AD9951 FOR STAR

Rev 3 of Sept 19, 2007. © G3XJP 2006.
As of this date, enough of these have been built successfully to give a very high level of confidence in this design.

INTRODUCTION

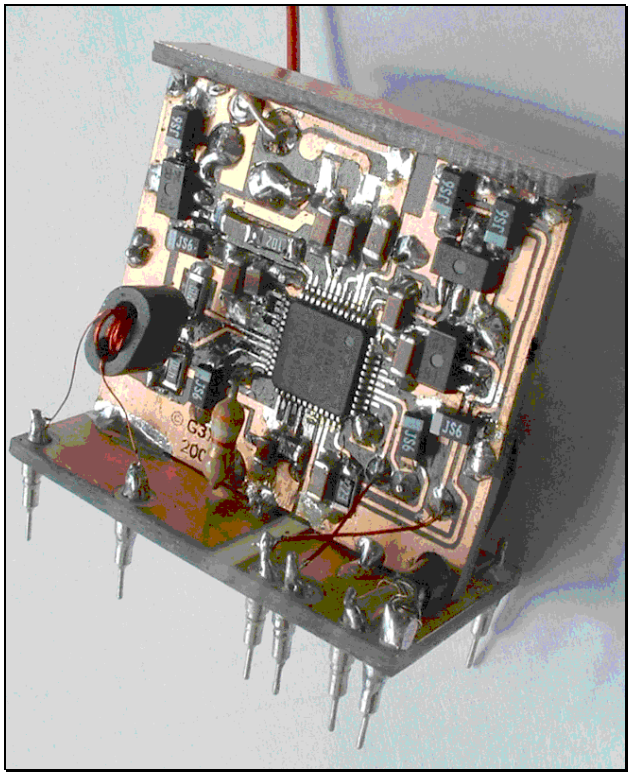
This document describes the constructional detail for building and fitting an AD9951 DDS chip as a one-for-one plug-in replacement for the AD9850 (and subsequently AD9851) as fitted in PicNMix for the STAR transceiver. There are no changes to the user interface.

This replacement is precisely to obtain the benefits from the 14 bits of DAC resolution (as opposed to 10 bits for AD9850/1). It exploits the demountable DDS carrier as fitted in the original design 10 years ago and specified in anticipation of this occasion.

This gives a 25dB reduction in DDS spur levels. It might be possible to achieve more by clocking the AD9951 faster. This option was carefully not chosen since this would require a modification to the reference clock and increased thermal dissipation issues - all for no apparent operational benefit.

The starting point is an entirely acceptable level of spurs on STAR with an AD9850/1 when in Best NF mode - but less than acceptable on the higher bands in Best IP3 mode. If you do not start from this point, you may still effect some improvement - but your installation will continue to be construction-practice limited.

The end-result on the G3XJP-build standard STAR is DDS spurs that are *very* hard to find while tuning across any HF band - in either Best NF or Best IP3 mode.



The G3XJP AD9951 assembly ready for commissioning.

