Background
My 62 GT Hawk was purchased about 12 months ago. Although the previous owner had thrown a lot of
Money at it, the standard brakes were refurbished but standard.
They were good in their day but fall short of today’s standards.
My aim was not to go “all out” but modify the brakes to a good level of safety and performance.
Because the M/C is under the floor, to run 4W discs using a dual master cylinder means two power
boosters and a lot of effort for very little gain. A lot of 4WD and SUV, s and commercial vehicles are being
produced with rear drums these days so I re-thought the 4W disc idea. The drum rear end should be fine.
There are a lot of conversions about all using older style calipers (floating single piston, etc). Drive one of
the newer cars with 4 spot or 6 spot calipers and you know this is the way to go. In between here and the
next stage is weeks of dredging thru catalogues etc to find components which will meet the objectives
easily.
Some calculations of bore sizes, pressures, pedal ratios and fluid consumptions are relatively easy.
I then knew what I needed. A set of 40mm bore 4 spot calipers on 300mm discs, a 1-1/16” dual
circuit master cylinder with remote fill, a power booster that will fill the front calipers, and transfer
the front wheel cylinders to the rear to increase their performance. (I intended to tune the rear
wheel cylinder bore size downwards to stop rear lockup if required) The calculations and preliminary
investigation is easy, Finding suitable donor parts is time consuming.
Component selection
After a lot of research here is what I selected.

Calipers

A pair of Nissan Skyline GTR alloy 4 spot calipers, (also used on 300zx, Subaru WRX and a few others) I also looked at Toyota Hi Lux and Land cruiser calipers but the mounting lugs are in a different position. Most other GM and Fords use twin sliding style. (Except hi performance stuff which commands very high prices)
The design of these 4 spots is such that a disc rotor protrudes almost right through the caliper. This means that a 298mm rotor plus the caliper will fit inside a 15” rim (just) great for that “original resto”
Next I measured up the stude stub axel, hub and caliper and drew it up on CAD. I then had some idea of the disc rotor that was required.
Rotors
From a catalogue I found a 298mm OD x 28 thick vented and slotted rotor that would fit exactly. (DBA 504 Ford Falcon XR6)

The above 2 photos show the calipers on a dummy bracket to prove the assembly would work.
Master cylinder

The master cylinder is all important. You cannot use any dual master cylinder. Here is a simple explanation. (As simple as I can).

In a dual master cylinder under normal operation, the primary and secondary pistons are hydraulically coupled by the fluid trapped between the two pistons. There are also two springs in the system that control the sequence of front/rear application.

The primary spring is stronger than the secondary spring

As the pedal is pushed the primary piston pushes on the 1st spring which subsequently pushes the secondary piston and spring.

Because the secondary spring is weaker it now compresses and fluid is moved to the rear brakes. The column of fluid between to two pistons is also compressed but at a lower rate. For example the pressure in the primary circuit may be 10PSI, while the pressure in the secondary or rear circuit will be 10PSI + the difference between the two springs. This has the effect of applying the rear brakes first. In some earlier systems a valve called a hold off valve was placed in the primary circuit to achieve this. It simply "held off" the pressure being applied to the front brakes until the pressure rose above a pre determined amount by a spring mechanism in a similar way. The whole aim of this is to eliminate nose dive caused by the front brakes grabbing too soon.

As the pedal is pushed harder the pressure rises and the effect of the springs become relatively negligible. For example when the pedal pressure increases the Hydraulic pressure to 500PSI the additional 20PSI added to the rear is of no consequence.

When the pedal is released the springs return the pistons to the neutral position.

Now having said all that lets ignore the effect of the springs and look at a simplistic explanation of what a dual circuit master cylinder does in a failure.

As the pedal is pushed the piston assembly pushes fluid into the rear wheel cylinders, when they are full the pressure in the master cylinder rises and the primary piston pushes fluid into front calipers. At this point the pressure increases in the entire circuit and the brakes are applied. From the diagrams you can see that both pistons can only travel a certain distance before they hit a stop.

The amount of travel in either (front or rear) circuit must be sufficient to fill their cylinders before they hit their respective stops. This includes an allowance for badly adjusted brake shoes etc. Now consider the front brakes have lost a hose or some other failure. As the pedal is pushed the piston assembly pushes fluid into the rear wheel cylinders, when they are full the pressure in the master cylinder rises and the primary piston pushes fluid into a broken hose. As there is no resistance the primary spring compresses until the piston hits its stop.
A 4mm spacer could be assembled in here to reduce the primary stroke.

