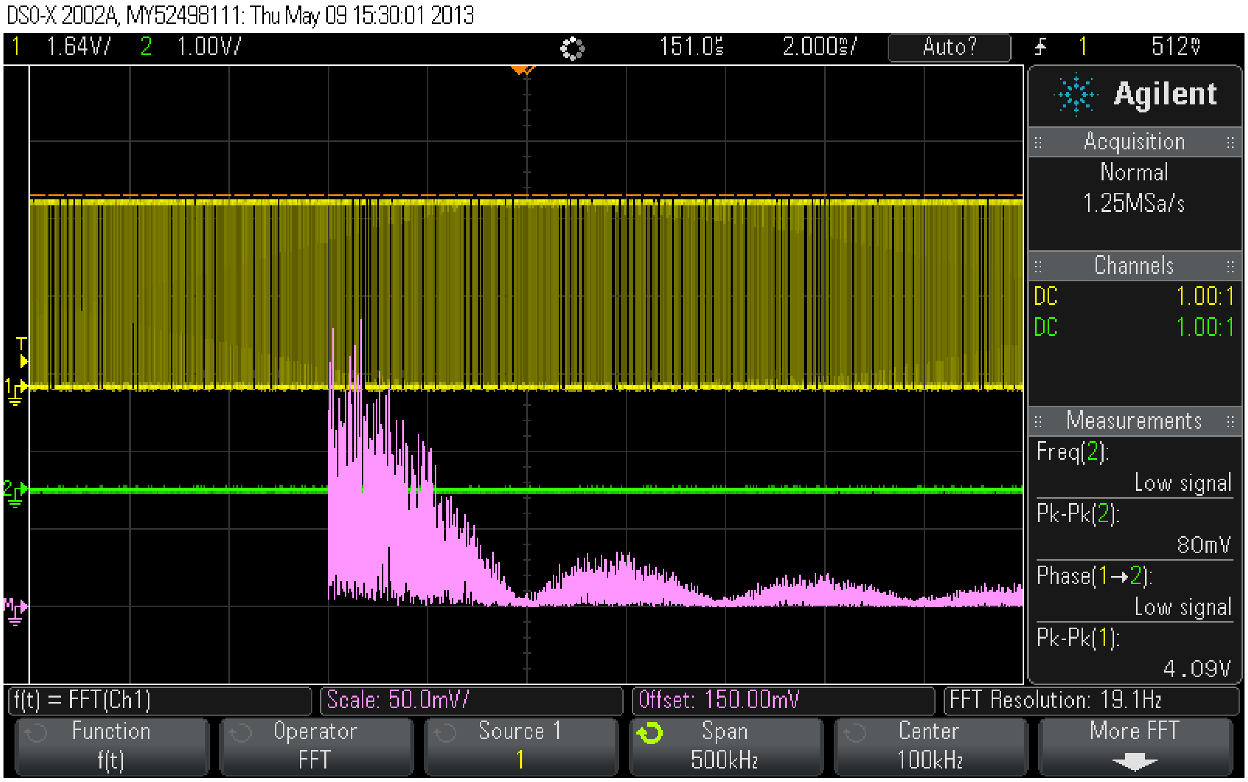
3.2.2. *B).* modulating with $10kHz 1V_{p-p}$ unipolar PRN.
Using filter 25Hz
Explain form of spectrum. as before $Y(2\pi f) = M\left(2\pi(f-10^5)\right) + M\left(2\pi(f+10^5)\right)$
where M this time is a PRN signal.
It is symmetrical like before, as that is a product of the modulation.
Basically we see the Frequency shift and sum of the PRN spectrum.

3.2.3. *C).* Modulating 1kHz 2 V_{p-p}unipolar periodic retangualr rignal;

3.2.4. *D) Eye diagram.* modulating signal to a 1 kHz 1Vp-p unipolar PRN sequence

3.2.5. *E) Eye diagram.* Add 5v noise
We can see that the signal becoem more shaky

3.3. **Binary Phase Shift Keying (BPSK).**



DSO-X 2002A, MY52498111: Thu May 09 15:30:01 2013

Acquisition: Normal, 1.25MSa/s

Channels: DC 1.00:1, DC 1.00:1

Freq(2): Low signal

Pk-Pk(2): 80mV

Phase(1→2): Low signal

Pk-Pk(1): 4.09V

f(t) = FFT(Ch1)

Scale: 50.0mV/

Offset: 150.00mV

FFT Resolution: 19.1Hz

Function: f(t)

Operator: FFT

Source 1: 1

Span: 500kHz

Center: 100kHz

FIGURE 3.2. Unipolar PRN Signal (Yellow)
and It's frequency spectrum (pink)

3.3.1. *a.* Generate a binary PSK signal by using a 100kHz 2Vp-p sinusoidal carrier and a 10 kHz 1Vp-p polar periodic rectangular signal.