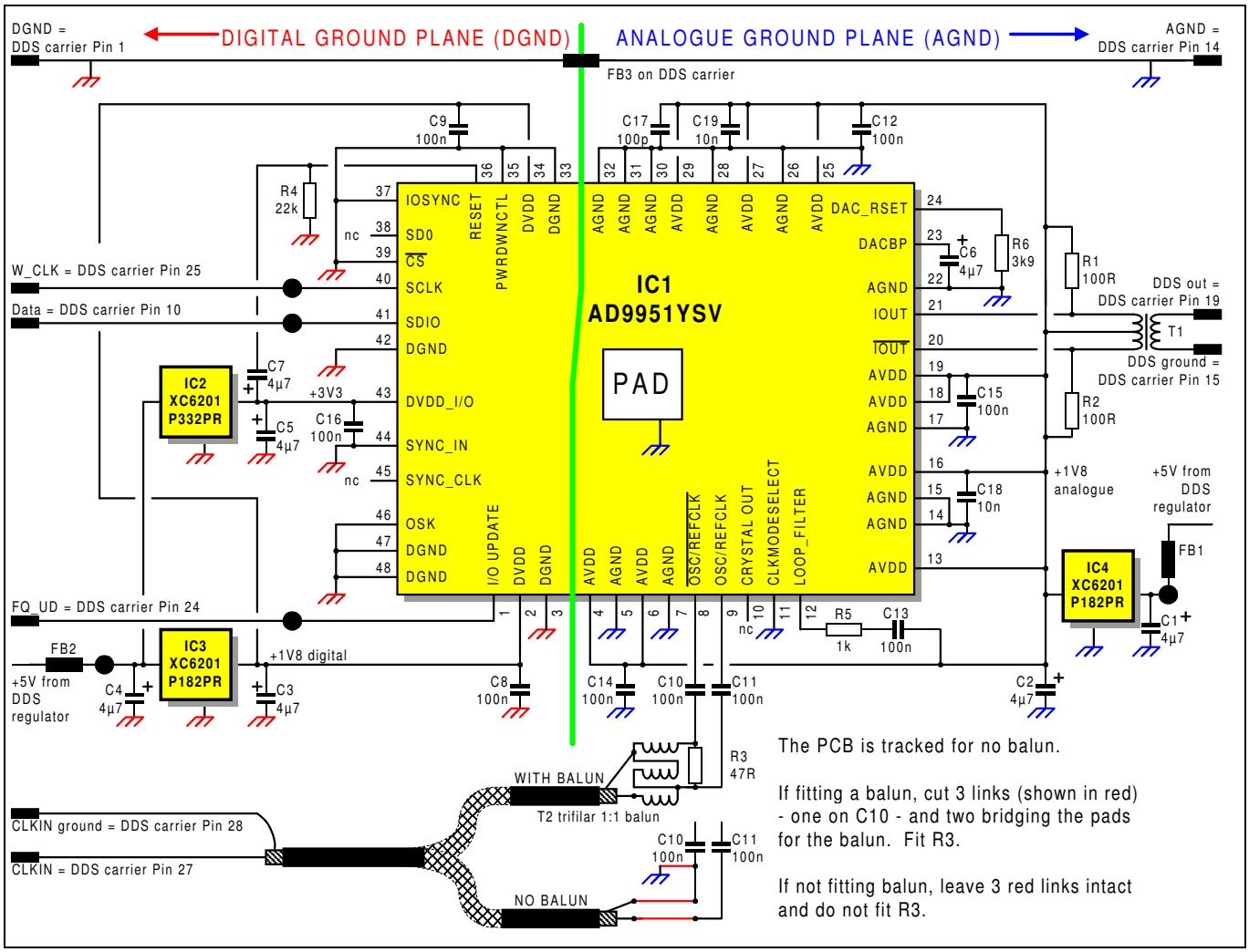


Fig 1: AD9951 circuit diagram. This assembly plugs into the PicNMix DDS carrier on the main DDS board.