The hydraulic coupling has failed but the mechanical backup now takes over and applies the rear brakes with the remaining 20% of pedal left. The point at which the primary piston hits the secondary must coincide with a maximum of 80% pedal travel. This is OK because the rear wheel cylinders do not require much fluid to activate them.

A similar scenario happens if the rears are lost. As the pedal is pushed the primary piston pushes fluid into the rear brakes, but there is a leak so the piston assembly moves forward until the secondary piston hits its stop. At this point the pressure increases in the primary circuit and the front brakes are applied. The amount of travel in the primary (front) circuit must be sufficient to fill the front calipers before it hits the piston in front. The point at which the primary piston hits the secondary piston must coincide with a maximum of 60% pedal travel. So in a rear hose failure the front brakes are applied with the remaining 40% of pedal travel.

So you can see all of these characteristics are very important. Some M/C's have the primary and secondary circuits reversed but the principles are the same.
You need to dismantle the M/C and measure these parameters to confirm your selection.
They are all different.

From calculations: The rear brakes need to be upgraded because the M/C is larger in bore and the front disc assembly is so much better. It is therefore essential that the rear wheel cylinders be replaced with the front ones.
Swapping the cylinders has a nett gain of about 30% on the rear brakes with the 1-1/16” master cylinder. This turns out to be ideal.

A Nissan 1992 Patrol 1-1/16" dual master cylinder, (4W disc model) has a 17mm initial stroke on primary and 12.5mm on the secondary pistons before the mechanical activation. The bore is sufficient fill front or rear before this mechanical activation, so it was ideal. The Hawk uses a pedal ratio of 7:1. This gives about 23mm maximum travel at the M/C. As stated above, in the case where 1 circuit is lost due to a hose break or other fault you require 20% pedal travel (minimum) to activate the remaining good circuit.
So   6/23x100=26% pedal left on a primary fail
     10.5/23x100=46% pedal left on a secondary fail
In hindsight after finishing the project I would probably fit a 3mm spacer in the primary piston assembly to reduce the stroke to 14mm. This would still leave plenty of fluid to fill the front calipers and leave 39% of pedal for the rears in a fail scenario.
Here you can see the M/C assembly. The pipe from the primary M/C port runs directly to the power booster. The 2lb residual valve is mounted on the angle mounting bracket for the power booster. It is in the line between the power booster and the front calipers. The 10lb residual valve is mounted in the line to the rear brakes on the other side of the chassis. (Not visible here)

**Residual Valves**

Another feature of drum brake systems is a residual pressure valve. In a drum brake system they retain a pressure of 10lb in the system between the M/C and the rear brakes. A drum rear M/C usually has them mounted in the outlet port. There is some confusion about their function and some cars don’t even use them. Here are some of the benefits of using them

- Stop air being drawn in past the cups when they are retracting
- Hold back the maximum amount of fluid in the rear system to reduce M/C travel. (better pedal)
- Prevent fluid draining back into a under floor mounted M/C reservoir.

In some cases a 2lb residual valve is installed in the front disc system also. In this system I chose to install one in both circuits for all of the above reasons.

**Proportioning Valves**

Here is a contentious issue. (My summation)

In vehicles like the Studebaker with 4W drums and no power assist they were unnecessary. The system was designed for the correct bias by utilizing the correct cylinder size, drum diameter, drum width, shoe length, etc. etc.

When disc brakes arrived they (generally) required a booster because of higher operating pressure. This was fine, an inline booster was simply added to the front circuit and components “tweaked” to get the correct bias.

Evolution saw the pendulum pedal and eventually the Mastervac system where the M/C was mounted on the booster on the other side of the pendulum pedal. We now have a dual circuit M/C mounted on the output side of a power booster. This then required the pressure to the rear drums to be substantially reduced. Here is where the proportioning valve arrived. Also a combination valve which incorporated the above mentioned hold off valve in one unit. I know proportioning valves are varied and are not linear etc. I am sure this will start a huge debate of “Ah yes but arguments”. Anyhow, In Australia to my knowledge adjustable proportioning valves are not street legal. So I did not want to use one. To find a factory preset one from a similar vehicle is destined to fail for various reasons. It must (is) be possible to achieve correct bias by “tweaking” the rears or by even using different shoe lining/pad material.

So this avenue I took. After all this is what Studebaker did when it put discs on the front of Hawks.

