Descent Planning with a Mechanical E6-B Flight Computer

Most pilots are familiar with an E6-B mechanical flight computer as it is considered to be an integral part of a new pilot's training for use with flight planning.

A mechanical E6-B has two main parts: a dual sided main body which has a circular slide rule on the front side and a transparent compass rose on the back side and a rectangular slide portion that fits between the two sides of the main body.

The circular slide rule side of the main body is called the "computational" side and the back side is commonly called the "wind" side.

The computational side is used to solve problems concerning time, speed, and distance, perform fuel consumption calculations, unit measurement conversions, and other calculations such as true airspeed and density altitude. The wind side of the main body, along with the moveable slide, is used to perform calculations involving wind such as determining ground speed and wind correction angles.

This article will discuss features of the E6-B that, while not commonly understood, also makes it an excellent tool for use in real time descent planning. Using a mechanical E6-B, pilots can easily perform computations to determine top of descent, angle of descent, vertical descent rate required, glide ratio, maximum glide distance based on altitude, plus many other computations that are not commonly associated with a mechanical E6-B and, most surprisingly, all of these computations can be made with a single turn of the rotating disk.

The computational side of an E6-B consists of a fixed outer scale of numbers (outer scale) that surrounds a rotating disk with an equivalent scale of numbers (inner scale) along its edge. The numbers on the outer and inner scales represent values 10 through 90 but can also be scaled up or down in multiples of 10 to represent all possible numbers. For example, the number 12 on either scale can represent the values 0.12, 1.2, 12, 120, or 1200. Between the numbers listed on both scales are graduation lines which represent values between numbers such as 0.121, 1.25, 12.3, 124, or 1210. Also found on both scales are "tick marks" such as IMP GAL, KM, US GAL, and FT which are used to identify values that are used for unit conversions.

One of the main benefits of a mechanical flight computer over an electronic one (besides the most often touted one of not needing batteries) is the fact that a circular slide rule allows you to establish a ratio of two numbers, one over the other (outer scale over the inner scale), and then by default automatically displays all equivalent ratios of numbers allowing you to easily see and visualize the relationships between the equivalent ratios.

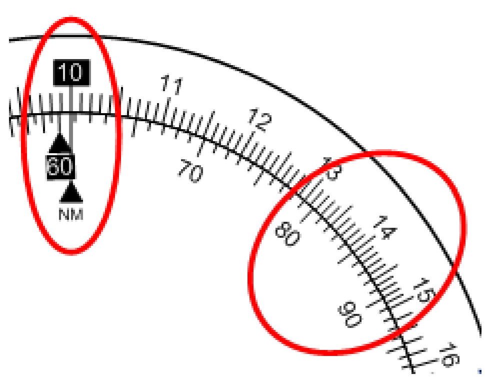
As an example, if you were to rotate the movable disk to place the number 50 on the inner scale directly under the number 10 on the outer scale you will have established the ratio of 10 over 50 which is equal to the value .2 but, more importantly, is also equivalent to all other ratios now established between the two scales such as 11 over 55, 1.4 over 7, 20 over 100, .4 over 2, 6 over 30, etc., all of which are now visible on the mechanical E6-B without having to make any adjustments to the rotating disk.

Descent planning computation with an E6-B is based on this concept of equivalent ratios. The ratio of altitude to descend (expressed in nautical miles) over the distance traveled during the descent (also expressed in nautical miles) is equal to the ratio of 1 over a value commonly called the Glide Ratio. These ratios are also equivalent to the value of the mathematical tangent of the Angle of Descent (AoD) which can be easily expressed as a ratio on an E6-B (which we will now call the AoD Ratio™) using a mark that is already present on the E6-B scales but not currently identified (one of the surprises most pilots may not be aware of). These equivalent ratios are also very closely equivalent to the ratio of vertical descent rate in feet per minute over ground speed in knots. As will be demonstrated below, all of these equivalent ratios can be quickly established with one turn of the rotating disk for whatever AoD is desired.

The secret to being able to easily establish these equivalent ratios is based on identifying and labeling two specific "tick marks" on the inner scale on the rotating disk of an E6-B. One mark is already there but not labeled, the other mark needs to be added by hand.

A standard E6-B has special tick marks on both the outer and inner scales that are strategically placed and labeled for use with unit conversions such as converting nautical miles to statute miles. While there are many different types of unit conversions that can be performed using the standard E6-B conversion tick marks, one conversion that is omitted and yet very important for descent planning is the conversion of feet to nautical miles.