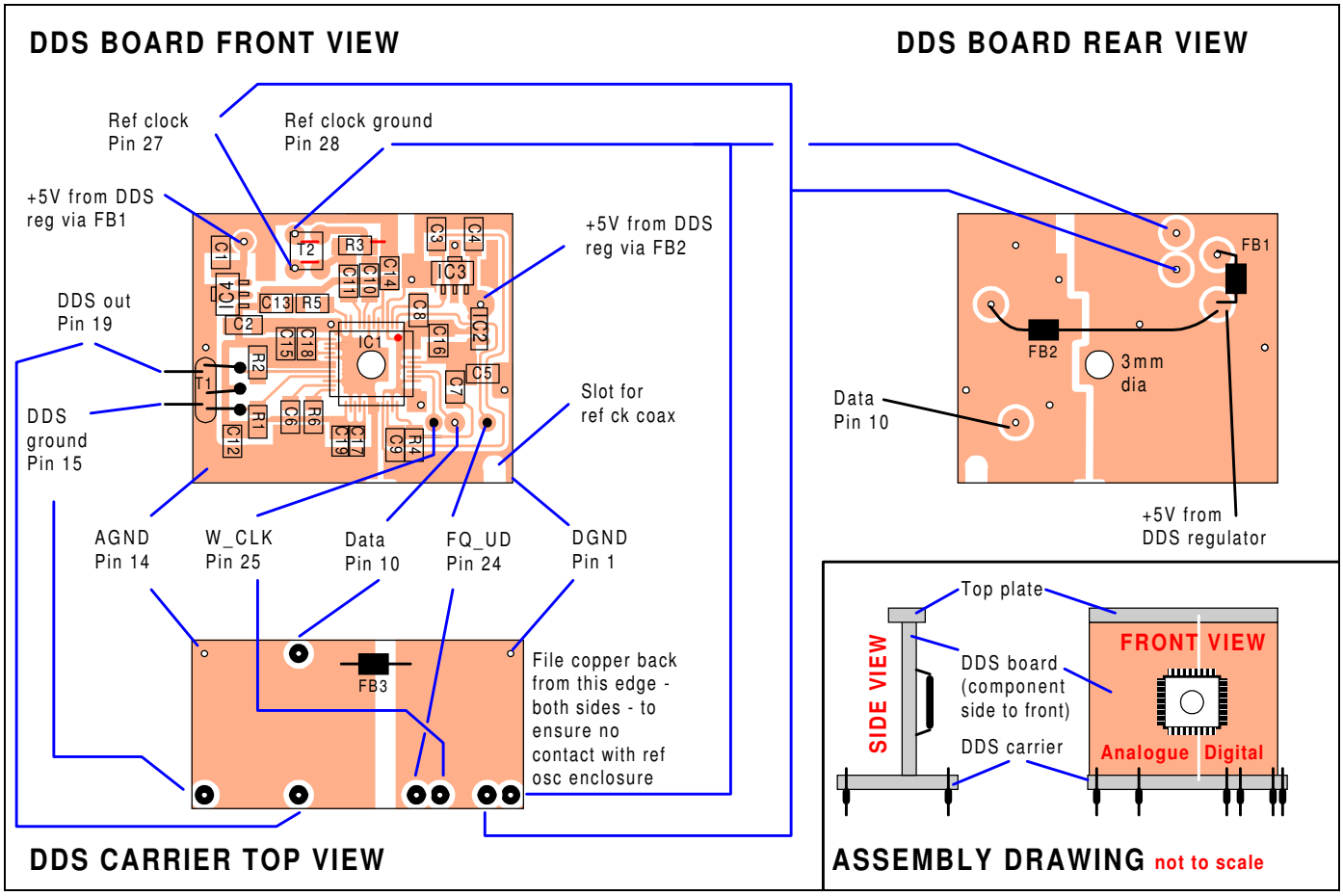


Fig 2: Component location and board assembly. The DDS board is slightly narrower than the DDS Carrier to ensure it does not touch the existing reference oscillator enclosure. The rear of the DDS carrier is not shown since it has no components. The Top plate is specified in the text.

PIC SOFTWARE

You need the latest release of PIC code for PicNMix for the AD9951 option. The code segment to drive the AD9951 is based on the work by Manfred, DK5RM to whom I am very grateful.

Options for no PLL and for x4 PLL are supported. Options for higher PLL multipliers are selectable in the source code - but not supported.

COMPATIBILITY

This build assumes your PicNMix is precisely to current modification state for STAR use. Non-STAR use is not supported. In particular, a separate +5V feed to the DDS carrier - and the Butler reference oscillator as defined in the STAR article are assumed. Note that the latter is specified as feeding via C7 68pf. The oscillator frequency does not need changing. It may be up to 400MHz - but 150-180MHz is more typical.

PROCESS, TOOLS AND TEST EQUIPMENT

This board is similar in constructional concept to the STAR CODEC board. The AD1885 CODEC chip and the AD9951 DDS chip both come in the same package - except the latter has a pad under the chip which must be connected both electrically and thermally to analogue ground (AGND).