Determine the phase that a logic 1 (0.5V) and a logic 0 (-0.5V) are encoded with using the oscilloscope.

$s_0(t) = cos(10^4 \times 2\pi t - 0.5)$

$s_1(t) = cos(10^4 \times 2\pi t + 0.5)$

3.3.2. *B).* The Specturm of the BPSK signal is basically the same as the ASK signal, except for the carrier impuse.

This is because they output the same signal if the modulating a One.

Whereas when modulating a Zero, the BPSK outputs a phase shifted signal (which has roughly the same frequency spectrum as a unphase-shifted signal), but the ASK outputs just 0 (thus the Carrier Impulse).

3.3.3. *C).* The Costas PLL can successfully demodulate a BPSK signal

4. CONCLUSION

This experiment confirmed the expected behavior of our binary modulation techniques.

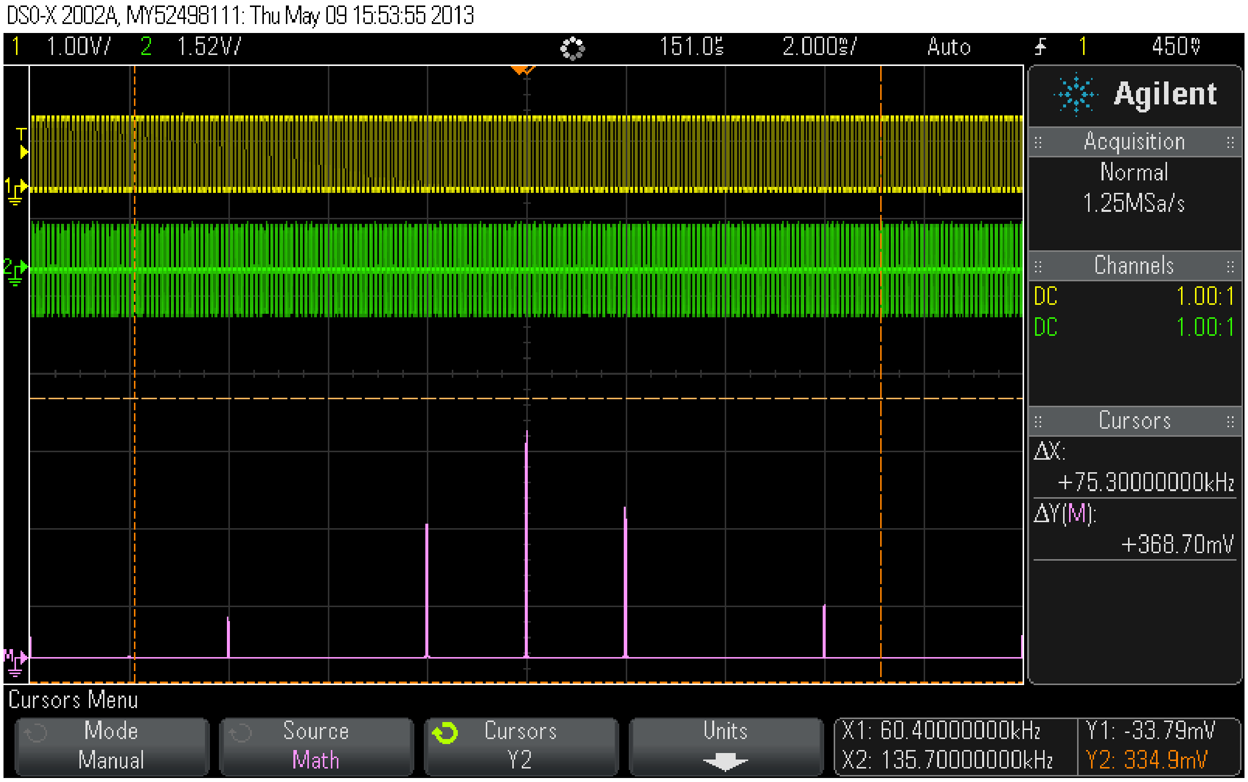
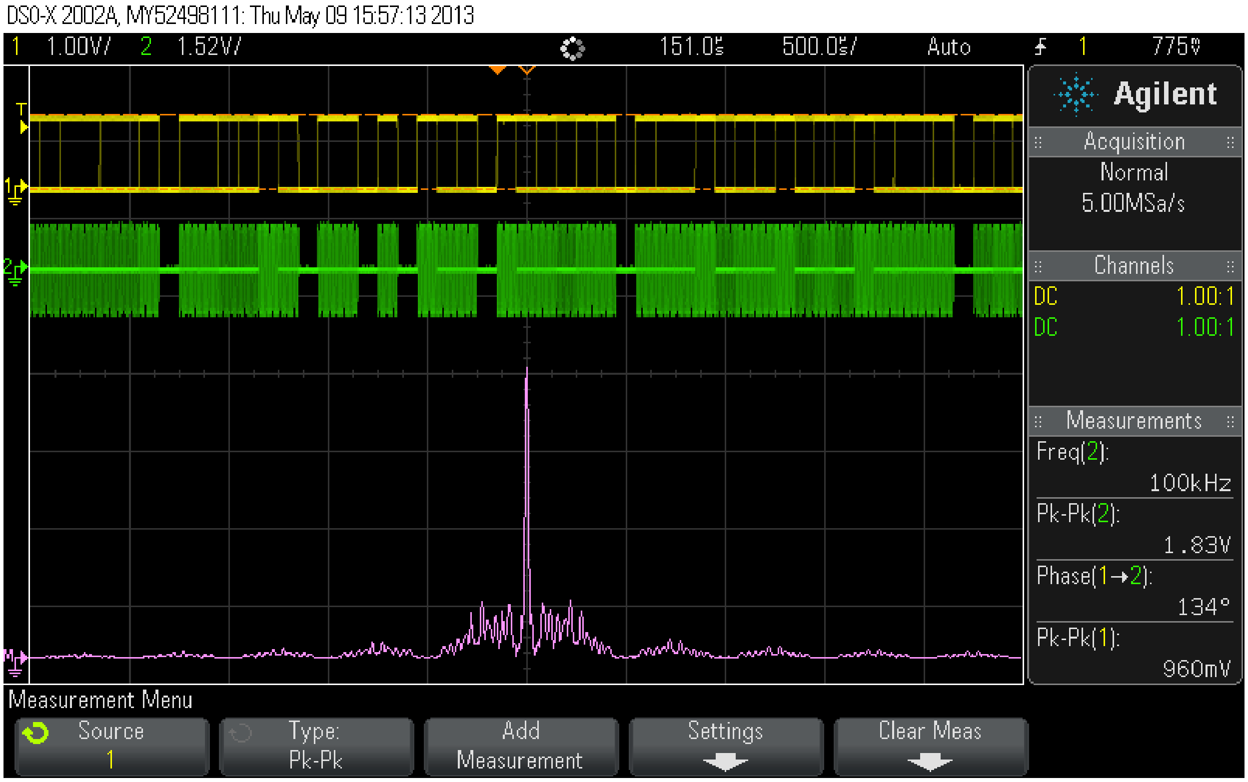


