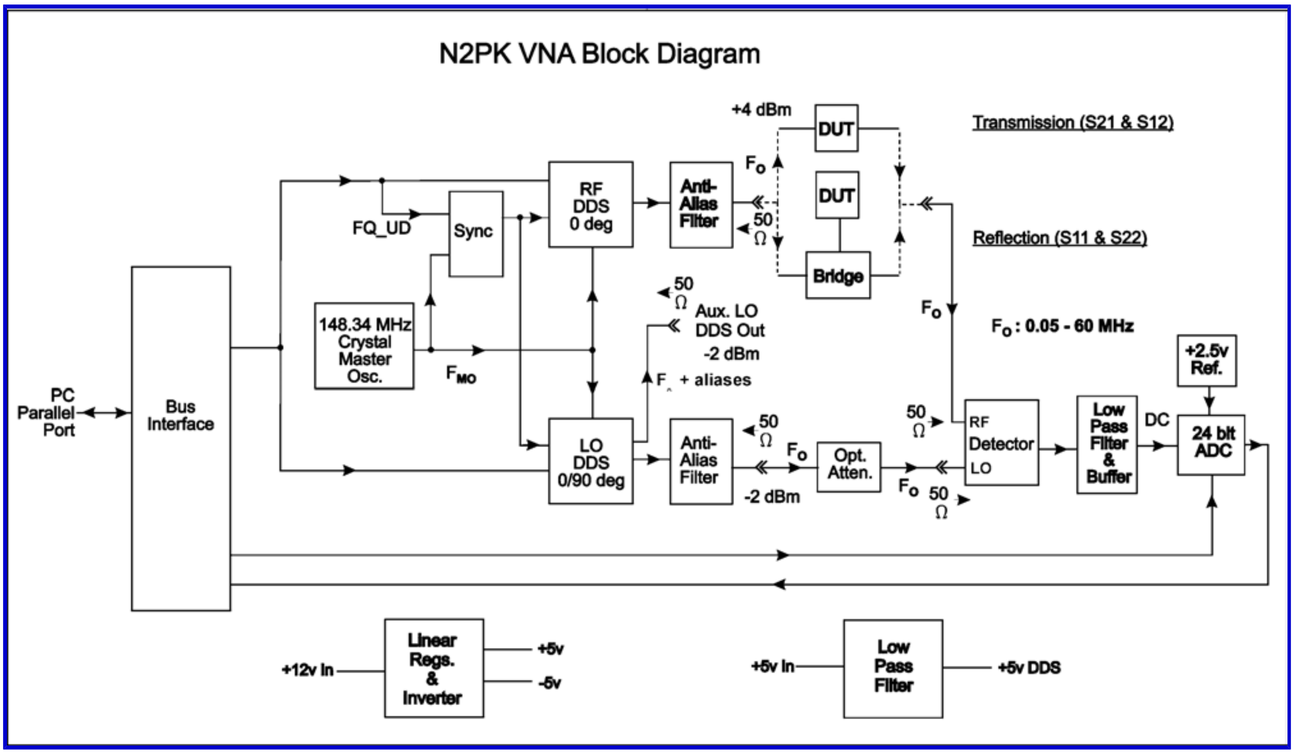
# N2PK VNA - How it Works

Imagine a simple transmission measurement through a DUT on the block diagram. The RF DDS generates an RF voltage at the reference phase of 0 deg, and this signal is applied to the input of the DUT. The output from the DUT to the Detector input is an RF signal with amplitude |VRF| at a phase Theta. In addition, the RF signal at the Detector input is measured with a 'Through' in place of the DUT. The 'Through' is simply a short length of transmission line that is assumed to have unity gain and zero phase. The Detector output is also measured without any intentional RF signal at the Detector input. This test condition is referred to as the 'Open Detector.' For test flow reasons, the 'Through' and the 'Open Detector' measurements are made before the DUT is inserted and measured.

From these three vector measurements at a single frequency, all DUT transmission characteristics, such as gain and phase, can be calculated. Group delay requires two or more frequencies.




(The block diagram can be enlarged for better clarity by clicking on it in an 800x600 window or larger.)