The approach is thus the same - and the general process for making the board and for mounting these chips as described in the STAR article on the Server should be followed. The most critical success factor is rigorous testing after each soldering sequence to ensure track end-to-end integrity - and no inter-track shorts. If this process is not performed frequently, then when something does go wrong (as it inevitably does) you will not know how many steps to reverse to clear the problem.

Visual inspection is a complete waste of time - and worse, dangerous since it leads to a false sense of security.

I strongly recommend (ie mandate) the W4ZCB Beeper (see Server) since this has a very low terminal PD and presents no risk of terminal damage to the chip. This will beep at very low resistance values - so you also need an Ohm Meter to measure these; but do not use it except where explicitly stated.

CONSTRUCTION SEQUENCE

This sequence is critical to a successful outcome. If you follow it, there is no reason why this board should not work first time. If you don't, you rarely get a second chance. So tick as you go!

PCB MANUFACTURE

The PCB artwork is provided as a separate file. There are 3 sub-boards. See the Assembly Drawing in **Fig 2**. The DDS board and Carrier are designed to be etched both sides as one board - and separated after. The artwork is provided with over-sized ground/toner round the edges - and specific holes for registration of the front and back tracking. That said, the registration requirement is not particularly onerous. A trivial Top plate is made and added at the very end.

1. Make the DDS board and Carrier PCBs - and trim to size.
2. Drill all holes 0.6mm or 0.7mm.
3. Drill the hole under the AD9951 out to 3mm - from the component side.
4. Remove all burrs and sharp edges.
5. Check the integrity of each and every track on both sides of both boards.
6. Clean/polish both boards both sides - and spray immediately with SK-10 to prevent oxide build-up.
7. Using the smallest amount of solder, tin about ¼ of the circumference - on only the very edge of the 3mm hole - on the component side. See **Fig 3**. Wick off all surplus solder.

POWER SUPPLIES

Fit and test the three regulated on-board supplies first.

8. Temporarily bridge the analogue and digital ground planes.
9. Mount IC2, 3, 4. Note that IC2 is mounted vertically with the tab upwards. IC2 orientation is as shown in the photograph but it must be mounted vertically (ie not as per the photograph) to clear the tracking underneath. Do not solder down IC3 and IC4 tabs at this stage just in case they need to come off again.
10. Fit C1, 2, 3, 4, 5 - observing correct polarity.
11. Add all the inter-side wire links - typically using wire from a leaded 1/4W resistor. Confirm integrity.
12. Fit FB1, 2 and links - on the rear of the board.
13. Fit a flying lead to a +5V supply - and a ground return. NB +6V absolute max.
14. Test the correct voltage from all three regulators - best measured on the +ve end of the tantalum capacitors.
15. Remove the temporary inter-ground bridge - and absolutely confirm with the beeper that AGND and DGND are separate.
16. Solder a temporary 39R resistor between AGND and DGND. This allows you to safely measure between AGND and DGND with an Ohm meter. Measure across the 39R resistor frequently. Depending on which AD9951 pins are actually touching the tracks at the time, this resistance may read less than 39 Ohms. By the time you have finished, it will read about 19 Ohms. But it must never drop to zero which proves an AGND to DGND short which should be removed before continuing.

ALIGNING AD9951

This is best done with a helping hand to hold the chip in place.

17. Locate the Pin 1 dot in the correct corner.
18. Register the chip immaculately on all the pins.
19. Pressing the chip firmly down (blunt end of a pencil is a good tool), briefly solder Pins 46, 47, 48 to DGND.
20. Check for alignment. Correct if in any doubt.
21. Pressing chip firmly down, briefly solder Pins 30, 31, 32 to AGND. Recheck alignment.

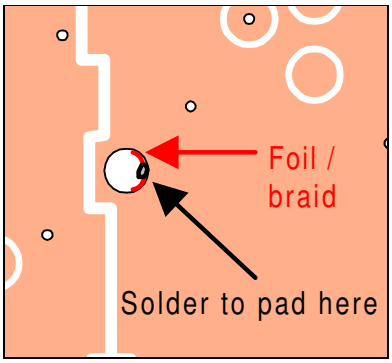


Fig 3: Solder point for AGND pad - and location of foil / braid joining the front and rear AGND planes. Rear view of board.