FIGURE 3.3.

We also saw that that the binary signals, can be recovered very will even with noise.

ASK, works by either passing the carrier, or passing no signal, depending on the input signal.

BPSK, works by shifting the carrier phase, in proportion to the modulating signal.



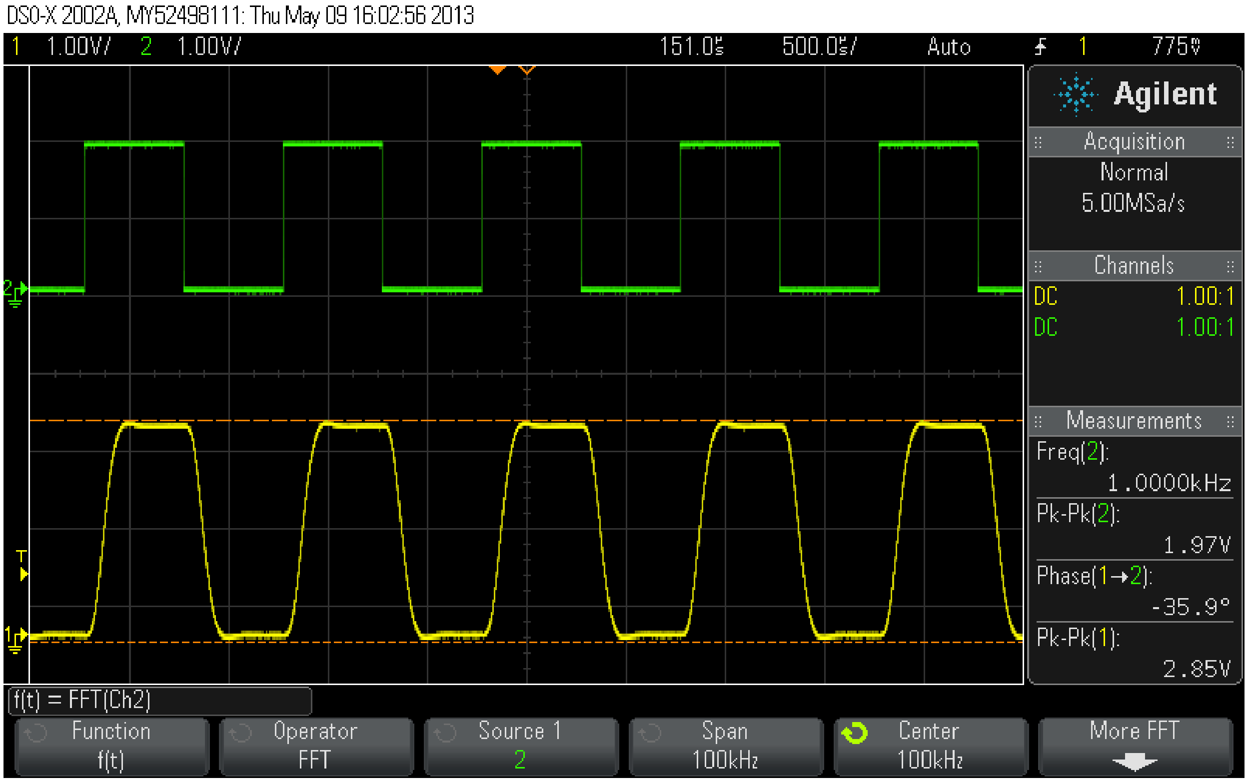
DSO-X 2002A, MY52498111: Thu May 09 15:57:13 2013