Altitude to descend is usually expressed in feet while distance traveled during the descent is usually expressed in nautical miles. To establish the ratio of altitude to descend over the distance traveled during the descent in a manner that will make that ratio equivalent to the AoD Ratio™, the value for altitude must be expressed in nautical miles, the same unit as the distance. To perform this conversion, a tick mark needs to be created on the inner scale with a label of NM. This tick mark should represent the value 6076 which is approximately the number of feet per nautical mile. To identify the location for the new NM tick mark, place the graduation line representing the value 85 on the inner scale directly under the number 14 on the outer scale. You can then make the NM tick mark on the inner scale directly under the number 10 on the outer scale (see Picture below).



You can now convert altitude in feet on the outer scale to altitude in nautical miles by placing the NM tick mark on the inner scale directly under the value representing altitude in feet on the outer scale and then identify the nautical mile representation of that value on the outer scale directly above the number 10 on the inner scale. For example, to convert 8000 feet to nautical miles, place the NM tick mark under the number 80 on the outer scale to identify the value 1.316 directly over the number 10 on the inner scale. That is the value you would use to represent 8000 ft. when establishing an altitude over distance ratio. To convert altitude in nautical miles back to feet simply reverse the process by placing the number 10 on the inner scale directly under the altitude in nautical miles value on the outer scale and read the altitude in feet value on the outer scale directly over the NM tick mark on the inner scale.

Having to convert altitude from feet to nautical miles and then back to feet again as part of the descent planning process can be a very tedious task and does not allow for a single rotating disk turn to perform the descent planning calculations as promised. The trick is to perform altitude conversions ahead of time for standard altitude values and mark those conversions on the outer scale of your E6-B with tick marks representing “Alt. in 1000 ft. as NM”. Diagram 1 shows the proper locations for tick marks representing altitudes from 2000 ft. to 19,000 ft. with 500 ft. increments between 2 and 10 thousand feet on the outer scale. You can easily make these marks yourself on your own E6-B with a pen or pencil using the NM conversion tick mark described above.

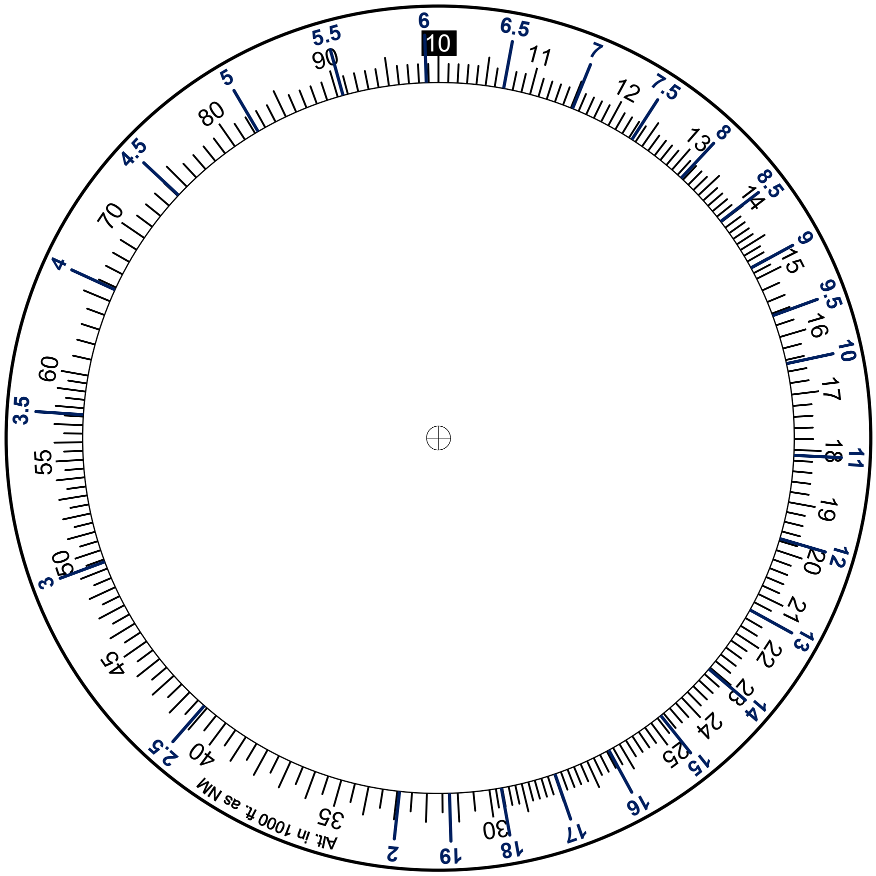
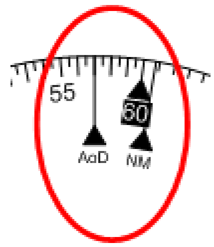