AGND PAD

This process is to solder the pad to AGND on both sides of the board. Refer **Fig 3**. You need to avoid using excessive quantities of solder since there is a risk of it wicking under the chip - and ultimately it could bridge AGND and DGND. Should this happen, it will all still "work", but you will lose about 3dB of SFDR - so it is well worth taking excessive precautions to avoid.

22. Use a pointed bit on the soldering iron. Apply the bit to one point on the pad on the very edge of the 3mm hole. See **Fig 3**. Add just enough solder - ie very little - both to tin the pad and to flow-solder the pad to the component-side AGND plane. It does not require very much heat.
23. Check AGND / DGND separation.
24. Cut a short length of copper foil to about 2mm wide (or flatten some very clean braid from some sub-min coax). Tin one end - and trim it so that only the very end is tinned. Form it round eg a 2mm drill bit so that it can be inserted into the 3mm hole - round the circumference - but occupying no more than half the circumference. See **Fig 3**.
25. Insert the foil/braid until it just touches the pad at the solder point. Solder quickly to the pad - with minimum new solder.
26. Check AGND / DGND separation.
27. Trim the foil/braid flush with the board rear AGND surface.
28. Stuff some copper braid (or copper leaf from any Art/Craft shop) into the hole, pressing it down and packing it firmly until it is flush with the rear face. Fill the hole. Trim any surplus.
29. Check AGND / DGND separation. This is your last chance. From now on, the chip will never be realistically removable.
30. Solder the braid/leaf to the rear AGND face of the board.
31. Confirm AGND / DGND separation.

MOUNTING AD9951

It is best to completely finish one side of the chip and prove it before moving on. Preferably, grip the board so that it is *not* horizontal so that surplus solder tends to run away from - rather than under - the chip. Although it is possible to wick off substantial surplus solder, it is best if this is kept to a minimum. To this end, pretend you are soldering each pin down one at a time - and when you have soldered all 12 pins, then wick the surplus away from the chip on that side. Then confirm integrity.

32. Press the ends of all the pins down with a small screwdriver to ensure they are touching the board.
33. Confirm DVDD and DVDD_I/O and AVDD are all isolated from both DGND and from AGND.
34. Complete pins 25-36 as described above.
35. Complete pins 1-12 as described above.
36. Complete pins 13-24 as described above.
37. Complete pins 37-48 as described above.
38. Mount all the remaining components - but not the optional balun at this stage.
39. Solder down the tabs on IC3, IC4 regulators.

DDS CARRIER

Whenever soldering to the pins on the carrier, ensure pin alignment is maintained by plugging it into a spare socket (or sockets).

40. Having removed all the shrouding from the SIL pins, insert them all in the PCB with the larger diameter end through the board.
41. Plug into a spare socket to establish pin alignment in both planes.
42. Solder the pins to the top of the board.
43. Turn it over and from the outer edge, flow-solder the pins to the bottom of the board.
44. Ensure that the Pin 1/28 end of the PCB does not protrude beyond the end of the socket. File back as necessary.
45. Fit the Ref Osc coax to pins 27 and 28.
46. Check that the Ref Clock coax fits in the slot provided on the AD9951 board - and file the slot as necessary.
47. Mount the AD9951 board on the carrier - trapping the Ref Clock coax in the slot. The front/back position of the board is unimportant. But it must be mounted flush-left on the carrier to ensure it will not foul the Ref Osc compartment on the main PicNMix board. Seam solder both sides - except adjacent to the Ref Clock coax slot.
48. Make off the Ref Clock coax to the back of the AD9951 board using the shortest reasonable coax length.
49. Add short flying leads from the AD9951 board to pins 10, 24 and 25. Self-fluxing wire is easiest.
50. Make off the secondary leads from T1 to pins 15 and 19 - either way round.
51. To make the top plate, cut a strip of PCB approx 10mm wide by 35mm long. Mark off the AGND/DGND separation from the AD9951 board - and file off the copper from the top plate to avoid bridging. Seam solder the top plate to the AD9951 board - both sides.
52. Confirm final AGND/DGND separation - remove the temporary 39R resistor - and then fit FB3 on the carrier.