**Power booster**

A PBR VH40F power booster was selected after discussions with Hydroboost in Melbourne. (Most helpful and very reasonable price, don’t bother with 2nd hand stuff just by a new one)

**Remote Reservoir**

A remote reservoir from a Nissan Urvan was chosen. Unlike many other manufactures Nissan are good at using the same components across a range of cars. The reservoir on top of the Patrol M/C can be unplugged and the Urvan remote pipe adapters simply plug in. They all just connect up with no modifications, just longer hoses. I used heater hose for the hoses. Brake fluid (dot5) is basically a glycol, ester, mineral oil formula. (Water soluble). Radiator coolant is a water, glycol, ethylene, mineral oil formula. So this should be the right choice. The Urvan reservoir + the hoses hold heaps of fluid. I initially used 700ML to fill it up.
Valves and fittings
(Nissan use double invert flares (same as Stude) you just use M10x1 flare nuts or 3/8"UNF as required. The pipe size is the same.)
The following hardware is required

- 6 off M10 flare nuts. (2 in M/c and 4 for the front caliper pipes)
- 6 off 3/8 flare nuts. (2 for the power booster and 4 for the residual valves)
- 4 off 3/8 UNF parallel thread to 3/8 UNF inverted flare adapters. (Very common part available at any brake place).

- A 10lb Residual valve (rear) and 2lb Residual valve (front) were used. These have the Inverted flare adapters included. Two brake hoses. 300mm long with EF204 fittings on each end. You can use 3/8UNF ends and flare nuts the hose just needs to be 300mm long. The local brake specialist (ABS Brakes) can make up whatever you require.

- 10 off S222 wheel studs
- 8 off 3/8 x 1-3/4 long UNF grade 8.8 bolts and nuts. These may appear too long but it is very important that the loads applied to shear stressed bolts must be on the shank, not on the threaded part. Cut the excess thread off if you want.
- 8 off 6mm thick spacers to fit between the caliper bracket and the stub axel.

Fabricated Components
The M/C bracket, it looks a bit complicated but it's easy to make. I wanted to minimize any big mods to the pedal so the bracket needs a hole /slot in the rear to allow the M/C bolt lug to sit hard against the chassis. The brake pedal needs to be modified. I added a fork or clevis plate to the stude pedal...
The M/C bracket does not have the chassis mount holes drilled in it at this stage. These are marked and drilled on assembly. Here the bracket is shown upside down. To make a left hand version it’s just a matter of orienting the 3 components to suit and welding them together.

The pushrod can be mounted in its original position or on the outer fork for the new M/C. So it will work with either M/C. I used a longer clevis pin which goes thru the whole lot. Better than original. Still uses the stock push rod. The bracket uses the 2 original M/C mounting holes. The Rear one was slotted to angle the M/C to align parallel with the pushrod. The tie back to the pedal pivot was fabricated from the original one.

Master cylinder bracket (fabricated from 6mm plate or laser cut to DXF file supplied)
The Hubs
See the note below on the removing of the rear drums from the hubs.
There are a couple of different styles of Stude hubs. I found (early style I think) which have only the 5 wheel stud holes drilled in the flange. The others have a single additional hole drilled between two of the others. This prevents drilling 5 new holes to accept the NS222 studs. If you can get these hubs get them re-drilled with 5 new holes (39/64") to suit the NS222 studs.
The other solution is to use NS204 studs pushed into the existing hub and open out the holes in the rotors to suit the slightly larger stud shoulder diameter.

The overall geometry
Front caliper brackets were laser cut. (Fabricated from 10mm plate or laser cut to DXF file supplied)
Because the 4 spot calipers are self centering they apply very little bending moment to the bracket.
The pistons move in from either side and the hydraulic pressure is about the same on both sides.
Here is the caliper bracket with some simple FEA (finite element analysis) applied to it. The bracket is fabricated from 10mm 250Mpa steel plate. In this study it has ~1000kg (10000N) applied to each of the 2 caliper mount bolts.
A total of about 2 tonne (2000kg) more than the total weight of the car on one bracket.
The 4 bolts to the stub axle are held firm. The colours show the stress in the plate. The slight warm spots (blue moving up to light green) at the bottom load point) applied load points are due to the point load and can be ignored. The maximum stress in the plate is about 120N/mm² Maximum allowable as can be seen is 932N/mm² I don’t believe this will fail.

From a practical point of view 12mm plate would suit the standard mount bolts better but is not necessary.
Installation

Important!

This installation requires that the front wheel cylinders (1-1/16” bore) are fitted to the rear brakes. To do this you will need two 3/8 UNF parallel thread to 3/8 UNF inverted flare adapters. These screw into the back of the wheel cylinders to accept the inverted pipe flare and nut. (In the photo below I have fitted self adjusters. This involves hub removal and back plate replacement)

He has separated the drums from the hubs you say?
Yes. Cut the studs off level with the drum. Drill down into the stud with a ½” drill to just below the drum, Punch the studs thru with a heavy punch. Purchase 10 of ns220 studs (Volvo 240) and press these into the Stude hubs. These are a perfect tight fit on the Stude drum. No more hub pulling. I removed the hub and installed the self adjust back plate and mechanism from a later model. With these self adjusting rear brakes the 6mm of M/C in an emergency will always be sufficient.