Diagram 1 – Outer Scale

We can now focus on the second and most important tick mark required for use in the descent planning computations, a tick mark that represents the AoD Ratio™. This tick mark is actually based on the existing graduation line that represents the value 57 on the inner scale. You can extend this line towards the center of the rotating disk and label it with the identifier AoD (see Picture below).



As mentioned previously, the AoD Ratio™ equals the mathematical tangent of the angle of descent. Angles of descent used in aviation typically range between 2 to 7 degrees. For all angles less than 10 degrees, a very close approximation to the mathematical tangent of the angle can be obtained by dividing the angle by the number 57. On a mechanical E6-B this is accomplished by placing the graduation line representing the value 57 on the inner scale directly under the value representing an angle on the outer scale. The actual value obtained by this ratio is not important. It is the actual establishment of this ratio on the E6-B that is important because once set, it establishes all of the other descent planning ratios such as altitude over distance and vertical descent rate over groundspeed.

As an example, let's say that you are currently flying at 18,000 ft. MSL (FL180) and need to descend 8000 ft. to be over a particular waypoint at 10,000 ft. You would like to know at what distance from the waypoint you should start your descent (top of descent) and what your descent rate should be, based on your ground speed, to accomplish that descent.

Assuming that you would like to use a standard 3 degree angle of descent as an initial starting point for planning, you would rotate the inner scale to place the AoD tick mark directly under the value of 3 (represented by the number 30) on the outer scale to establish your AoD Ratio™ for 3 degrees. If you now look at the tick mark you created previously on the outer scale that represents 8000 ft in nautical miles, directly below that you will see the value 25 on the inner scale which indicates that it will require 25 nautical miles to descent 8000 feet at a 3 degree AoD.

To establish the 3 degree AoD in flight, you will need to set your vertical descent rate (VDR) to a value that is associated with your actual ground speed (GS). Vertical descent rates are typically expressed as whole numbers in increments of 50 feet per minute. With the E6-B set with a particular AoD Ratio™, you can now use the values on the inner scale to also represent your ground speed in nautical miles per hour (knots) and then determine the required vertical descent rate required (in feet per minute) by selecting the whole number value, in increments of 50, on the outer scale that is closest to the ground speed value on the inner scale.

In our example of using a 3 degree AoD Ratio™, if you were going to use a ground speed of 150 knots, directly above that value on the inner scale you will see that 800 is the closest whole number, in increments of 50, on the outer scale. That means you should use a vertical descent rate of 800 feet per minute to maintain a 3 degree angle of descent at 150 knots ground speed. If you wanted to use a different ground speed with the same AoD, such as 110 knots instead of 150, no change would be required to the E6-B. Just look above the value 110 on the inner scale and you will see that the closest matching VDR would be 600 feet per minute.

All of the ratios mentioned above can be represented graphically with the following equations:

$$\frac{\text{AoD}}{57} = \frac{1}{\text{GldRatio}} = \frac{\text{Alt (nm)}}{\text{Dist (nm)}} = \frac{\text{VDR (ft/m)}}{\text{GS (kts.)}}$$

Using these equations, we can now expand on the previous example demonstrating the ease of use of our modified E6-B flight computer in a real world scenario.