The assembly is now ready for commissioning. You should have a flying lead for the +5V supply connected.

COMMISSIONING

Never apply power to STAR with the AD9850/51 fitted - but with AD9951 software in the PIC - or vice versa.

53. Power off and remove the original AD9850/51 carrier.
54. Power on and confirm there is no DC voltage on Pin 27 of the DDS carrier socket. If there is, your DDS board is not to current modification standard and you need a track cut (and that in the right place) on the back of the main PicNMix DDS board.
55. Note your IF offsets.
56. Power off - if removing the PIC for programming.
57. Re-program the PIC with the AD9951 code provided. Preferably edit the source code for your IF offsets and Ref clock frequency and re-assemble before loading. Failing that, proceed as in next step.
58. Power on. Enter/Save your IF offset frequencies. Enter at least your approximate Ref clock frequency. Roughly right will suffice for now.
59. Power off. Fit the new AD9951 assembly. (Removing the spare 28-pin socket first)
60. Solder the +5V flying lead to the +5V DDS regulator. Please don't use a connector. This supply must not fail in service.
61. Connect a scope to monitor the PicNMix output.
62. Power on and immediately key 0. You should then observe some DDS output.
63. Check that the AD9951 chip runs barely warm to the touch.
64. Confirm that the output is sinusoidal - and of approximately the right frequency.
65. Re-calibrate your Ref Clock (XJPload Option 6 and/or DDS 33 and 933). Because the Ref Clock oscillator now has a slightly different load, there may be some small frequency change to compensate.
66. Confirm that you notice a significant reduction in DDS spurs in Best IP3 mode on 10m.

Neither your IF offset frequencies nor the balance pot on the Magic Roundabout should need adjustment.

REF CLOCK BALUN

This optional balun provides common-mode rejection of the Ref Osc signal. But using either a 1:1 balun with R3 = 47R - or a 1:4 balun with R3 = 200R, I could detect no difference in performance. If you want to try it, cut the 3 prescribed tracks on the board with a craft knife, check integrity and then fit the balun. This process is clearly easily reversible.

ACKNOWLEDGEMENTS

To Manfred DK5RM for the original AD9951 driver code. To Paul G3ZCU and Ray G4TZR for Beta testing - which turned out to be non-trivial. To many other STARs for proving code and offering suggestions - and in particular, Steve G6ALU for much insight.

COMPONENT LIST

These may be Pb-free (RHOS compliant) or not - or some mixture of both - at your discretion.

Integrated circuits:-

IC1 ..... AD9951YSV DDS
IC2 ..... XC6201P332PR 3V3 regulator
IC3, IC4 ..... XC6201P182PR 1V8 regulator

Capacitors:-

Tantalum SMD 1206 rated at least 6V3.
Miniature radial electrolytics could probably be used - but these will make constructional access much more difficult.
C1-C7 ..... 4µ7
All others capacitors are 1206 ceramic but 0805 could be used in most cases.
C8 - C16 ..... 100n
C17 ..... 100p
C18, C19 ..... 10n

Resistors:-

All are 1206 but 0805 could be used in most cases.
R1, R2 ..... 100R
R3 (not fitted if balun not fitted) 47R
R4 ..... 22k
R5 ..... 1k
R6 ..... 3k9 (could be a leaded resistor as in photograph)

Ferrites:-

T1 ..... BN 43-2402 core
Primary 3 bifilar turns, approx 34 swg
Secondary 6 turns, approx 34 swg
T2 ..... Optional balun
BN 43-2402 core
3 trifilar turns approx 34 swg.
FB1-3 ..... 1 turn though Type 43 bead

Connectors:-

9 off SIL plug pins - cut from a SIL plug strip. Remove all plastic shrouding.
Spare 28-pin DIL turned pin socket for use during construction.