Acquisition: Normal 5.00MSa/s

Channels:
DC 1.00:1
DC 1.00:1

Measurements:
Freq(2): 100kHz
Pk-Pk(2): 1.83V
Phase(1→2): 134°
Pk-Pk(1): 960mV

FIGURE 3.4.



DSO-X 2002A, MY52498111: Thu May 09 16:02:56 2013

1 1.00V/ 2 1.00V/ 151.0µs 500.0µs/ Auto 1 775mV

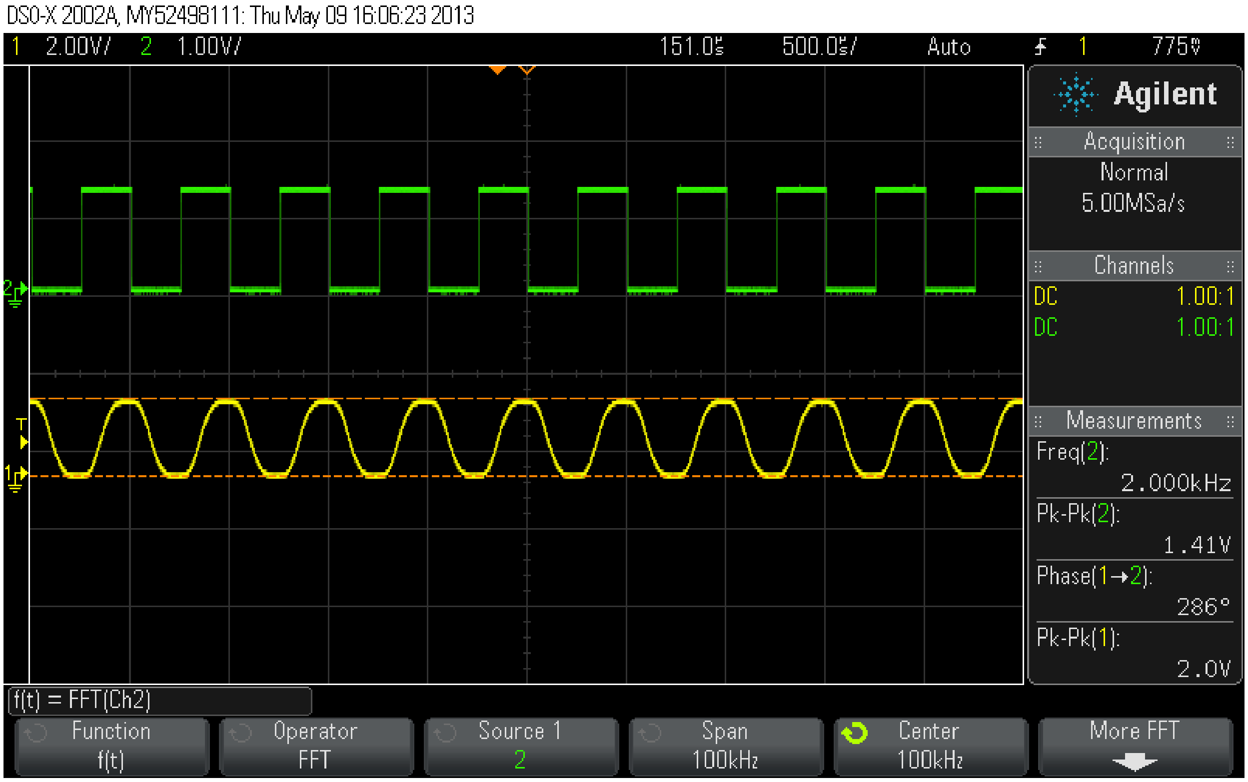
Acquisition
Normal
5.00MSa/s

Channels
DC 1.00:1
DC 1.00:1

Measurements
Freq(2): 1.0000kHz
Pk-Pk(2): 1.97V
Phase(1→2): -35.9°
Pk-Pk(1): 2.85V

f(t) = FFT(Ch2)