If you don’t want this feature you should look at that spacer in the M/C primary circuit.

The master cylinder was installed on the fabricated bracket.
The Hawk pedal had the additional clevis plate added.
The original pushrod and boot fit the new arrangement OK. I shortened the pushrod about 4mm. With the M/C assembled into position hold it at the correct angle and mark thru the chassis the two mount holes. These can be drilled and the assembly re installed. The rear one can be slotted vertically to allow it to swivel on the front bolt.

This allows it to be rotated to ensure that the pushrod enters exactly in the center. I chose to mount the booster under the existing cover.
The cover needed a bit of “bashing” to get it all to fit.
The mounting of the caliper brackets is important. The holes must be match drilled. The bolts must be a snug fit thru all holes as an assembly. This is to ensure all bolts share the load, and not just 1 that is out of place even a small amount.
First mark out all of the mounting holes on the bracket.
Drill the first 1 (the one out on the hook). Then bolt it to the old drum brake backing plate so the other marked out holes can be seen thru the back plate. Drill the next hole (furthest away). Bolt thru this hole and drill the remaining 3.

Drill one of the caliper bolts. Next cut off 20mm of thread from a spare caliper mounting bolt. Put this piece in a lathe and drill a ¼” hole thru it. Cut a screwdriver slot across the top with a hacksaw. Bolt the caliper to the bracket; (tightly) make sure the other marked hole on the bracket is visibly in the middle of the undrilled hole. Screw the part bolt into the other hole. You now drill thru the bracket with a ¼” drill. Now remove the bracket and use this ¼” pilot hole to drill it to the correct size. This ensures that the 2 holes in the bracket are exactly the same centers as the caliper and both bolts will be loaded together when the brakes are applied.
The grease slinger on the stub axel needs to be installed in its original position. Cut the middle out of the old back plate and use that or make a new spacer from 4mm plate. After a lengthy installation (I replaced all brake lines and hoses) on to the next stage.

**Testing and bleeding**

I needed to prove the calculations by actually testing it, so here is the sequence.

Remove the fitting from the outlet of the power booster and block it. (Use a 3/8UNF set screw with a copper washer)

Fill the reservoir with fluid, bleed the front circuit up to this point. When you depress the pedal it should go 2/3rds to the floor and stop hard. (I mean hard like the pedal has hit a steel stop).

So what does this mean? The rears have air in them and no action in the rear. (As if there is a failure) The front up to the booster output is full of fluid. As the pedal is pushed the pressure builds up in the primary circuit, it’s full so the primary piston moves the fluid down the bore pushing the secondary piston in front of it until it hits its mechanical stop. (Because it is empty as if a rear hose is lost) At this point it stops dead because you are trying to push fluid against a blocked front port. This happens at about 2/3rds travel which is perfect.

I still have 1/3 left to activate the fronts in an emergency.

So on to the next stage.

Bleed the rears and you should find the pedal only moves about 25mm before full power on the rear brakes, even with the 27mm bore wheel cylinders. The pedal should be VERY firm.

So from this we can say that the rear brakes use about 3.5mm of M/C travel to activate.

Next connect up the fronts and the pedal should travel about ¾ to the floor and lock the rear brakes. (Fronts being full of air simulating a failure.

After bleeding the fronts the pedal travel should be about ¼-1/3.

A photo showing the almost complete system.

**Note:**

- Routing of the vacuum hose. (Most of this hose is SS braided, not really necessary but it was lying around)
- Breather hose from the vent cap on the booster to the engine bay.
- Brake reservoir hoses. (This routing is a bit longer but keeps them well away from the exhaust manifolds).
The protective wrap around hoses prevents chaffing. The existing cover goes over the booster.  
After reinstating the rubber splash shield all of the hoses are concealed.

Testing

During testing the rear right wheel had a slight tendency to lock just before the front under severe braking on 1 or two runs. I think the balance is spot on. I did 4 120kph to 0 stops in succession with no brake fade. All 4 wheels lock simultaneously (or close to it) a perfect result. I was pleased not to have to adjust the brake bias by changing rear wheel cylinder sizes, or less desirable start playing with proportioning valves. Yes I know they work but its far better to have a system that works without having to fix it with band aids.

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