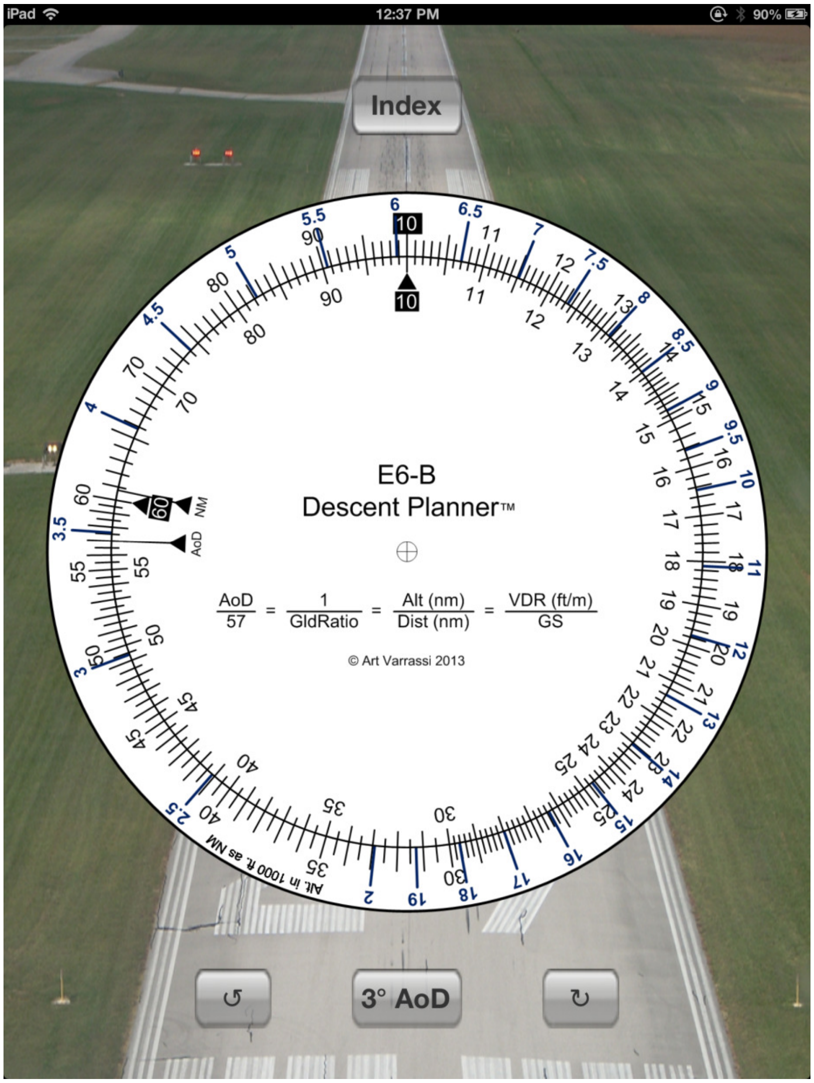
Let's say that we have now reached our top of descent point 25 nautical miles away from the waypoint we need to descend towards but for some reason we are not able to begin our descent, perhaps Air Traffic Control will not allow us to descend due to traffic or perhaps we are flying VFR and there is a solid cloud layer below us that we need to pass before we can descend. If we were to delay our descent until only 20 miles from the waypoint, how will that effect our descent computations?

To accommodate this change all you need to do is rotate the inner scale to place the value 20 under the tick mark on the outer scale representing 8000 ft. in nautical miles. You will then see that this descent will require an AoD of approximately 3.75 degrees which can be obtained by establishing a VDR of 1000 ft. per minute with the same ground speed of 150 knots we used previously. If you don't wish to descend at 1000 ft. per minute and would prefer to stay with the originally planned 800 ft. per minute VDR, you will simply have to slow your ground speed to 120 knots as already indicated on the E6-B and you'll be all set.

Another very useful computation that can be obtained using the equivalent ratio equations listed above is being able to determine your maximum glide distance in an engine out situation based on your altitude above the ground. Most aircraft POH manuals have either a published maximum glide ratio for the aircraft or a table or graph that shows maximum glide distance based on altitude (based on establishing best glide speed). For a Cessna 172SP, as an example, the maximum glide ratio is 1 over 9 (9 feet forward for each foot of altitude lost). During normal cruise flight you can set your E6-B Descent Planner™ to the maximum glide ratio for your aircraft (I like to use a glide ratio of 1 to 8 instead of 9 to compensate for older aircrafts and the time it would take me to recognize and accept the engine out situation). At a glance, you can then quickly determine your maximum glide distance based on your altitude, once you have established your recommended best glide speed.

At the end of this document you will find a copy of Diagram 1 listed previously that shows a modified E6-B outer scale, along with Diagram 2 which shows a modified E6-B inner scale. These two diagrams can be cut out and Diagram 2 can be mounted on top of Diagram 1 to make a functioning E6-B Descent Planner™

You can also download the E6-B Descent Planner™ app (pictured below) from the Apple App Store, for free, with the following link which will provide you with a fully functional E6-B Descent Planner™ that will work on your iPhone or iPad.



Search for **E6B Descent Planner** in the Apple App Store or click on the link below:

https://itunes.apple.com/us/app/id673252710

Enjoy experimenting with equations I've presented here and using the AoD Ratio™ as part of your descent planning computations.