FIGURE 3.5. Modulating signal (Green)
demodulated Modulated signal (yellow)



DSO-X 2002A, MY52498111: Thu May 09 16:06:23 2013

1 2.00V/ 2 1.00V/ 151.0s 500.0s/ Auto 1 775V

Acquisition
Normal
5.00MSa/s

Channels
DC 1.00:1
DC 1.00:1

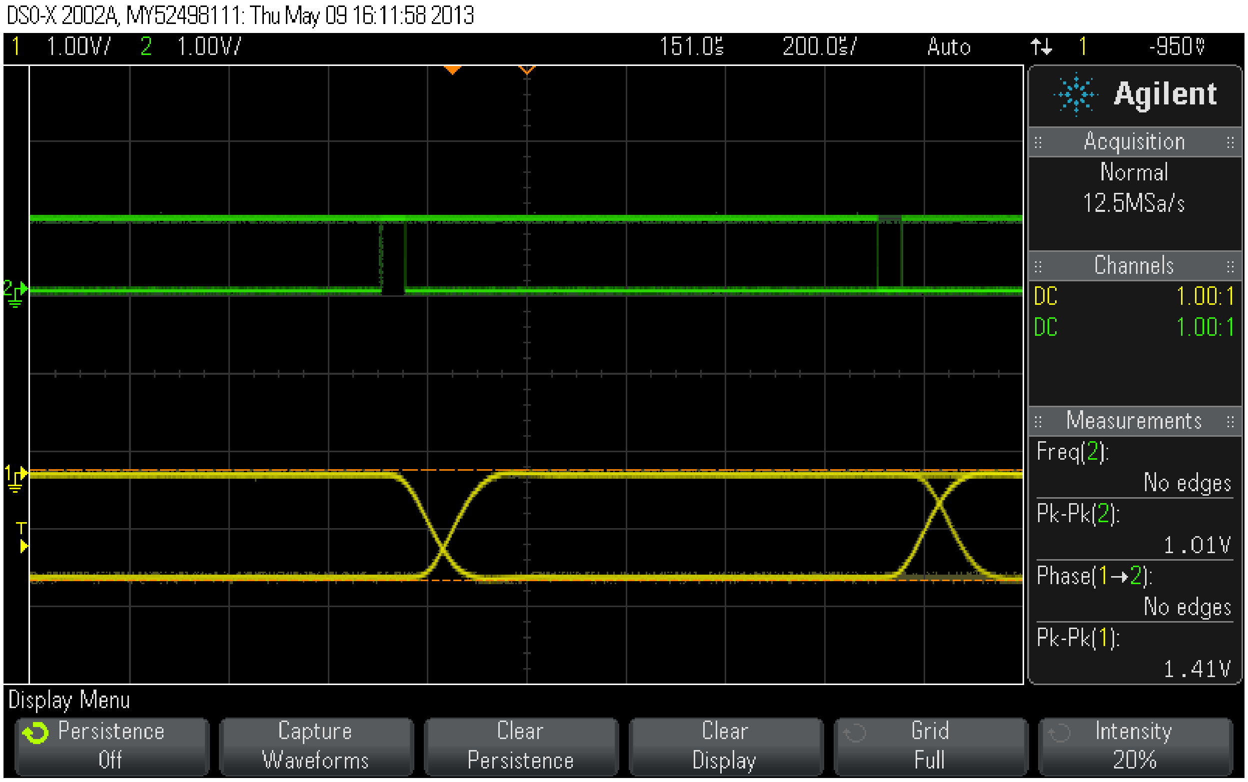
Measurements
Freq(2): 2.000kHz
Pk-Pk(2): 1.41V
Phase(1→2): 286°
Pk-Pk(1): 2.0V

f(t) = FFT(Ch2)

Function f(t)
Operator FFT
Source 1 2
Span 100kHz
Center 100kHz

FIGURE 3.6.

Modulating signal (Green)
demodulated Modulated signal (yellow)