Similarly, all impedance characteristics of the DUT can be measured at each frequency of interest using a standard Wheatstone type reflection bridge. Here, the DUT |VRF| and Theta are measured relative to three precision terminations. The terminations are typically an open, a short, and one that approximates the system reference impedance (usually 50 ohms). These three calibration standards also allow the use of other measurement fixtures (not strictly bridges) that provide improved accuracy for high or low DUT impedances.

|VRF| is quite easy to measure, but there are several different ways to determine the relative phase information Theta.

Most lab-quality VNAs use a superhet architecture that converts both the reference signal and the detected signal to a fixed IF for precision amplitude and phase detection. These conversions occur via conventional mixing or sampling. This architecture, as normally implemented, is complex and expensive. A much simpler architecture is used in the recent 'VNA on a chip' device - the Analog Devices AD8302, with its broadband logarithmic detection of amplitude information and high-speed logic for the phase comparison. The disadvantage here is considerably reduced accuracy compared to a lab-quality VNA.

This VNA is different - it uses a narrow-band direct-conversion architecture that is much simpler than superhet VNAs, but is also much more accurate than the log-detection devices. Because the Detector in this VNA converts down to DC, the only output available is a DC voltage, which is dependent not only on the magnitude of the RF voltage at its input, but also its phase relative to the RF signal at its LO input. Highly accurate measurements of this amplitude and phase dependent DC voltage are obtained using a precision linear analog detector, a 24-bit analog-digital converter (ADC), and precise phase control of the LO DDS.

The phase information is obtained, in a novel way, by making two sequential DC measurements for each frequency and test condition (Through, Open Detector, and DUT). In each case, the first measurement is made with the LO at the reference phase of 0 deg; the second measurement is made with the LO phase shifted by 90 deg. This process results in the quadrature or vector components of each signal at the Detector RF input.

The result is a very simple hardware architecture, which takes maximum advantage of modern developments: the ability of a computer-controlled DDS to generate precise frequencies and phase shifts; precision 24-bit analog-to-digital conversion; and the power of computer control and post-processing. The computer processing completely eliminates setup adjustments, and allows many common sources of measurement errors to be 'calibrated out'. This greatly simplifies home construction.

## N2PK VNA Photo Gallery

Here are some pixs of N2PK VNAs (click on each to enlarge):

W7AAZ

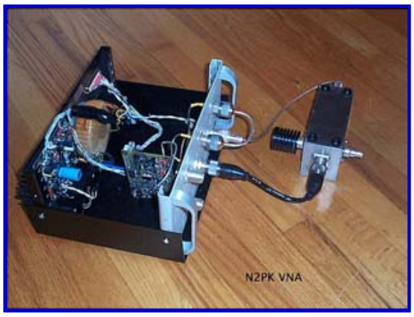
W4ZCB

N2PK

G3SEK

G4PMK

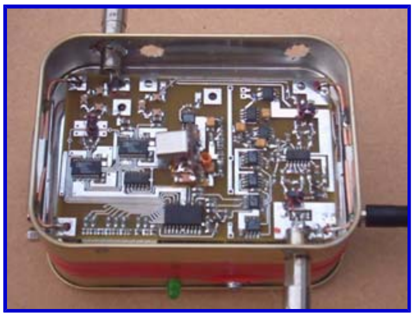

AC6AO




KE9OA

OZ9MO

OZ1DUG

AG4AY | KD4PBJ | AE4IC


I am also aware of many other units either completed or in progress..