Please send any comments directly to me at avarrassi@tx.rr.com

Regards,
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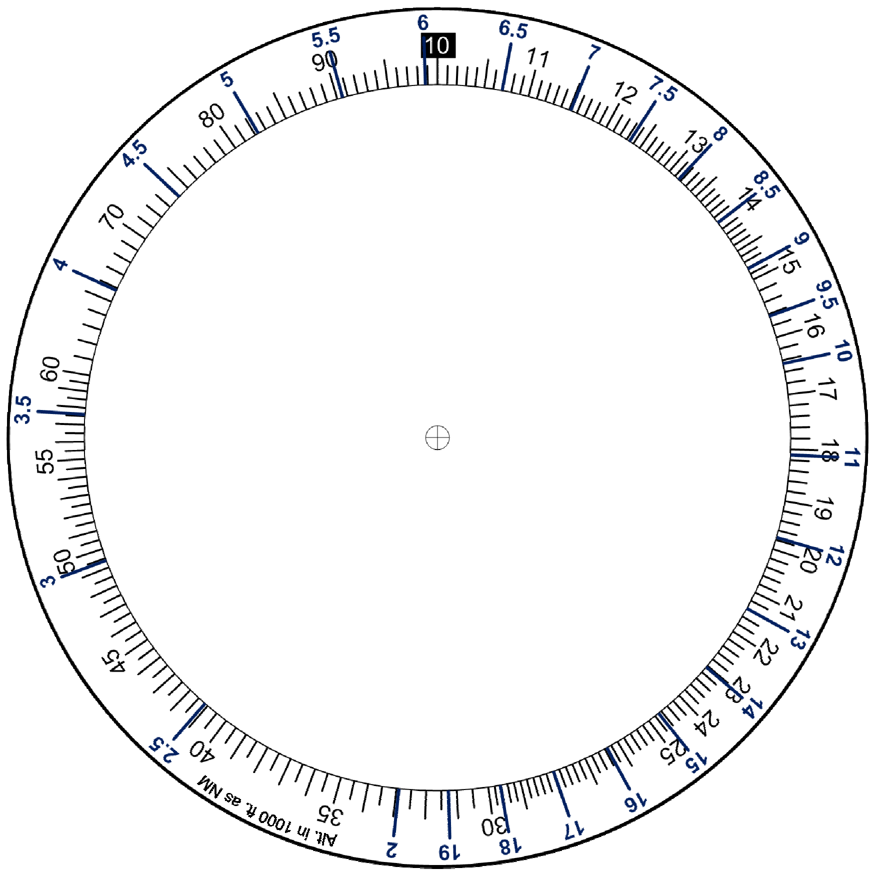

Diagram 1 – E6-B Descent Planner™ Outer Scale

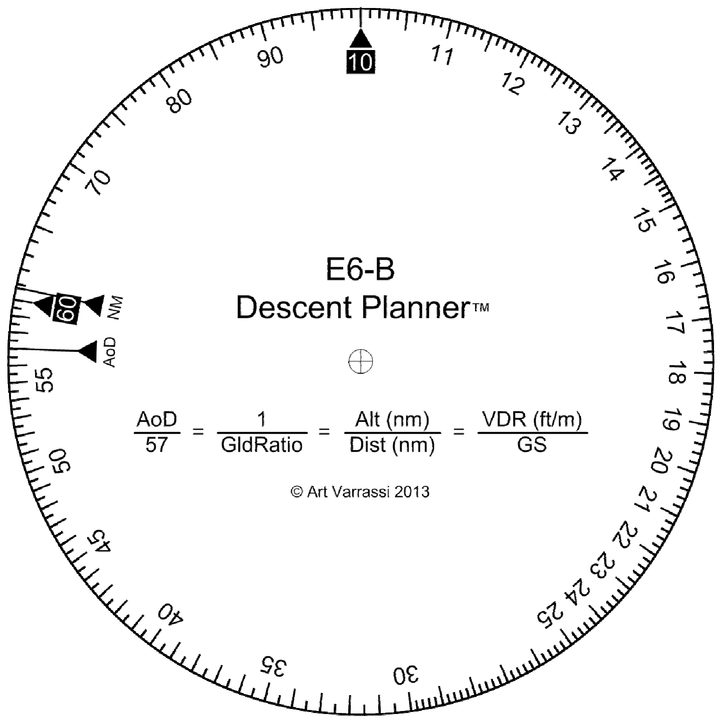

Diagram 2 – E6-B Descent Planner™ Inner Scale