DSO-X 2002A, MY52498111: Thu May 09 16:11:58 2013

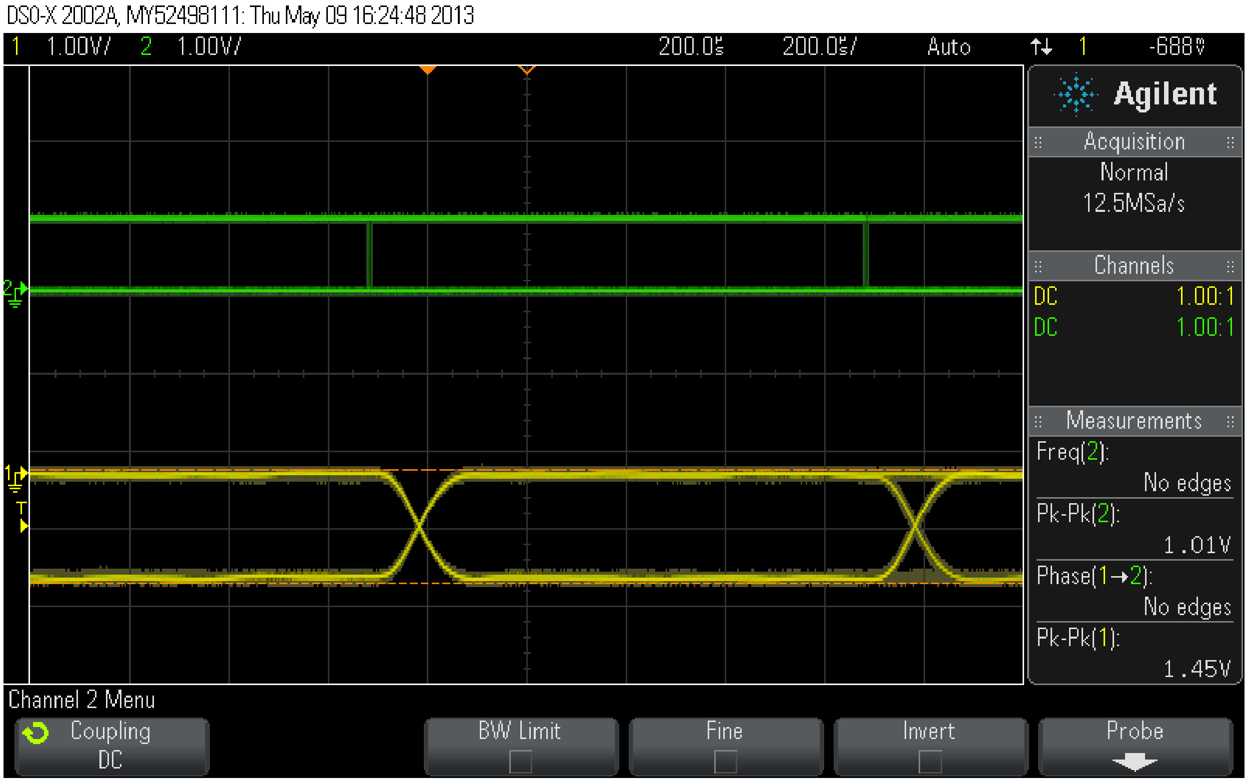
1 1.00V/ 2 1.00V/ 151.0s 200.0s/ Auto 1 -950V

Acquisition: Normal, 12.5MSa/s

Channels: DC 1.00:1, DC 1.00:1

Measurements:
Freq(2): No edges
Pk-Pk(2): 1.01V
Phase(1→2): No edges
Pk-Pk(1): 1.41V

FIGURE 3.7.