## N2PK VNA - 'The Rest of The Story'

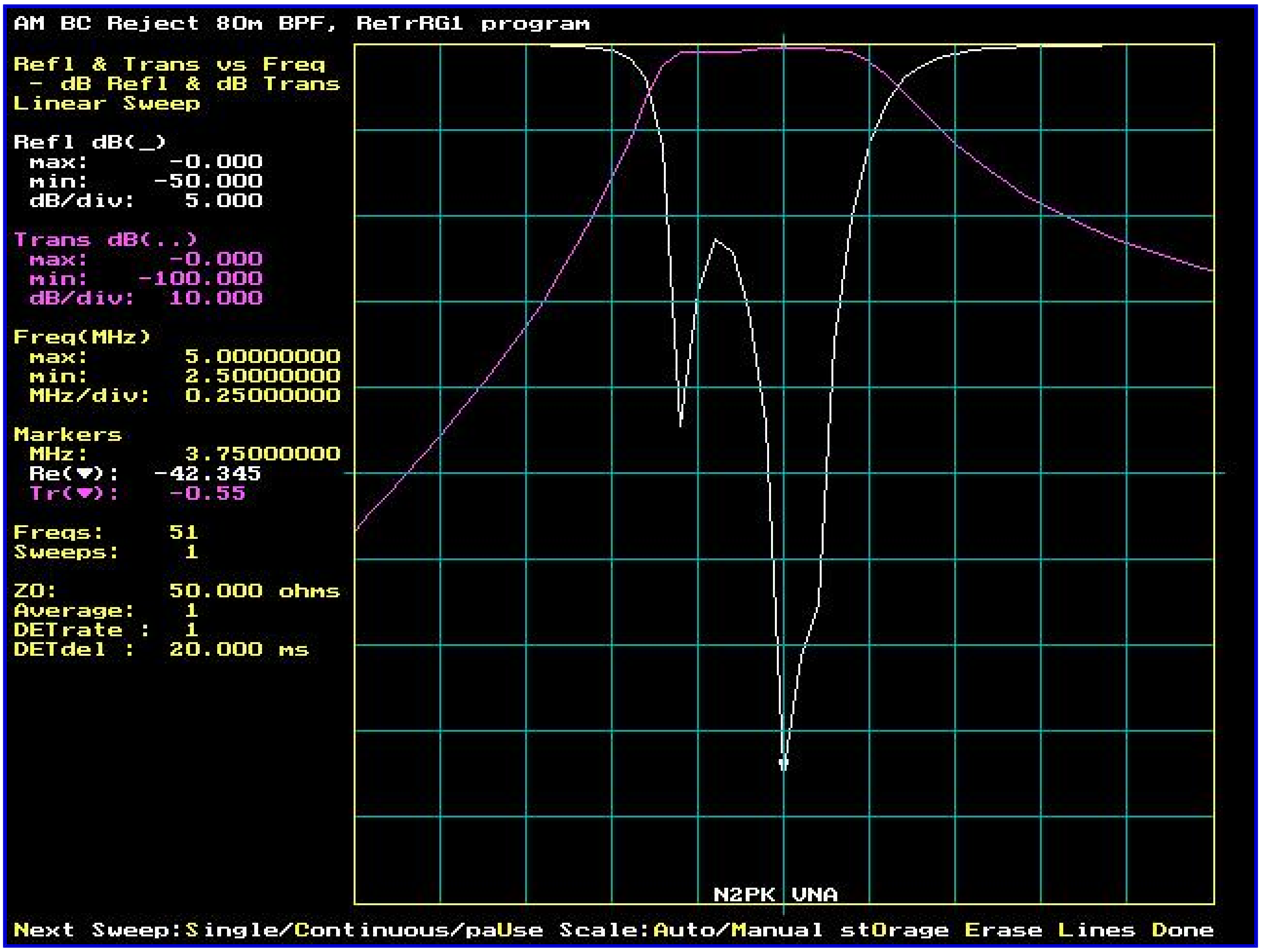
If you're still reading and interested in more, click on each document or ZIP file named below to either view or download it:

1. Part 1 PDF (Ver. C, 588 KB)
2. Part 2 PDF (Ver. B2, 3,690 KB) **Minor correction to pin numbers on U160 in Fig. 1**
   The Part 3 PDF, as referenced in Parts 1 & 2, will not be available for some time. However, it is not needed to build and use most of the capabilities of the VNA.
3. VNA PCB 'Build Info' ZIP (Ver. 1C, 839 KB) **Minor corrections to G3SEK build notes & the annotated images have been deleted due to availability of better images below.**
4. VNA PCB Ordering Procedure PDF (Ver. 2, 24 KB)
   There are changes in this "VNA_PCB_Ordering_Procedure.pdf" that are important ONLY to
   builders that intend to use something other than the ExpressPCB Miniboard service.
5. Master Oscillator 'Build Info' ZIP (Ver. 1B, 324 KB)
6. Master Oscillator Test Board 'Build Info' ZIP (Ver. 1B, 99 KB)
7. Testing of the Fox JITO-2 as the Master Oscillator **This oscillator is unacceptable for general purpose VNA usage due to relatively poor phase noise, but could be acceptable for reflection only measurements.**
8. T1-6T Bridge 'Build Info' ZIP (Ver. 1A, 172 KB)
9. VNA PCB, top view, G3SEK Annotated, Hi-res JPG Photo (Ver. 2, 339 KB) **R120 annotation added.**
10. VNA PCB, bottom view, G3SEK Annotated, Hi-res JPG Photo (Ver. 1, 364 KB)
11. Fast ADC & 2nd Detector Overview **This also describes the planned key features of the 'Expanded N2PK VNA' and its planned parallel port assignments.**
12. Fast Detector PDF (Ver. 1a, 405 KB) **This document provides the fast detector hardware update to the original single detector N2PK VNA as well as the dual fast detectors of the Expanded N2PK VNA. With the later addition of the S-Parameter Test Set and new software, the Expanded N2PK VNA will support all of the features shown above in Fast ADC & 2nd Detector Overview**
13. Fast Detector PCB, top view, Hi-res JPG Photo (Ver. 1a, 1,136 KB)
14. **To see the adaptation of the N2PK VNA to the USB port as done by Dave Roberts,**

G8KBB, click [here.]()

To my knowledge, the only software that supports Dave's USB interface is VNA4win and is available [here.]()

**All N2PK VNA software developers are encouraged to support the fast detector and the dual detectors in the Expanded N2PK VNA. The architecture of the dual detector N2PK VNA allows simultaneous real time display of reflection and transmission, as shown here:**




**When the fast dual detectors are functioning at their faster rates, the combination of simultaneous display of reflection and transmission can be very useful during adjustment of a variety of DUTs.**

**Also, even without the S-Parameter Test Set which is needed for 12-term error correction, a dual detector VNA can provide improved transmission measurement accuracy over a single detector VNA by being able to account for additional error sources.**

**Item 12 above shows a block diagram of a VHF/UHF VNA Transverter (Fig. D) that extends the capabilities of the Expanded N2PK to 500 MHz in narrow band fashion. A simpler transverter, that is compatible with a single (slow or fast) detector N2PK VNA, will be described in detail in the near future. All N2PK VNA software developers are also encouraged to support "VNA Transverter mode" or "Synchronous Common LO up/down mixing mode" as it is currently referred to in my software below.**

If you print the PDFs, use the "Fit to page" option in Adobe Acrobat Reader.
To download Adobe Acrobat Reader which is needed to view PDF files, click [here.]()
An unZIP program, such as [WinZIP](), will also be needed.

## N2PK VNA Software

First click on one of the README files for software installation instructions and usage. Then download the software. The PDF has been bookmarked and could be a handy reference.

1. README - PDF (48 KB)
2. README - TXT (46 KB)
3. SOFTWARE ZIP (Ver 2.01, 860 KB)

**The above software does not currently support the fast or dual detector VNAs. If you would like a copy of some incomplete beta software, please send me an e-mail requesting it.**

**Some other sources of software, compatible with the N2PK VNA at various levels, are Windows based and as follows in alphabetical order:**

1. **Exeter, by Greg Ordy, W8WWV.**
2. **VNA4WIN, by Roger Blackwell, G4PMK, and Ian White, G3SEK.**
3. **WINVNA, by Joakim Soya, OZ1DUG.**

## N2PK VNA YahooGroup

A YahooGroup called "N2PK-VNA" has been set up as a forum to aid builders and users of the N2PK VNA.

To simply view the messages, go to:

http://groups.yahoo.com/group/N2PK-VNA/

If you want to post messages, you must get a Yahoo ID by going to:

http://edit.yahoo.com/config/eval_register?.done=http://groups.yahoo.com&.src=ygrp

and then subscribe by either

clicking on "Join This Group!" at the first URL above or by sending an e-mail to :

N2PK-VNA-subscribe@yahoogroups.com

To unsubscribe from this group, send an e-mail to:

N2PK-VNA-unsubscribe@yahoogroups.com

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*Please feel free to contact me with any comments or questions at:*

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73,
Paul Kiciak, N2PK

*URL: http://users.adelphia.net/~n2pk/VNA/VNAarch.html*
*Last updated: 26 Jul. 2005*