DSO-X 2002A, MY52498111: Thu May 09 16:24:48 2013

1 1.00V/ 2 1.00V/ 200.0µs 200.0µs/ Auto ↑↓ 1 -688mV

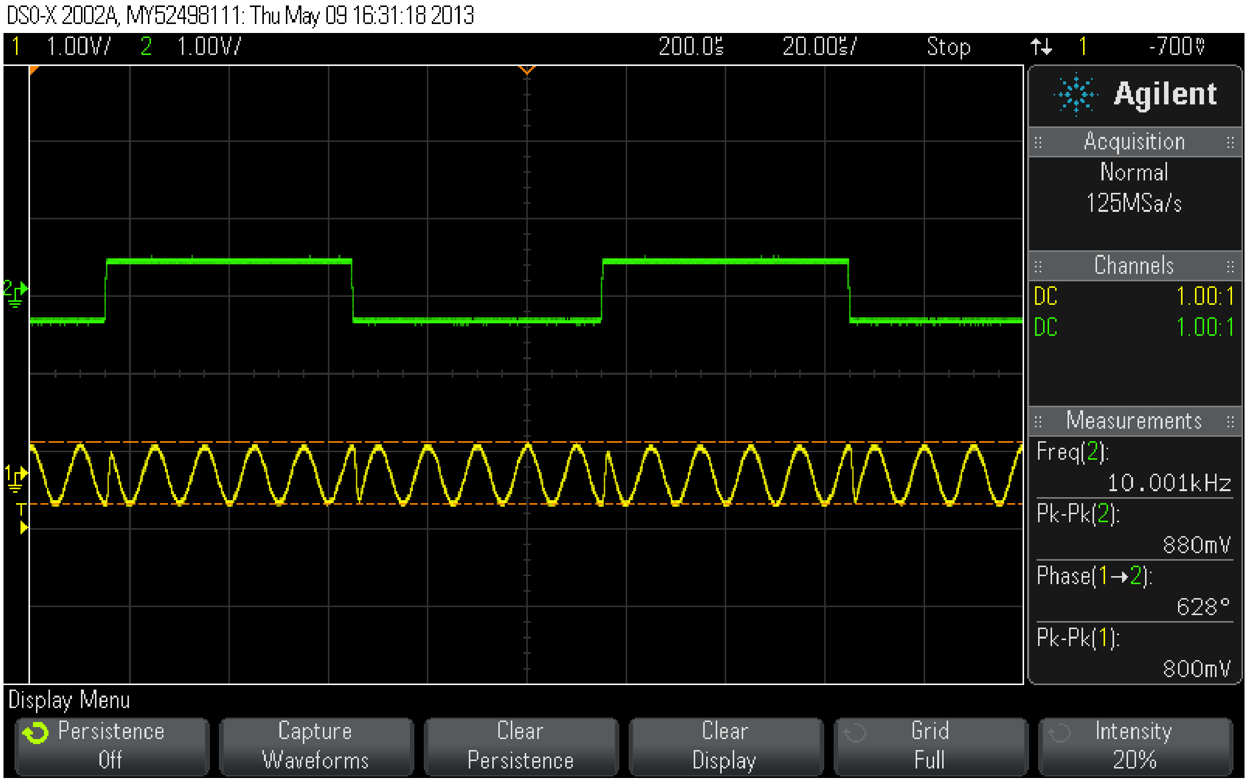
Acquisition
Normal
12.5MSa/s

Channels
DC 1.00:1
DC 1.00:1

Measurements
Freq(2): No edges
Pk-Pk(2): 1.01V
Phase(1→2): No edges
Pk-Pk(1): 1.45V

Channel 2 Menu

Figure 3.8.



DSO-X 2002A, MY52498111: Thu May 09 16:31:18 2013

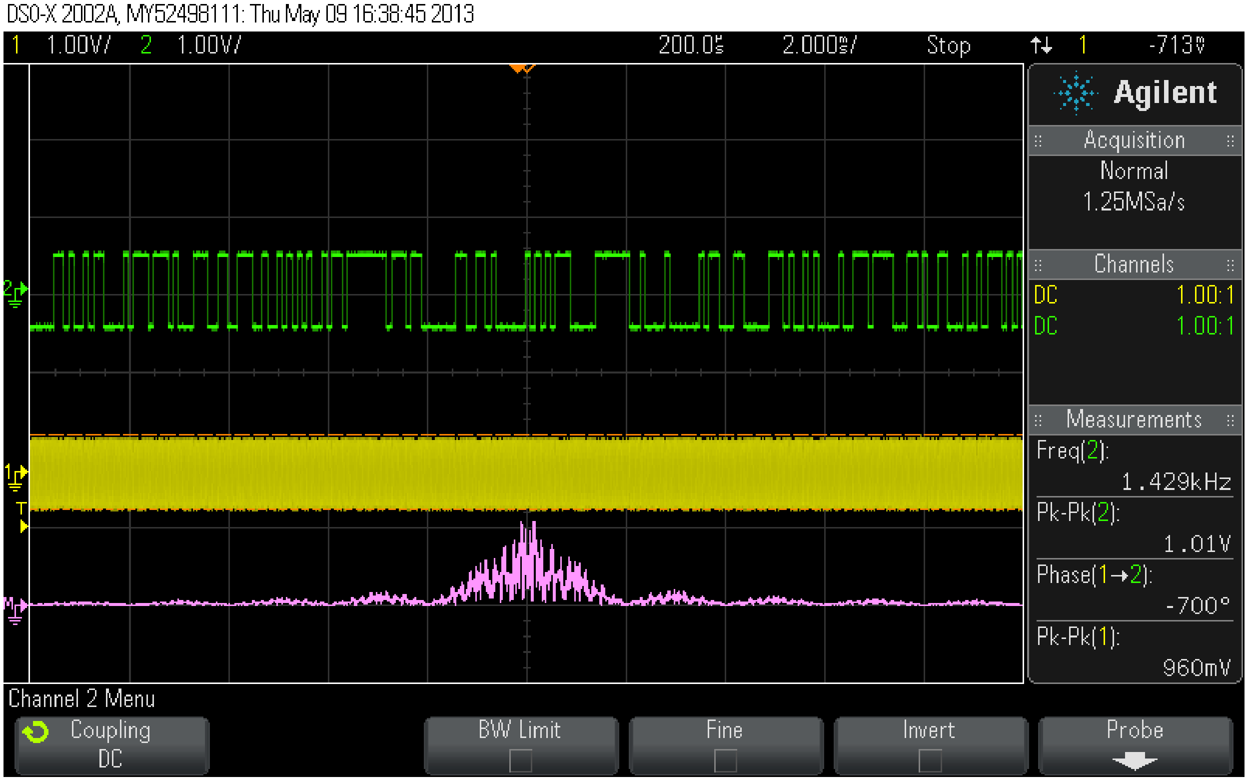
1 1.00V/ 2 1.00V/ 200.0µs 20.00µs/ Stop ↑↓ 1 -700mV

Acquisition
Normal
125MSa/s

Channels
DC 1.00:1
DC 1.00:1

Measurements
Freq(2): 10.001kHz
Pk-Pk(2): 880mV
Phase(1→2): 628°
Pk-Pk(1): 800mV

FIGURE 3.9.



DSO-X 2002A, MY52498111: Thu May 09 16:38:45 2013

1 1.00V/ 2 1.00V/ 200.0µs 2.000ms/ Stop 1 -713mV

Acquisition
Normal
1.25MSa/s

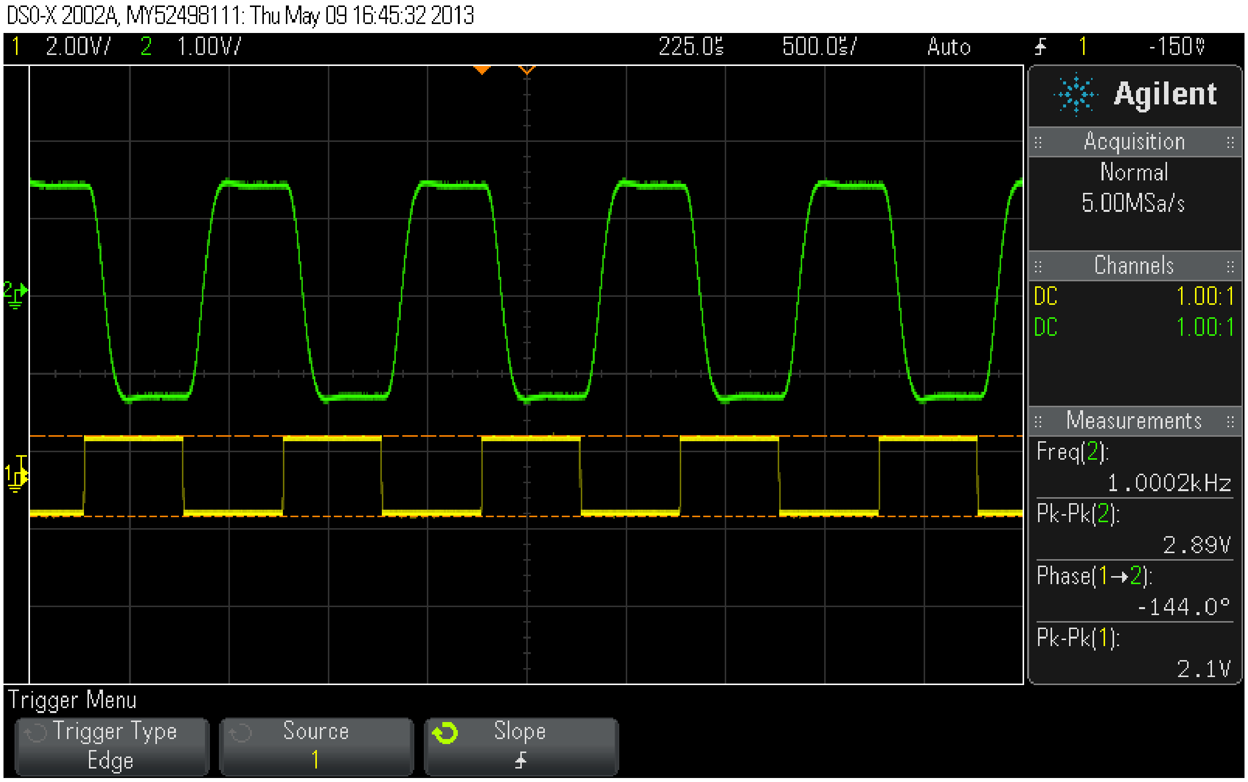
Channels
DC 1.00:1
DC 1.00:1

Measurements
Freq(2): 1.429kHz
Pk-Pk(2): 1.01V
Phase(1→2): -700°
Pk-Pk(1): 960mV

Channel 2 Menu
Coupling DC

FIGURE 3.10.

FIGURE 3.11.



DSO-X 2002A, MY52498111: Thu May 09 16:45:32 2013

1 2.00V/ 2 1.00V/ 225.0µs 500.0µs/ Auto 1 -150mV

Acquisition
Normal
5.00MSa/s

Channels
DC 1.00:1
DC 1.00:1

Measurements
Freq(2): 1.0002kHz
Pk-Pk(2): 2.89V
Phase(1→2): -144.0°
Pk-Pk(1): 2.1V

Trigger Menu
Trigger Type: Edge
Source: 1
Slope

Modulating signal (yellow)
Demodulated signal (Green)
(Note: they are the same amplitude - the oscilloscopes scales were set different)